Scientific Literacy and Undergraduate Education at Rutgers University

by

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ABSTRACT OF THE THESIS

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As has been described extensively (Ryder et al., 1999; Gambro and Switzky, 1996, Korpan et al. 1997) there is a serious discrepancy between the scientific knowledge possessed by scientists and academics and that possessed by the general public. Both knowledge of basic scientific facts and understanding of current environmental problems are significantly lower than would be expected from a well-educated, informed public. In this thesis, I will first discuss the concept of scientific literacy, which addresses an individual or group's understanding of basic scientific principles. We will explore a series of definitions that incorporate factual, application, and emotion-based definitions, then address the current state of scientific education in the United States and major areas of success and failure.

There is a significant correlation between courses taken at the undergraduate level and scientific literacy; thus, we examine student responses to the large, introductory classes at Rutgers University, and we propose methods to improve instructional techniques to result in more effective science instruction. By increasing student involvement, shifting the roles of technology in the classroom, and regularly assessing student performance, we can improve student learning and, thus, enhance the development of scientific literacy.

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"Facts alone are wanted in life. Plant nothing else, and root out everything else. You can only form the minds of reasoning animals upon Facts: nothing else will ever be of any service to them. This is the principle upon which I bring up my own children, and this is the principle on which I bring up these children. Stick to Facts, sir!"

Schoolmaster Gradgrine, in Hard Times. (Dickens, 1854).

"Nothing in science – nothing in life, for that matter – makes sense without theory. It is our nature to put all knowledge into context in order to tell a story, and to re-create the world by this means."

E.O. Wilson, Consilience, 1999.

TABLE OF CONTENTS

Title page ………………………………………………………………………….………. i

Abstract ……………………………………………………………………….……. ii

Acknowledgements ……………………………………………………………….. iii

Table of contents …………………………………………………………………… v

Introduction ……………………………………………………………….……... 1

History of scientific literacy in American education …………………….…. 2

Scientific literacy: Why does it matter? …………………………………......… 3

Literature review: Defining scientific literacy ………………………………......… 7

Fact-based systems …………………………………………………………….… 7

Application-based systems ………………………………………………………. 9

Scientific literacy and society …………………………..………………… 12

Conclusions: Defining scientific literacy ………….……………………………… 14

Methods for assessment: Improving scientific literacy and science education ……..…. 19

Technology in the classroom and science education ……………..…………. 20

Case study: Rutgers University Oceanography ……………………………..……. 25

Student learning in an introductory oceanography course ……………...…… 26

A proposed assessment method for oceanography students …………..………. 28

Improving student learning in large classes ……………………………...….. 30

Conclusions …………………………………………………………….………. 35

Bibliography …………………………………………………………………...…. 36

Appendix 1 ……………………………………………………………….……….. 42

Appendix 2 ………………………………………………………………...…… 47

Appendix 3 ………………………………………………………………………..……… 49

Appendix 4 ………………………………………………………………………...… 50

Appendix 5 ………………………………………………………………………...… 52

Appendix 6 ………………………………………………………………………….. 54

INTRODUCTION:

The most recent IPCC report has sparked a widespread interest in science and in science-based public policy (Kennedy, 2007; Kristoff, 2007; Stevens, 2007; An *Inconvenient Truth*, 2006). However, public levels of science understanding in the United States are still extremely low (Gambro and Switzky, 1996; Pooley and O'Connor, 2000; Miller, 2004; Blumstein and Saylan, 2007). While studies suggest that public knowledge of science in the US is comparable, and according to some studies slightly superior, to that in the EU and Asia, this should not be a cause for celebration. Rather, Miller (2004) points out that 80% of American adults are unable to read and comprehend the science section of the *New York Times* or a comparable newspaper. While the majority of studies of pubic awareness of and understanding of science focus on adults, changing awareness in the adult population is extremely difficult. Instead, shifts in instructional methods for college and even high school and middle school students can be expected to have a broader, more substantial effect (Miller, 2004). By examining accepted definitions of scientific understanding and performance, and methods for analyzing student learning and retention, I can better evaluate science education in an undergraduate environment. To that end, I will:

1) Address the history of science education and attitudes in the United States

2) Examine current methods of science assessment

3) Evaluate undergraduate science education in Rutgers University's oceanography department

4) Propose methods for improving student learning and information retention.

