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An Integrated Approach to Educating a Diverse Population on Environmental Management Systems

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Abstract

This paper describes the interdisciplinary learning modules being developed with the help of a National Science Foundation CCLI (Curriculum, Course, and Laboratory Improvement) grant to educate students from diverse disciplines about environmental management systems (EMS). The modules are intended to enhance student understanding and appreciation of environmental issues by engaging them in an integrated approach to learning math, science, business, law, social, and engineering concepts. Environmental management systems are "next generation" responses to environmental problems that go beyond regulatory compliance by integrating interdisciplinary science, quality management and systems engineering practices to redress point, non-point and process aspects of pollution. A significant challenge of the project is to design the learning modules so that students can better understand and experience first hand the benefits of environmental management in real-world settings by interacting with students from diverse disciplines and professionals. The project team is assisted by an advisory team consisting of experts from a number of universities and companies. The learning modules are being designed using the Kolb learning cycle and include a variety of active-learning strategies such as class discussions, case studies, guest speakers, web applications, and team projects. Details of the learning modules, pedagogical strategies, and assessment results are presented in this paper.

1. Introduction

Environment touches our lives in many ways and we profoundly impact the environment as policy-makers, scientists, engineers, corporate decision-makers, and citizens. To protect the environment in today's technological society, balance the needs of the population, and minimize impacts of environmental hazards, we need technically informed citizens with knowledge of environmental issues, especially those who are being educated and trained professionally to face this challenge. This is true whether one is pursuing a career in business, law, education, science, engineering, social sciences, or political science.

Knowledge of environmental management systems (EMS) and how it encompasses subfields in the sciences, math, public policy, business, law, and engineering is generally lacking among students. This contributes to their inability to comprehend the value of basic math and science courses in solving real-life environmental problems. An interdisciplinary approach to educating students from diverse disciplines about environmental management systems will help them to not only understand the importance of environmental issues but also appreciate the value of an integrated approach linking mathematics, science, business, social, political science, and engineering concepts.

Since the early 1990s significant changes in environmental policies and standards, concerns about global warming, and the impact of globalization have increased the need for an integrated approach to environmental management practices focusing on pollution prevention. In addition, pollution prevention is among the most popular “disciplines in demand” in environmental careers today [11]. To meet these needs, Northern Illinois University’s EMS faculty group, drawn from four colleges, have combined efforts with four other institutions of higher learning, five companies, representatives from governmental and regulatory bodies, and an advisory team consisting of nationally recognized experts in EMS to explore the design, development, implementation, and dissemination of an interdisciplinary EMS curriculum. The EMS group is paying particular attention to pedagogy, interdisciplinary curriculum development, and dissemination to diverse groups of students and practitioners in this proof-of-concept effort funded by the National Science Foundation CCLI grant.

The educational objectives of this effort are for students to: (1) comprehend the benefits of an interdisciplinary approach to learn fully about life-cycle issues of pollution prevention, (2) apply a systems-wide, performance-focused approach to environmental management issues, (3) develop analytical, synthesis, and evaluation skills by engaging in collaborative activities, (4) experience the benefits of diversity not only from interdisciplinary curricular content but also from the participation of women and underrepresented students in the course, and (5) develop an appreciation for learning science, engineering, and business concepts along with social, political, legal, and global issues related to environmental management systems. Along with students at academic institutions, the project is also intended to educate business and industrial practitioners on environmental management issues through the instructional modules that are being developed and disseminated through this project.

