A New Approach to Teaching Environmental Literacy: A Text for Teachers

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Abstract

Environmental issues affect, and are affected by all of our activities to varying degrees. Citizens should have a working understanding of the fundamental principles involved for environmentally responsible decision making in our technological society. The interconnected nature of environmental problems, the interactions between social and individual decision making, their effect on the development of solutions for environmental problems, and the technical nature of many of these issues require that a coherent environmental literacy course include the social, economic, organizational, ethical and scientific dimensions. An active project-based approach to teaching such a course enables students to address the many issues in environmental decision making. Over the last decade we have developed such a course based on a systems approach that integrates disciplines while relying on pedagogy that involves active, participatory learning. This participatory learning is achieved in large part through the use of decision-making exercises. We assembled this curriculum so that teachers can adapt it for their courses. In other words, we developed a **text for teachers**. We feel such a text is necessary for an interdisciplinary field such as the environment since no one teacher can be expected to know all the topics. As such our text includes the necessary content and pedagogical techniques that constitutes environmental literacy. This paper describes the general features of the text material.

1.0 Introduction

Environmental issues affect, and are affected by all of our activities to varying degrees. The need to have a working knowledge of environmental issues is not confined to environmentalists, environmental scientists, and/or environmental engineers. In fact, environmental professionals are primarily involved in trying “to fix” environmental problems. However, the general populace – citizens, corporations, institutions, and governments- are the primary shapers of the environment. Therefore, citizens should have a working understanding of the fundamental principles involved for environmentally responsible decision making in our technological society. The interconnected nature of environmental problems, the interactions between social and individual decision making and their effect on environmental problems, and the technical nature of many of these issues require that a coherent environmental literacy course include the social, economic, organizational, ethical and scientific and technical dimensions. The possibility of student engagement and the complexity of the topic make the environment one of the most exciting and challenging areas of inquiry for teaching and learning.

Over the last decade we developed a course based on a systems approach that integrates these topics while relying on active, participatory learning. In an ideal scheme of learning, the students' existing framework of knowledge is realized, corrected if necessary, classified and enhanced. This participatory learning is achieved in large part through the use of decision-making exercises. This article describes the curriculum and the text that we developed. We feel such a text is necessary for any course that attempts to teach environmental literacy due to the range of disciplines that must be covered. No one teacher can be expected to know all the topics that should be covered. And, few teachers have the professional experiences to place these issues into a realistic context that allows for active, participatory learning. We expect that literacy courses will be taught by teachers from a variety of disciplines – engineering, sciences, and the humanities- given the need for literacy among the general population. As such this text includes the necessary content that constitutes environmental literacy in as brief a form as possible to allow teachers to add their particular disciplinary flavor. Suggestions to facilitate the teacher's ability to guide student learning in a participatory way are included as part of the text. An extensive compilation of student exercises and an extensive list of references categorized by topic complement the teachers' text.

In this article the reader will find a brief discussion of the teacher's text and curriculum, and examples of the pedagogical tools used. A more detailed article describing the pedagogy is being prepared for ASEE.

2.0 The Teachers' Text

We must emphasize that the text is for teachers. In other words, this book is designed to help teachers "teach" the material included. It is not intended as a text for the students. There are many good disciplinary specific introductory texts on environmental engineering, environmental science, and environmental policy. We did not want to duplicate those, nor did we want to combine all of those disciplines into one text (an impossible goal). We suggest that this curriculum be used by the teacher in conjunction with a disciplinary text, or a reader of environmental writings depending on the teacher's course objectives. What our text does is to provide teachers with materials that can be used in class to achieve a participatory, project-based focus that we feel enhance the instruction of environmental literacy.

Target Audience: The potential audience for this text is large and varied. As stated in the introduction, the curriculum in this text is designed to help the citizen gain a working understanding of environmentally responsible decision making on several levels. The citizen may be a student of engineering who needs to understand the impact that engineering decisions can have on the environment and factors that into his or her designs. The citizen may be a marketing representative who should be concerned about the environmental attributes of the product he or she is trying to sell. The citizen may be defined at the personal level in terms of how the student (and eventually the graduate) makes decisions regarding the purchase and use of consumer goods. The curriculum is designed to accommodate courses in environmental literacy for various academic departments from the humanities to the technical fields.