History of scientific literacy in American education

An individual or group's understanding of basic scientific principles is traditionally discussed in terms of "scientific literacy" (SL) (DeBoer, 2000). SL is a fluid concept, and its definitions and applications in American society have changed with shifts in social and political values. As first used in the mid-1950s, SL referred to the ideal of a citizenry as aware of scientific knowledge as of any other basic facts (DeBoer, 2000). The Rockefeller Brothers Fund Board report (1958) explained that "as we must insist that every scientist must be broadly educated, so we must see to it that every educated person be literate in science." A major focus of Cold War science education was the projected ability of American students to compete with their Russian peers. Therefore, science education focused on material that was appropriate for military and economic development, with a particular focus on advancing "the cultural roots and the goals of science" (Seitz, 1958; Leslie, 1993). This emphasis on the link between science and society resonated with both Congress and the National Education Association (NEA), who argued that science education for public school students should revolve around national defense, preparation for war, and the defense against rise of Communism (Rudolph, 2002).

By the 1980s and 1990s, the waning of the Cold War and the release of the "A Nation at Risk" report[1] led to another shift in the focus of science education and the definitions of SL – there was a strengthened development of the association between SL, science, and public policy issues and a new focus on strengthening knowledge of basic scientific facts (Shamos, 1995; Trefil, 1996; DeBoer, 2000). Since then, while the basic

[1] "A Nation at Risk" is the 1983 report of the National Commission on Excellence in Education. The report calls attention to the poor test scores of American children and drew parallels between academic performance and national security.

premise of SL as a requirement for an educated citizenry has remained, science educators have renewed their focus on the applications of technology in daily life and on the importance of global environmental problems (Korpan et al., 1997; Blumstein and Saylan, 2007). Bolstered by increasing awareness of the impacts and implications of global climate change at both the academic and public levels, SL levels have increased significantly in recent years (Miller, 2004; Blumstein and Saylan, 2007). However, this begs the question: How do we evaluate SL for the American public?

Scientific literacy: Why does it matter?

In the United States today, there is no single standard definition of SL (DeBoer, 2000; Pooley and O'Connor, 2000). Rather, there are a large number of competing definitions based on understandings of some combinations of technology, scientific methodology, and basic facts. Other definitions are application-based and incorporate students' abilities to identify problems requiring further scientific investigation, to design research methods, and to evaluate data (Shamos, 1995; Korpan et al., 1997; Pooley and O'Connor, 2000). The particulars of the competing definitions are causes of no insignificant contention, and any discussion of SL must grapple with the difficulties in selecting which definition is most apt. However, the underlying principle behind the push for SL is simple to explain: the discussion of the evolution of an individual or group's SL can be a way of examining the development of understanding of basic concepts and methods of scientific research, hence the development of SL leads to a change in an individual's understandings of science, technology, and the environment (Cobern, 1995).

Even if we do not consider the sciences inherently interesting and worthwhile (the *ars gratia artis* of science), there are two compelling reasons to emphasize science education for non-policymakers. First, even citizens who will never set foot in a classroom or a courtroom are still responsible for the election of officials who will create environmental policy for the nation (O'Neill and Spash, 2000). In order to carry out this responsibility effectively, citizens must be able to be fully aware of the consequences of their votes and of their elected officials' actions. That is, when choosing between, say, candidates who support or do not support the Kyoto protocol[2], a responsible citizen must be able to differentiate not only between the rhetoric of the candidates, but also between their stances on policies, and must be able to evaluate the long-term and short-term implications of each policy (Tytler et al., 2001). Second, we as Americans have a large environmental footprint, leading the world in fuel consumption, as well as in per-capita ecological footprint (IEA, 2001; Blumstein and Salyan, 2007, Dorling, 2007). By making intelligent, well-informed lifestyle and purchasing choices, we can decrease our environmental impact significantly – for example, a 50% reduction in the average American's annual beef consumption would result in a 26% reduction (0.6 tons) in annual CO_2 emissions due to food consumption (Eshel and Martin, 2005).