2. Literature Review

Since the establishment of the federal Environmental Protection Agency in 1970 and the sweeping environmental legislation in the 1970s-1980s, there have been significant improvements in air, water, and hazardous waste conditions in USA. Yet much remains to be done, especially regarding non-point pollution sources [2, 9]. The challenge being faced is the “third wave” in environmentalism, having moved away from the pioneering ideals of conservation (1890s-1960s), to governmental environmental regulation and remediation (1970s-1980s), to the current emphasis on pollution prevention. As Metzenbaum [24] notes, “The current [regulatory] system is too process-focused and not sufficiently results-focused. It is rigid and stifles innovation”. “At its worst, command and control keeps the focus on better ways to *comply*, instead of on dramatic improvements in environmental quality,” observes Cook [11]. This reality has simulated a wide-ranging discussion on the need to supplement “command and control” environmental regulation and enforcement with locally based, flexible environmental management systems whose purpose is to foster additional environmental performance and pollution prevention by applying science-based life-cycle analysis and systems engineering [11, 12, 14, 24]. Interest in EMS first developed out of the "total quality management" movement in business, was reinforced by growth of environmental sciences and industrial ecology, and received international prominence when the Swiss-based International Organization for Standardization released an influential set of EMS standards known as ISO 14000 in 1996 [2, 3]. Recently, major U.S. corporations including Ford, General Motors, and Motorola have implemented ISO14000 certification for their plants and/or suppliers. Policy institutes, environmental NGOs, and governmental agencies are studying improved environmental performance through EMS approaches (e.g. [30], WRI [35], MSWG [25], Brookings [8], U.S. EPA [33]). As a result, there is currently underway a "fundamental shift,…from reliance on end-of-pipe technology toward pollution prevention and greater efficiency throughout the entire 'life cycles' of human use of materials and energy" [2].

This shift brings challenges but also opportunities for environmental science education. It will continue to be important to teach sound environmental science, but that alone is no longer enough for pollution prevention. It requires a fully interdisciplinary orientation to take life in higher education. A recent survey by the National Association of Environmental Management found that both academics and environmental professionals advocated greater emphasis on teaching basic skills in communication, judgement/problem solving, teamwork/collaboration, and analysis/problem assessment. The report found that academic institutions "don't adequately reach out into other disciplines for integration" [27], and concluded: "Educational institutions must go beyond a single discipline focus, and develop multi-disciplinary programs that will address the needs of future environmental managers. Managing for a sustainable future requires building progressive, non-traditional relationships [27]."

In view of these developments, it is crucial to begin to explore how EMS-based concepts can be combined with environmental and science education. Fortunately, there is a growing literature in four areas to assist in this process. First, in engineering, industrial ecology has become a major area of research with relevant publications adaptable for instruction [1, 13, 31]. Second, in business, there is a growing interest in accounting and management procedures that provide demonstrable bottom-line rewards to companies for environmentally smart policies [6, 17, 18, 23, 34] but for a more cautious assessment [26]. Third, a significant body of work in sciences emphasizing EMS and eco-systems approaches (e.g. Buchholz [9], Hammond [19], Kneese and Bower [20]). Finally, educational research indicates that increased student retention and motivation, reduction of repetition in the curriculum, and the opportunity for a meaningful framework for learning are some of the benefits that will follow from developing an integrated curriculum in EMS [5, 10, 15, 29].

3. Project Methodology

The project follows a four-stage methodology: (1) needs analysis, (2) design and development, (3) implementation and evaluation, and (4) dissemination and continuation of effort. During the needs analysis stage, the project advisory team was convened, scope and requirements of the project plan were finalized, and the evaluation plan was initiated. In the design and development stage, pedagogical techniques for conveying EMS content were identified and the instructional modules were designed, with input from the advisory team. In the implementation and evaluation stage, the developed instructional modules were delivered through a new interdisciplinary course, IDSP451 Environmental Management Systems, at NIU and evaluated by students and the project evaluation team. During the dissemination stage, selected EMS modules will be disseminated and pilot tested at the other institutions and practitioners in the industries through traditional and web-based dissemination methods. The pedagogical basis for the design of the instructional modules is discussed in the following section.