Because the student audience is diverse, the audience of teachers is also diverse, as are the ways of using the material. The curriculum is designed so that a teacher can use it as a complete literacy course, or the teacher can use segments to supplement disciplinary-specific courses. For example, a professor of chemical engineering thermodynamics may decide to use the exercises on energy transformations as a supplement. Similarly, a course on water resources may include a segment on the salmon management case study that is included in this text. An English professor may choose to target writing assignments based on some of the topics suggested. And so on. At the same time, a political science professor may be asked to teach an environmental literacy course as a general education requirement. We designed the curriculum so that a non expert can use the material in such a literacy course.

The depth of coverage also varies according to the needs of the teacher. As such, much of the material can be used at the pre college level that further expands the audience pool. In fact, we have successfully used portions of the material for high school, middle school, and elementary grades.

Scheme of text: Because environmental issues are interdisciplinary and often complex, topics have to be treated in a spiral fashion. Therefore, a topic often appears in several chapters. For example, we introduce global climate as a topic under earth-sun system. The details about this problem are developed in terms of energy systems chapter as we talk about the impacts of various energy sources. The problem is also developed in the materials systems chapter as we discuss carbon cycles as an example. The topic is treated further in the text in terms of social/institutional systems to formulate policy about this issue.

In keeping with the approach described, the teacher's text:

- Follows a systems approach organized around the core knowledge areas
- Introduces each chapter with history and context followed by the fundamental knowledge
- Includes traditional close-ended problems to help students master the quantitative core knowledge skills
- Builds on the close-ended problems to introduce the interdisciplinary aspects
- Includes exercises for student-generated maps of their pre-existing mental models to introduce relevance of concepts, relations / connections, degrees
- Includes realistic problems (of various depths) to develop student decision-making skills, to have students define explicitly the most relevant questions, to develop the subject area competence needed to understand and move towards the solution of problems, and to look at the parties affected both directly and indirectly. By parties here, we mean the people and institutions as well as natural entities such as animal populations and ecological niches.
- Includes writing and other creative and expressive mode exercises to develop student interaction and communication skills
- Concludes each chapter with an outline of emerging issues

Specific Material Included: The text is divided into seven chapters each focused around a core knowledge area. They are as follows:

- Introduction (Teaching About the Environment)
- Introduction to Environmental Issues
- Ethical Systems
- Physical-biological Systems
- Biological-ecological Systems
- Energy Systems
- Materials Systems
- Risk Systems

Within each chapter we include basic definitions, basic history, and the fundamental principles that are necessary to meaningfully discuss environmental issues. In each section, we include suggested participatory exercises to help engage the student in the process of learning. These exercises may be modified or replaced by the teacher and are intended as examples. The exercises range from traditional quantitative problems to reading exercises, internet exercises, discussions/debates, and more extensive cases studies and role playing. At the end of each chapter, we include a list of definitions that students should know, and a list of analytic tools that they should have.

There are several appendices to supplement the curriculum. First is an extensive compilation of exercises of various kinds that we have used over the decade. The exercises are organized according to the chapters in the text to make it easier for the teacher. The next appendix includes a listing of journal articles and books that can be used as resource material. Again, these are organized by the text chapters. There is an additional appendix on basic chemistry facts that can be used to supplement the course for some non science students.

3.0 The Learning Goals

Science, technology, and individual and institutional behavior each shape environmental problems, their context, and solutions. The entire system is necessary for decision making. In relation to the environment, decision making at all levels is an increasingly complex hierarchy made up of objectives, processes, participants and interactions among these. We feel the best way to enhance environmental literacy is to immerse the students into decision-making contexts regarding environmental issues. In this way, students experience first hand this environmental decision-making milieu. Our approach is to integrate subject matter (the necessary environmental science and policy) and pedagogy to attain our objectives. This approach should help students attain three learning goals:

- Core knowledge central to most issues
- Analysis, synthesis and evaluation skills
- Learning to learn skills including the sense of confidence, autonomy and ownership

The philosophy for each of these is described below briefly. The emphasis is on active, participatory, problem-based, experiential learning, incorporating teamwork and students systematizing their knowledge as appropriate. Cognitive and affective learning objectives as well as pedagogical methods are interwoven in the curriculum to provide an integrated framework for teaching and learning.