As Blumstein and Saylan (2007) argue, the bulk of the national debate regarding environmental policy has shifted from the personal to the economic – for example, the most-cited reasons for opposition to the Kyoto Protocol were based on arguments of potential injury to the U.S. economy, rather than to arguments regarding the protocol's

[2] The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change. Nations ratifying this protocol commit to reduce emissions of CO_2 and other greenhouse gases, either directly or via emissions trading. While more than 160 countries (accounting for >60% of global greenhouse emissions) have ratified the protocol, the United States has not done so.

scientific validity. While environmentally-based courses are often student favorites, environmental education must make the jump out of the classroom – continued environmental degradation, even since the advent of the environmental movement in the 1970s, may be indicative of a broad failure of these courses (Gott and Duggan, 1995; Pooley and O'Connor, 2000; Blumstein and Saylan, 2007). While it is simple enough to crunch the numbers of environmental policy – what will be the cost of converting a fleet of busses to biodiesel, what will be the economic benefits of reduced emissions standards? -- analyzing the problems fully is far more difficult. Environmental policy is full of not only economic concerns, but also ethical dilemmas (DeBoer, 1995; Korpan et al., 1997; Pooley and O'Connor, 2000; Miller, 2004).

In order to effectively evaluate both the economics and the ethics, the development of SL becomes particularly vital. Citizens must learn to evaluate the claims of scientists and politicians, and the ability to ask questions about "evidence is . . . of critical importance for the public and for science workers alike" (Pooley and O'Connor, 2000). For these purposes, perhaps the most effective definition of SL is Miller's (1983): "the level of understanding needed . . . to be sufficient to read and comprehend the Tuesday science section of *The New York Times*." An alternate definition of scientific literacy takes the need for a scientific literacy standard based on evaluation one step further: Korpan et al. propose a focus on an ability to evaluate news briefs and other short articles. They suggest that the ability to ask questions about the articles – the ability to recognize what additional information is necessary – is indicative of a high-level understanding. Korpan et al. (1997) stress that students are more likely to request further information on subjects with which they have greater familiarity or understanding, and that students are less likely to request information about news briefs with more unfamiliar subjects.

While other definitions (which have included Shamos' (1995) suggestions that a scientifically literate public would be equal to his undergraduate physics students, or Turney (2003), that serious levels of scientific knowledge are impossible for the general public and that the bulk of science education ought to be concentrated towards politicians) are more precisely testable, and possibly more intellectually rigorous, they are, perhaps, excessive. We might be content with a public aware of a proscribed set of facts, but the ability to evaluate those facts is significantly more indicative of a genuine ability to process scientific materials (Sousa, 2001). The validity of this concept will be discussed further in this thesis, where we will reconcile these systems to create an operational definition for SL assessment at Rutgers University.

LITERATURE REVIEW: DEFINING SL

In order to discuss the nature of SL, we must first precisely define that quality. To do so more easily, some of the more common definitions must first be divided into two major groups: the fact-based and the application-based. The fact-based definitions focus on public awareness of basic information regarding science and the environment. The application-based definitions, however, are centered on demonstrated understandings of basic scientific concepts and an ability to read and evaluate science-based articles in the mass media. These two forms of understanding may appear difficult to reconcile, but, in fact, they merely represent two different forms of learning and are deeply interrelated. I will conclude with a proposal of a new, hybrid definition of SL.

Next, I will discuss current methods for assessing levels of SL, both in academic settings and in the public at large. I will review techniques used for analyzing data sets, and will present an overview of typical questions asked in SL assessment surveys.

Fact-based systems:

A fact-based assessment of SL generally takes the form of a series of surveys, addressing a basic slate of environmental or scientific facts, which would be covered in high school or even junior high school courses. In Lightman and Miller (1989), ability to recognize standard scientific knowledge (that the sun is a star, that the universe is expanding, etc.) is considered sufficient for SL.

Gambro and Switzky (1996) address data from the Longitudinal Study of American Youth (LSAY) (1991), a study of high school and middle school science and mathematics knowledge and achievement. Their primary focus, a seven-question test referred to as the "environmental knowledge scale," is based on ability to recognize sources, implications, and basic facts regarding environmental problems (acid rain, greenhouse effect, alternative energy, etc). They follow a national sample of approximately 2,900 high school students, evaluating both their SL and their attitudes towards environmental causes.