Pedagogical Techniques: Literature on curriculum design and development generally emphasize instructional goals and objectives in three domains of learning - cognitive, affective, and psychomotor [28]. In the cognitive domain, Bloom's [7] pioneering work shows how the recall or recognition of knowledge is part of the general development of students' intellectual skills. This includes six levels to be addressed in course design: knowledge, comprehension, application, analysis, synthesis, and evaluation. With Krathwohl and Masia [22], Bloom also investigated the affective domain, which emphasizes feelings, emotions, beliefs, and values. In the psychomotor domain, Armstrong et al. [4] emphasize how neuromuscular experience and skills directly reinforce the depth and nuance of conceptual understanding. To achieve instructional objectives and have a long-lasting impact on student learning, curriculum researchers recommend that the all three domains be included in curriculum design [16]. To assure the integration of cognitive, affective, and psychomotor skills is one of the objectives of the proposed instructional modules.

Kolb [21, 32] has developed a model framework for understanding learning style differences in which he organizes the elements of learning and learning styles into four quadrants (see Figure 1). Type 1 learners want to know WHY they have to learn a particular material. Type 2 learners want to WHAT they need to know to solve a problem. Type 3 learners often ask HOW they can solve a particular problem. Type 4 learners want to know WHAT IF they face a slightly different problem and how they should synthesize what they have learned to solve that problem. The Kolb Learning Cycle has been used as the pedagogical basis for design of the instructional modules and Bloom's taxonomy has been used as the curricular basis for design of the EMS curricula.

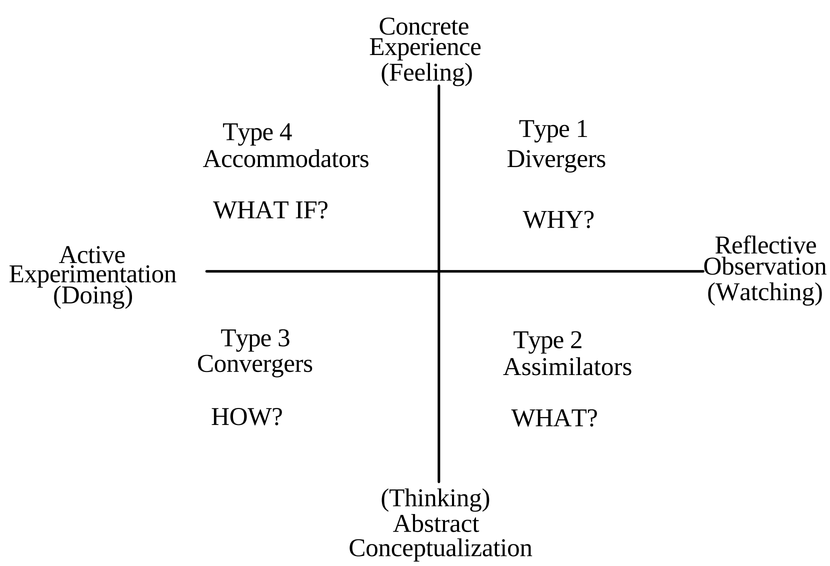

Figure 1. Elements of Learning and Learning Styles [21, 32]

*Instructional Modules***:** The project team has envisioned EMS concepts to be conveyed through seven integrated instructional modules as shown in Figure 2 and explained in the next page.