Core Knowledge: A fundamental core of principles and methods form the foundation for environmental literacy. This is a sufficiently comprehensive set so that all the issues in the problem area of "environment" can be understood without disciplinary expertise. The general nature and applicability of these principles should be made explicit to the student so that they form the basis for understanding a broad array of problems. Ideally, the core knowledge should be interdisciplinary so that artificial disciplinary divisions such as science, economics, and technology will not be an impediment to the student facing a complex situation. This fundamental core in the area of environment includes an understanding of:

- Energy, particularly the first and second laws of thermodynamics, practiced as energy balances
- Law of conservation of mass practiced as materials balances
- Basics of ecological structures
- Growth models focusing on the interaction between population growth and resource consumption
- Risk, focusing on how quantitative risk is calculated, how it is communicated, and how it can be managed
- Ethical frameworks

Analysis, synthesis and evaluation skills: The ability to apply knowledge is a requirement for environmental literacy. The critical judgment to discriminate between options is normally a faculty developed with expertise and practice in a given subject area. Yet, here we want to develop this evaluative faculty in a "non-expert." This means that the student should learn not only the core knowledge, but also develop an understanding about the context, decision processes, and their strengths and limitations.

The dimensions of environmental issues have to be presented in a coherent, yet adaptive and flexible conceptual framework so students can continue to learn as issues emerge and paradigms change. This framework rather than being of a prescriptive and rigid structure, should be developed by students from the subject material they learn and the pedagogical techniques that place them in decision-making contexts and provide them with skills of constructing such frameworks. Therefore students studying this curriculum should acquire skills that fit into the traditional knowledge hierarchy described by Bloom as: knowledge, comprehension, application, analysis, synthesis and evaluation. A useful way to frame the learning is to first elicit student knowledge on the subject in the form of their mental model, and then to correct and enhance this model. This approach helps students develop the capability to search and find the relevant knowledge for a given problem or situation. One example is the concept of how energy contributes to environmental problems. Students are asked to describe their understanding of our societal energy choice. Then via discussions, readings, and decision-making exercises, their understanding of the available choices is clarified and enhanced.

Another framework we have used successfully to organize student learning is that of engineering design. Engineering design starts with the identification of a need, then the use of concepts and tools to analyze the problem and to generate alternative solutions, the comparison of these alternatives for relative merit according to criteria, and then the selection of the best alternative. This "optimal alternative" might then need to be re-designed if the initial testing detects problems that are unacceptable. These aspects are brought in naturally into this "education as design" framework. In addition to these cognitive goals, design provides a setting in which important aspects of learning such as student ownership of the knowledge and relevance of the subject can be fostered as an inherent part of the educational setting. Pedagogical and motivational factors such as teaching knowledge in context, learning through trial and error, extended periods for observation and testing, using the class material, and ethical responsibility, are all automatically built into the design paradigm for learning. All of these factors have been cited by numerous authors as necessary to attract and retain students, including females and minorities. [1,2,3,4,5] We use several decision-making exercises including the siting of a solid waste management facility within a hypothetical community. Through active role-playing, the students discuss the technical, economic, and social issues.

Learning to learn: The environment in which we live is constantly changing. The education of students as citizens needs to evolve and to continue to serve them when things change. Therefore, the literacy course should also teach the "scientific and humanistic ways of thinking," including methods of structuring a new problem, and methods of recognizing commonalities and differences in classes of problems so that the transfer of learning to a new problem can occur. Gentner has shown that such translation of learning does not occur automatically.[6] It is necessary that generality and limitations be discussed explicitly in the course. Again the conceptual frameworks and tools in our curriculum aid in this development. In fact, most of the contextual exercises designed for students involve them framing problems, researching issues, and developing alternatives on their own. The teacher is expected to act as a facilitator rather than an expert. To be competent decision-makers students also have to develop a problem-solving mentality that can enable them to feel confident and take "ownership" when adapting solutions to new problems. This means that the pedagogy of teaching has to place the students in situations not only of solving a specified problem, but in situations where they have to define the problem, collect data from many sources, and formulate strategies for solutions.[7]

Active problem-based learning through the case studies presented in this text is one way to help students develop these skills. These case studies require students to represent the points of view of diverse stakeholders in the issue at hand. They also have to develop and present solutions founded on substantive knowledge and evidence. Over the years, we have seen that a byproduct of this problem-solving approach is the confidence and ownership that students develop towards their knowledge.