Gambro and Switzky (1996) use an eight-point scale to rank a cohort of students' environmental knowledge. They observed an average score of 3.56 for 10th graders, with an increase to an average score of 3.80 for 12th graders. They then use a ranking system to divide the questions dealing with basic knowledge and those dealing with consequences and solutions: of these, they see ~65% of students able to answer basic knowledge questions (the use of fossil fuels as an energy source, the connection between sulfur emissions and acid rain), but only ~43% able to answer questions applying that basic knowledge to real-life situations. Furthermore, they see minimal growth in performance on these tests between grades 10 and 12, which suggests that, while high school students do have a basic level of factual knowledge about environmental problems, they are not able to use that knowledge to draw conclusions about environmental policies. As reflected in Pooley and O'Connor (2000), Gambro and Switzky (1996) find that students report significantly greater belief in environmental causes than they report understanding of environmental/scientific facts. While Gambro and Switzky (1996) do not calculate precise SL scores, they base their experimental design on a study from Barrow and Morrisey (1988-1989), which suggests that, for SL, a student should have a score of at least 75% on a simple test which they provide. Of

Gambro and Switzky's surveyed students, only approximately 36% obtained such a score.

Lightman and Miller (1989) use an approach similar to Gambro and Switzky's (1996), but addressing a broader slate of concerns. They used a sample group of 1111 adults from 42 states, and asked each individual four questions. They then use logit[3] analyses to examine the connections between individual performance on the test and an individual's age, sex, and educational and religious background. On a four-point scale, they observe only ~31% of American adults able to answer more than 50% of their basic science questions, and only 10% of adults able to answer all four questions.

Application-based systems

The first and most important aspect of the application-based systems for defining SL is the recognition that students do not always apply – and, indeed, many are not always *able* to apply – scientific facts to everyday situations (Burbules and Linn, 1991; Cobern, 1995). This leads to the condition Cobern (1995) calls "cognitive apartheid" – the compartmentalization of "school knowledge" with information used on a daily basis. While it is possible for educators to provide students with so saturating an amount of scientific information, this condition is difficult to reach and can, by its very nature, not be achieved until students have reached a fairly high academic level (Hungerford and Volk, 1990)

Norris (1995) points out that scientific research is inherently dependent on a communal knowledge base – since no individual scientist can reasonably be expected to

[3] Logit analysis is a statistical technique most often used in marketing to determine which variables most strongly effect public responses. A logit analysis will define the relationship between consumers' stated intention to purchase and their ultimate purchasing decision.

become expert in all fields, and since it would be impossible for an individual scientist or even an individual lab to conduct each experiment reported on in literature, researchers must rely on the validity of the presentation of research in peer-reviewed journals. Development of the ability to read published material, to draw conclusions from it, and to use it as a base for further pursuits, is arguably one of the most important steps in the training of a scientist. However, while many fact-based systems for assessing SL have the inherent assumption that students will be able to draw upon their prior knowledge to evaluate situations they encounter in everyday life, this process is far more difficult than many educators realize (Brown et al., 1989). The learning of science, in this way, should be thought of as analogous to the learning of new vocabularies of all sorts (Miller and Gildea, 1987). Children, when presented with new words in a conversational or textual context outside of a lecture setting, are significantly better able to understand and retain materials than if they simply are presented with definitions from a dictionary or textbook. The average high school student is capable of learning 13 or more words per day, to a rate of 5000 words per year. However, when materials are covered in a dictionary style in a classroom, students learn only 100-200 words in a yearlong classroom course (Miller and Gildea, 1987).