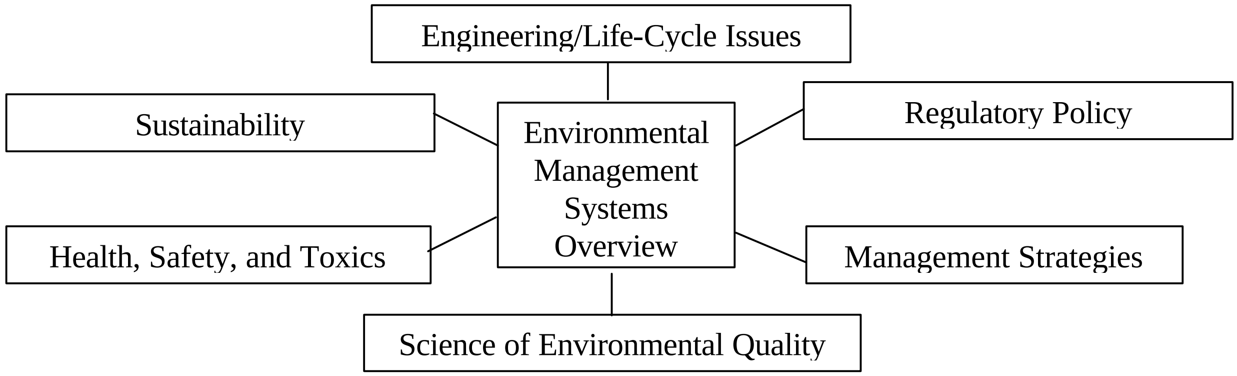

Figure 2. Framework of EMS Instructional Modules

1. EMS Overview – Basic features of EMS, EMS functions, leading environmental management programs, role of stakeholders, and social, environmental and bottom line benefits of EMS.
2. Engineering Life-cycle Issues – Systems approach to EMS, interactions between industries, environment, and the society; engineering life-cycle emphasizing design, materials, use, recycling and disposal, etc.
3. Science of Environmental Quality – Ecosystems and their functions, how pollutants spread, characteristics of contaminants, pollution measurement and reduction, etc.
4. Regulatory Policy - Environmental impacts addressed by governmental regulations, "command and control" approach, oversight and enforcement process, regulatory reform initiatives, etc.
5. Health, Safety, and Toxics – implications of environmental contaminants to health and safety, pollution-related health risk assessment, management, and communication, properties of hazardous waste and their impact, managing hazardous materials, etc.
6. Management Strategies – environmental considerations on businesses, contributions of environmental efforts to management functions, trade-offs between environmental and economic decisions, etc.
7. Sustainability - Environmentally conscious practices assuring that resources, productivity and diversity of nature are not systematically diminished for future generations.

Faculty from biological sciences, operations management, chemistry, industrial engineering, finance, geography, geology, history, public administration, and public health at Northern Illinois University were involved in the design and development of these modules. Each module consists of instructional materials, class activities, exercises, and online resources. The common thread in the modules is a detailed case study through which EMS concepts are learned from different perspectives (company environmental manager/engineer, scientist, environmental advocate, governmental regulatory officer, etc.). The case study and other class activities are designed to promote teamwork, diversity, and appreciation for basic math and science. The modules are intended to benefit students who enroll in the EMS curricula and industry and business personnel interested in learning about the basics of EMS.

4. Project Evaluation

Project evaluation includes both formative and summative evaluations through multiple assessment techniques designed for evaluating the impact of the proposed instructional modules, curricular approach, and the success of the project. The Formative evaluation was conducted to verify the progress of the project and its activities and to make positive changes during the course of the project. Summative evaluation will take place at the end (June 2002) of the project and will measures project success, results, effectiveness, and impact. Summative evaluation will include assessment of student learning, process, methodology or any aspect of the course or the project that needs to be measured. Project evaluation team (see Acknowledgments) includes faculty from several universities, industry personnel, and Government and professional society representatives. Table 1 shows sample of evaluation objectives, measures, outcomes, and strategies.