4.0 Pedagogical Techniques Within the Teachers' Text

The pedagogical techniques used in the curriculum include a systems approach, active learning, concept mapping, and experiential learning. These are described below.

A Systems Approach to Incorporate Science: A systems approach, including the understanding of science and technology as a human system of model building, device building, and decision making is essential for environmental literacy. In his book, The Web of Life, Fritjof Capra defines a system as "an integrated whole whose essential properties arise from the relationships between its parts."[8] Thus an understanding at the systemic level means understanding not just isolated entities, but the relationships that connect these entities. A systems approach means that we cannot simplify or abstract problems to a level where their connections to the context are lost. The analytical modes of teaching we often use, especially in science courses, neglect interactions in the interest of clarity and simplicity. For most environmental issues, these patterns are complex and contain layers of interacting units.

An example of such an environmental issue is global climate change. This issue is studied by bringing together large working models of the atmosphere, of climate, and of the distribution and dispersion of releases of materials from human activity. While only a specialist can understand the details of this modeling, every student of the environment should recognize the complexity and inherent uncertainty of results emerging from such models, and what these imply for decision making. It is important therefore to present science as a work in progress—a model of natural phenomena that is refined and built continuously. An example of how this is done is to ask students to analyze data on changes to air temperature or precipitation over the last century for a specific location. Much of this data is available on the internet. This exercise can then be followed up with a discussion of the limitations they found, a comparison to the prediction models, and a more in-depth understanding of how these scientific uncertainties affect the decision-making process.

Systems Approach to Incorporate Technology: When environmental issues are discussed, technology is often at the heart of the discussion either as the cause, the solution, or more likely both. Technology is derived from the Greek word "techne" that means "art, craft, or skill," and logos that means "a logical order." Economists define technology as a human activity associated with the making and use of implements - devices and processes – that are designed to improve the human condition. When used in economics and social sciences, technology denotes a system that turns inputs or raw material into outputs, or, useful products. Traditional economics recognized that such activity produces things other than the useful outputs. However, consistent with the thinking of the environment as a limitless source of resources and an infinite sink for useless byproducts, this picture considered those by products as "externalities." Thus pollution was considered "external" to the economic system. This in essence means that mainstream economics regarded the economy as a closed system, isolated from nature, with no regard for the exchange of energy or material between the economic system and the natural environment. The leaving out of the absence of true systems thinking may be at the root of the many environmental problems we face today.

An example of how this issue is dealt with is a life-cycle analysis project where student teams are asked to evaluate design choices for a common consumer product. The students have to discuss the environmental issues associated with the product from raw materials to disposal. They then have to conclude with a recommendation of the best design choice from both an environmental perspective, and an overall manufacturing/retailing perspective.

Active Learning: Following an instructional scheme that continually engages the student requires more preparation on the part of the teacher. Focusing on student conceptual change and inquiry-based learning means that the teacher has to be somewhat flexible and prepared for course corrections along the way. Even though this type of strategy has a degree of fluidity, it nevertheless needs to be planned to ensure the learning goals are achieved. In planning the conduct of the course, we have designed each chapter of the teachers' text to support the tasks that lead to environmental literacy. Using the class time in a mix of activities prescribed by the specific topic at hand can provide a varied, and stimulating structure to class meetings. The activities may include lectures/discussion sessions, classes led by students, teamwork, and presentations. Despite the structure offered here, the best structure is of course, one that evolves as the teacher discovers the students' strengths, interests and weaknesses. The teacher should therefore feel free to adapt the material as needed.

Our experience shows that it is important to tell the students time and again the intent of this type of learning environment. As they are used to streamlined and uniform presentations in most courses, especially in college, students do not always react to a varied pattern of activities with enthusiasm unless informed explicitly of the purpose. If students are informed about the philosophy and objectives at the start of the course they can become active partners in the design of the strategies engaged in the classroom. It takes a short period of time to find the right approach for the specific group of students. However, including the students in this provides a rewarding environment and models the participatory decision making process.