Korpan et al. (1997) base their method of SL assessment on this concept: that learning is enhanced by the presentation and evaluation of material in context. While it is relatively simple to teach a specific, proscribed set of facts, they posit, it is both more difficult and more important to teach students the critical reading and thinking skills to evaluate scientific material as it is presented in widely read media. By providing 60 college students (all of whom were psychology majors, and who had completed a mean 4 university-level science courses) with a series of fictional news briefs summarizing scientific studies, then categorizing student responses into eight categories and ranking student-assigned “plausibility scores,” they can assess the study groups ability to read and analyze scientific material, the group’s knowledge of what defines good scientific methodologies, and their abilities to draw conclusions regarding societal implications of new findings (Korpan et al., 1997). To test the students’ interpretive skills further, one of the group’s trial news briefs was based on superstition rather than science (the abilities of wearers of particular kinds of crystals to predict the future). The students were asked to read the briefs, rate the plausibility of four potential conclusions, and then write a list of questions they would like to ask the authors of the brief. Students asked more questions about experimental design and other methods-based question for news briefs related to subjects they are likely to have studied in school, while they asked for more information regarding the social context (Who paid for the research?, How replicable are the results?, etc.) about subjects they are less likely to have studied. Furthermore, Korpan et al. saw very few requests for information about similar studies, which may have provided more information regarding the validity of the findings. This is a particularly interesting result: students are more likely to presume that findings about familiar-sounding phenomena were obtained using correct methods, but are more likely to focus their questions on experimental design when addressing unfamiliar subjects. This could be extremely useful as a guide for assessing the development of SL: the use of a rubric similar to Korpan et al.’s could help us examine the level of comfort a student feels with a subject – a student with a greater degree of SL can be expected to ask higher-level questions than a student who is less familiar with the subject material.

Scientific literacy and society

Based on the wide range of methods used to calculate SL in previous work (Gambro and Switzky, 1996; Lightman and Miller, 1989; Miller, 2004; Korpan et al., 1997), we are unable to directly compare one study's SL scores with those from another, which complicates the discussion of the levels of SL in the American public over time. However, while we cannot use studies by disparate groups using disparate methodologies to compare SL levels, we can indeed compare results from studies by a single group and using a single, consistent method, and from these studies can draw conclusions about the shifting levels of SL in the US. Using identical methodologies, Miller et al. performed national surveys of American adults over a 20-year period, and identified an improvement in SL over that period, including an increase in American adults' SL levels from 10% in 1988 to 17% in 1999 (Miller, 2004).

Within single studies, logit analyses show that SL is linked most strongly to the highest level of formal education attained (Lightman and Miller, 1989; Miller, 2004). There are further correlations between SL and gender (male), age (young), and parenthood (parents have slightly higher SL, likely due to the "science fair effect") (Figure 1). While the correlation between SL and educational level is most striking, the correlations between SL and "social institutions and values" are also remarkable (Lightman and Miller, 1989).

Using data sets from the U.S., as well as from the E.U., Canada, and Japan, Miller determines that American adults have slightly higher SL levels than adults in the other nations. Miller ascribes this to the American university's general education model, which often requires students to take a small number of classes in mathematics and the natural