Table 1. Sample of Evaluation Objectives, Strategy, Measures, and Outcomes

Objective	**Measures**	**Strategy**	**Outcomes**
Comprehension	▪ Course performance ▪ No. of discussions & performance	▪ Assignments & tests ▪ Class discussions ▪ Student evaluations	▪ Ability to understand EMS concepts and systems approach
Application	▪ No. of applications ▪ Types of applications	▪ Case studies ▪ Internships	▪ Ability to apply learning & solve real life EMS problems
Collaboration	▪ Performance in team projects ▪ Number of teams	▪ Team projects ▪ Students – practitioner teams	▪ Ability to work in teams and function in groups
Diversity	▪ Women and minority enrollment ▪ No. of Non-science, eng. & bus. majors	▪ Course records ▪ Class participation by women and minorities	▪ Attract women and minority students and retain them in the course
Appreciation	▪ Student performance in topics not related to their majors	▪ Focus groups ▪ Post surveys	▪ Appreciation for math, science, engineering. topics
Participation	▪ Student enrollment ▪ Industry participants	▪ Online access ▪ Role-playing	▪ Demand for EMS in academia and industry
Completion	▪ Course modules completion ▪ Project completion	▪ Design team survey ▪ Project team survey	▪ Fulfillment of project tasks, goals, and objectives
Dissemination	▪ Course offering ▪ Online access	▪ Schedule courses ▪ Post modules online	▪ Dissemination of project deliverables

Formative evaluation was also conducted during spring 2001 by pilot testing the EMS instructional modules in the new interdisciplinary course, IDSP441 Environmental Management Systems, at Northern Illinois University. The interdisciplinary faculty team delivered each module in class, and two of the members of the team coordinated the entire course. Students enrolled in the course were required to participate in two evaluations, one on various aspects of the course, instruction, modules, etc., and the other on their comprehension of EMS concepts. Table 2 shows summary of results from the students' evaluation of various aspects of the course.
Two Likert scales (one 4-step and the other 3-step) were used to evaluate various aspects of the course under two categories (how students rated each issue related to the course, and how important the issues were to them). Students were asked to rate statements listed under three headings- *content, teaching materials* and *outcome* of the course. The statements were further

sub-grouped broadly under twelve (total) groups. Each of these above groups included a range of statements covering all the important aspects. The number of statements varied from 6-16 depending upon the scope of group. There were some open–ended questions also about the class. The response of the students was based on the level of importance and agreement. For each statement, the students were asked to provide two responses. First, rate (on a scale of 1 to 4 with one being strongly disagree and 4 being strongly agree) how much they agreed/disagreed with the statement about the course. Second, rate (on a scale of 1 to 3 with one being not important and 3 being very important) how important that issue was to them.

Table 2. Results of Students Evaluation of Various Aspects of the Course

Topic of Questions	***A*** (4-step Likert Scale)	**B** (3-step Likert Scale)	**Weighted Scores A*B**
Improved learning skills (team work/ analysis)	3.35	2.21	7.49
Coverage of environmental topics	3.63	2.46	8.91
Career benefits	3.20	2.22	7.15
Quality of course content	3.14	2.24	7.04
Need for additional content	3.23	2.30	7.46
Educational value of case study	3.18	2.60	8.25
Clear expectations and goals	3.17	2.39	7.59
Quality of instruction	3.88	2.64	10.26
Course activities and materials	3.34	2.45	8.23
Use of web and media	2.59	1.97	5.22
Texts and Readings	2.84	2.32	6.80
Overall Evaluation	3.21	2.42	7.76
Overall Mean Scores	**3.22**	**2.32**	**7.57**

For every statement in each group, an average, measuring level of importance and the other, measuring level of agreement, were calculated. A *group mean* was calculated to measure the responses in each group. Further, for each group, a weighted score was calculated by multiplying the group means for both responses- agreement (4-step Likert scale) and importance (3-step Likert scale). Finally, a mean for all groups (overall group mean) was also computed.

Out of twelve groups, the group's means for 10 was 3 or above on 4-step Likert scale. Thus representing a positive response of students for majority of statements. The group means ranged from 2.59 to 3.88. The *use of web and media* scored the lowest group mean (2.59) and the *quality of instruction* scored the highest group mean (3.88). Besides *quality of instruction*, the other two groups that scored high on group mean were *coverage of environmental topics* (3.63) and *improved learning skills involving team work/ analysis* (3.35). Conversely, the two groups that scored lower on group mean score were *texts and readings* (2.84) and *quality of course content* (3.14). Finally, the overall group mean score was 3.22 which reflects positive response / agreeability of students on evaluation of the course.