Concept Maps and Other Useful Representations: Inherent to representing and reflecting on a systems view of the subject in question are ways of drawing relationships among concepts. Diagrams for representing knowledge frameworks, or logical sequences have been used in various disciplines under names such as concept maps, flowcharts, mind maps, and mental models. Such diagrams are a central part of learning that encourages students to construct their worldviews or "mental models" and reflect upon relationships and systems. The model of teaching students to construct their knowledge is generally called a *constructivist model.* An elaboration of this model and an extensive bibliography are found in a book by Dennis Cheek.[8] Novak and Gowin have elaborated on the construction of knowledge as the basis of learning to learn, and on the use of concept maps to facilitate this. Novak and Gowin discuss extensively the use of two such tools, concept maps and Vee Diagrams in their book.[9]

The use of such maps also serves as a starting point for active learning in which students organize their prior knowledge for the present context, and prepare to modify or add concepts and relationships. Practically, such a start for a topic also serves as a tool for brainstorming, for sparking discussion, and for the teacher to observe and correct existing misconceptions. The learning environment provided by starting a topic in this fashion also conveys to the student that there are alternate frameworks for representing and dealing with knowledge. We use concept maps for every new topic and every decision-making exercise.

In *Visual tools for Constructing Knowledge*, perhaps the most useful primer on a variety of simple diagrams, David Hyerle states that learners can use these "to become independent, flexible, and interdependent builders of knowledge." [10] There is no definite prescription for drawing concept maps, as they are simply "a schematic device for representing a set of concept meanings embedded in a framework of propositions", or "meaningful relationships between concepts in the form of propositions." [11] To accommodate alternate ways of thinking and knowing, it is important to retain this fluidity of definition. However, it is also important to show students various examples, or better still, devote class time to have them generate maps, and discuss the alternate representations of the same set of related concepts, and the clarity of communication necessary.

Experiential learning: We designed various exercises to allow students to observe themselves as agents of environmental change. One of these requires the student to keep a daily log of paper, water, and electricity use. The students use these records to calculate the number of trees cut down, gallons of water handled by the local utility, and the mass of carbon dioxide released into the air over a four-year stay at the school. Student involvement is further elicited through role playing throughout the course. We use case studies where teams of students play different stakeholders in a scenario.[12] We have written case studies related to salmon management, solid waste disposal, and a global climate protocol. While these exercises take quite a bit of time to orchestrate, the participation and enthusiasm of students make the effort rewarding.

Teamwork, collaborative learning and communication are natural byproducts of the course. The availability of software systems and electronic bulletin boards augment this teaching style by supporting teamwork and facilitating project management and communication. Over the years we have seen that a byproduct of this approach is the confidence and ownership that students develop towards their knowledge. They begin to gain the competence to go in search of the facts, analyze, synthesize and evaluate data, and examine the ethics of various decisions. During the course we observe students becoming increasingly adept at setting up and solving problems, and also become more autonomous in their decision making.

5.0 Conclusion

Over the last decade we used several means to evaluate student learning with this curriculum including the usual homework and tests, as well as portfolios. Project reports, presentations, debates, role-playing, and other group activities are evaluated as well. For the past three cycles of teaching the course, we used pre- and post- tests of the students to assess the enhancement of student knowledge in the area of environmental literacy after taking such a course. The pre- and post-tests are divided into four sections that include:

- Fundamental environmental science
- Fundamental environmental policy
- Knowledge about environmental issues
- Decision-making techniques

The results were overwhelming in terms of improvement in environmental literacy as we defined it. As expected, for the technical majors, the greatest improvement was in the policy and environmental issue sections, whereas non-technical majors improved more in the science area. The limitation with such testing is that the tests were designed knowing the material that would be covered, and there was no testing of loss of knowledge over time after the course was complete. However, the results showed definitively that students performed better on that test after completing the curriculum.

Our confidence in this curriculum is based on 10 years of experience using and refining the material, student evaluations, and ultimately student performance in the classroom. This participatory-based curriculum asks more of the teacher and achieves more with the student. The teacher's text is a tool for teachers interested in such an approach, and is intended to facilitate environmental literacy across college campuses. The draft text is currently being edited and will be submitted to a publisher in the near future. During this process the authors welcome comments regarding the text.

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