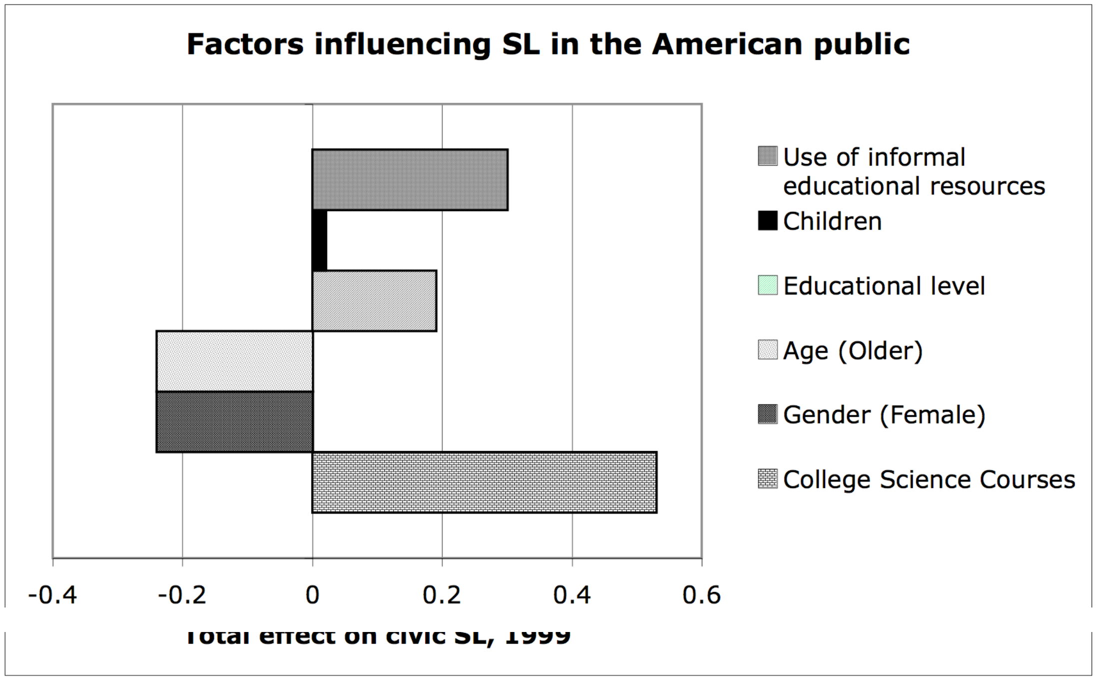

Figure 1: Effect of variables on civic scientific literacy. A value of 0 means that a variable has no effect on individual SL; higher values reflect increased levels of SL; lower values reflect decreased levels. From Miller (2004).

sciences (Miller, 2004). This means that even students who do not major in sciences will graduate with a small number of science courses at the university level, which can strongly influence SL (Lightman and Miller, 1989).

Attitudes about science among American adults and teenagers are overwhelmingly positive (Blumstein and Salyan, 2007; Gambro and Switzky, 1996). While approximately 80% of American adults believe that science has generally positive impacts on society and 90% of them believe that modern life is easier and more comfortable due to scientific research, these positive feelings do not reflect high levels of SL (Arcury and Christainson, 1993; Miller, 2004). Rather, only a small fraction of adults with those positive feelings have correspondingly high SL levels. Ultimately, this enthusiasm for science and its benefits can be construed as a positive aspect, and one we ought to foster in order to improve SL. While some groups describe science as having a "public relations" problem – as being either insufficiently interesting or too complex to truly capture the hearts and minds of the American public, this clearly is not the case (*Nature*, 1998; Nisbet et al., 2002). This directly counters Pooley and O'Connor's suggestion (2000) that science education programs address factually-based materials, but do not focus sufficiently on perceptions of science. Studying a group of 92 adults (ages 18-55), they find a high correlation between attitude and knowledge, which suggests that the fostering of positive feelings towards science is, ultimately, correlated with increased SL. Therefore, Pooley and O'Connor suggest, one of the major problems with current science education programs is not their failure to transfer more factual information, but their failure to target students' emotions and beliefs. However, the high reported incidence of positive feelings towards science, when coupled with low assessed SL, suggests that this is not the case (Blumstein and Saylan, 2007).

Conclusions: Defining scientific literacy

In light of previous studies of SL in America, we must use three separate methods when assessing SL. To that end, I propose a three-pronged assessment approach:

- Fact-based assessment. Since a strong understanding of the basic factual premises of science is necessary for the comprehension and analysis of even simple applications of science in day-to-day life, we must begin by assessing students' awareness of the fundamentals of the subject (Ben-Ari, 1998).
- Application-based assessment. While fact-based knowledge is important, it does not guarantee that students are able to use that

knowledge in the analysis and evaluation of science materials. In order to ascertain students' abilities to comprehend science-based materials and to apply them to non-classroom situations, we must provide students with science-based news articles, then use methods described by Korpan et al. (1997) to evaluate their abilities to read, comprehend, and ask further questions about the materials.

- Emotion/belief-based assessment. While a great majority of Americans do display positive feelings towards science, this feeling is not universal. A personal interest/strong feeling about material covered in the classroom often leads to increased pursuit outside the classroom of additional science-based materials, which then results in increased SL. By assessing students' emotional response to science, we may be able to better predict their future involvement in the sciences.