On the other category about the importance of aspects, it was interesting to find that the group mean for *use of web and media* scored lowest on 3-step Likert scale as well. The range for group means scores on 3-step Likert scale varied from 1.97 to 2.64 with overall group mean score being 2.32. The *quality of instruction, educational value of case study* and *coverage of environmental topics* scored high with 2.64, 2.60 and 2.46 on the group mean scale respectively. Contrary, *use of web and media*, *improved learning skills involving team work/analysis* and *career benefits* scored low on scale with 1.97, 2.21 and 2.22 as group mean score.

The weighted scores calculated were found to be consistent with the computed group means for the two responses. *Quality of instructions* scored the highest (10.26) and *use of web and media* scored the lowest (5.22). The overall mean was 7.57. The results suggest that although there was less use of web and media, students did not consider it as important. Overall the course was liked and positively evaluated by students and the use of web and media did not hurt the delivery of the course. The students, strongly agreed (on 4-step Likert scale) on *quality of instruction*, and also considered it as the most important group (on 3-step Likert scale). Similarly, *the coverage of environmental topics* was found as very important and students strongly agreed with its coverage in the course. Although, the course was highly evaluated by the students, the results suggests that the students find *the educational value of case study* very important (2.60) but "agree" more on *improved learning skills* (3.35) rather than *educational value of case study* (3.18).

Table 3. Results of Students Comprehension of EMS Concepts

Topic of Questions	Items	Number Correct	% Correct
EMS Overview	4	29/32	90.63%
Ecology/ Biology	10	51/80	63.75%
Air Pollution	6	38/48	79.16%
Ground Water	4	17/32	53.13%
Land Use/GIS	4	19/32	59.38%
Regulatory Issues	7	28/56	50.00%
Engineering Life Cycle	8	41/63	65.08%
Total	**43**	**223/344**	**64.83%**

Table 3 shows summary results of student comprehension of seven major topics covered during the semester. The results show students' responses for 43 multiple-choice questions on the seven major topics covered during the course. These 43 items covered all the areas. For example, *Ecology/Biology* had 10 statements, which was the highest number. Conversely, *EMS overview, ground water,* and *land use/GIS* each had the lowest number of 4 items.

The percentage of correct answers was highest for *EMS overview* (90.63%). The other three high percentages were for *air pollution, engineering life cycle,* and *ecology/biology* with 79.16%, 65.08%, and 63.75% correct responses, respectively. There were only 9 statements out of 43 on which all the students (100%) responded correctly whereas surprisingly there was a question that was responded incorrectly by all (100%) the students, suggesting that the question itself may have to be refined. 87.5 % of the students responded correctly on 11 statements, 75% on 3 statements, 62.5% on 6 statements with the declining frequency and percent of students with incorrect responses, suggesting that the tendency of the students was towards high scores. Overall there were 223 correct responses out of 344 (64.83%).

5. Conclusions

In this paper, the environmental management systems project currently being pursued at Northern Illinois University with the support of a National Science Foundation CCLI grant was discussed. The project has resulted in the development of learning modules on environmental management systems by an interdisciplinary faculty team. The modules use the Kolb Learning Cycle as the pedagogical basis and are being tested in an interdisciplinary course on environmental management systems. The modules are intended to promote environmental education, teamwork, diversity, and appreciation for math and science among students and industry personnel.

An advisory team consisting of industry, government, and academic experts is assisting the project team on module design and evaluation issues. During spring 2001, the modules were piloted in a new interdisciplinary course, IDSP 441 Environmental Management Systems, at Northern Illinois University. The various aspects of the course, including the modules, and student comprehension of EMS concepts were evaluated by students. The results of the preliminary evaluation have given useful information for refining the modules further and improving them before the project is completed in June 2002. The completed modules will be evaluated by the project advisory team and refined further, and then disseminated through the project website.

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