First, we must evaluate familiarity with basic scientific information. In a broad sense, this could simply be a multiple choice test examining basic knowledge (What is an atom? What is climate? Are tides caused by the moon or the sun?) (Gambro and Switzky, 1996; Lightman and Miller 2000). While the fact-based approach does not necessarily reflect an individual's ability to apply, analyze, or otherwise use scientific information, but knowledge of scientific facts is a necessary first step towards SL, and assessing students' understanding of those facts will allow us to separate those individuals who have a basic understanding of scientific material and are able to apply it, who are excellent readers and writers but who are lacking basic scientific knowledge, and who have a solid fact-based background but lack the ability to apply that material (Bransford et al., 1988).

In order to avoid the "inert knowledge" problem, we must incorporate some assessment of ability to apply scientific information to everyday situations (Gambro and Switzky, 2000). The Vanderbilt Cognition group (1990) refers to this as "knowledge that can be recalled when [it is specifically required] . . . but is not used spontaneously in problem solving even though it is relevant." Students can certainly memorize non-meaningful information for a brief period of time, but this memorized information is quickly forgotten, and cannot be accessed and applied to real-world situations (Bransford et al., 1988; Gambro and Switzky, 1997). The memorization process is useful, and knowledge of basic facts is vital for SL, but it is not sufficient. By assessing not only students' basic knowledge but also their ability to apply information, to draw conclusions, and to ask questions about presented scientific information, we are able to examine students' abilities to use science-based information in their daily lives, and to make decisions based on that material. To test students' application-based knowledge, we must provide a series of science-based articles (such as those which would appear in a newspaper or magazine), then ask students to draw conclusions or ask questions based on those articles. By evaluating the conclusions and questions students draw and ask, we can assess students' abilities to process fact-based knowledge and to use it outside the classroom to make decisions based on scientific fact.

Thirdly, and just as importantly, we must assess students' attitudes towards science and technology. While students' understanding of and ability to apply scienctific facts are extremely important, those students most likely to pursue scientific knowledge are those with the most strongly positive feelings regarding science. Most assessments of student attitudes towards science are very simple: they consist of a questionnaire on which students are asked to rate their feelings on a numerical scale (Pooley and O'Connor, 2000). Ideal questions for this assessment unlike for others, are vague and open to interpretation – we want to examine students' broad beliefs, rather than their precise understandings (Gambro and Switzky, 1996).

There is, of course, an inherent difficulty in discussing the purpose of science and environmental education, with regard to student attitudes: should we as instructors aim for simple knowledge transfer, or should we focus on the more-difficult goal of behavioral modification? Can we say a course is successful if students, upon completion, can design, carry out, and evaluate a scientific experiment but choose not to change their behaviors in response to the material they learn in class? While this may seem like a reasonable aspiration, it is an excessively difficult and complicated one. A student's response to what he learns in science class is affected not only by the class structure, but also by a large number of factors outside the classroom: his family background, his hometown (urban vs. rural vs. suburban), or his political/economic leanings (George, 2000). The role of science education is indeed to result in some sort of behavior modification – specifically, the development of the ability to discuss and analyze scientific data, etc. However, we as educators must avoid the mixing of the scientific and the political. By using behavior modification as a means of evaluating educational efficiency, we are coming dangerously close to making the statements that *all educated people behave in this way* or that *our preferred behavior is the only correct one*. We cannot allow ourselves to fall into the trap of believing that our politics are the only valid choice for an intelligent person, and hence we must carefully avoid using behavior modification as a means for defining SL.

METHODS FOR ASSESSMENT: IMPROVING SL AND SCIENCE EDUCATION:

The presence of students at the university level with declared majors in or stated interest in science fields is an excellent predictor for future levels of American SL. However, Seymour and Hewitt (1997) find that more than 50% of the students who enter college intending to pursue a major (and, ultimately, a career) in the natural sciences will change their minds or find other majors within their first two years of college. While much of this can be explained by students' simply finding other subjects of interest, many of which they were very likely unaware of when they first entered college, this is still a significant loss. The loss is made more significant by the students' reported reasons for leaving their majors: dissatisfaction with their professors, an emphasis on memorization, and a feeling that courses are designed to 'weed out" students who do not show strong natural aptitude.

DeHaan (2005) proposes that lecture courses are popular among faculty because of their historic position as the "industry standard" of science education. In many departments, absenteeism is rampant, especially among students who are already less interested in the material (Romer, 1993). While students can learn material in a traditional lecture situation, such environments are usually not ideal for most students (Cooper, 1995; Ebert-May et al., 1997). For a majority of students, there is a significant difference between passively processing information (by listening, or even by copying down notes from a PowerPoint presentation) and actively engaging material. The best mechanism for fostering student engagement may be simply asking questions – it appears that transfer processes that take place when students process a question and compose an answer can significantly enhance the learning process (Sousa, 2001; Thalheimer, 2003).

Furthermore, undergraduate students presented with information in an active learning-based class, in which they had lecture-style classes as well as smaller discussion groups and regular cooperative assignments, demonstrate a greater ability to synthesize information and to ask questions beyond the scope of the textbook than did students in a traditional lecture-style class (Marbach-Ad and Sokolove, 2000).

Technology in the classroom and science education:

A large portion of research in recent years has focused on the importance of bringing technology into a lecture setting. However, merely incorporating computers into the classroom is not sufficient to improve student participation or performance. Frequently, the incorporation of technology into a lecture class merely consists of the replacement of blackboard- or overhead transparency-based lectures with PowerPoint-based lectures. While this allows for more attractive, visually interesting lectures, it often does not significantly change the instructional methods or the information communicated (Goldenberg, 1995; Sipress, 1995). When lecture notes are then posted on the internet, it would appear that increased access to course materials would improve students' assessed performance in the course. However, this is not the case. Rather, the use of PowerPoint-based lectures may result in a decrease in student note-taking, as well as in students' feelings of the importance of the class itself (Guthrie and Carlin, 2004). Rather than merely incorporating PowerPoint and other technologies, the instructor must continue to actively engage students.

That the simple addition of technology to the classroom without also making a broad change in instructional methods does not help student learning does not, however, mean that professors should eschew the further development of technology-based learning. Even in courses not specifically focusing on laboratory methods or computer analysis, active participation in technology-based activities can still dramatically improve student performance. For example, in a medical-school anatomy course, McNulty et al. (2000) find that "the degree and manner of students' use of [computer-aided instructional methods] tended to correlate with their performance in class." McNulty et al. provide enrolled students with a fileserver containing tutorials, case studies, a discussion forum, and other course materials, then monitored the frequency and duration of each student's use of the website, as well as each student's grades on tests. They observe a strong correlation between student grades and the number of logins to the course website for students in the upper 33% (by final grade) of the class, as well as the absence of a correlation between students' self-reported computer literacy and their abilities to successfully use online resources. The latter conclusion is particularly important for our discussions of methods of improving student involvement in science courses, since it suggests that students' individual perceptions of their computer literacy are not directly linked to their abilities to use online materials. Furthermore, since the correlation between course website logins and grades is higher for students in the upper 33% of the class, which removes the suspicion that students with higher grades simply use the website more because they are more highly motivated. If this were the case, the correlation would be equally strong throughout the entire class. While McNulty et al. do not explore causal relationships between the higher grades and increased number of logins, it is reasonable to suggest that a student offered opportunities for online work would be able to reap its benefits, regardless of his prior experience with computers (Lillenfield and Broering, 1994).

While McNulty et al.'s work focuses specifically on anatomy classes at the graduate level, there is no reason to assume that their findings are specific to graduate-level students with a pre-existing scientific background. Rather, the incorporations of video, animated models, and other non-standard lecture elements is likely to have the effect of increasing student motivation and interest at all levels, particularly in introductory courses where students are less likely to have intrinsic interests in course materials.

At the undergraduate level, Frith et al. (2004) also address the benefits of incorporating technology-based learning methods into the classroom. Frith et al. point out the importance of presenting mathematics and other sciences in their social context. For an introductory-level mathematics course, they use not only traditional lecture methods, but also a series of Excel-based tutorials, which are given to different groups of students at different points in the semester. By tracking the performance of students in each cohort, as well as by tracking performance of students with similar abilities across several cohorts, Frith et al. (2004) were able to determine for which groups and at which times computer-based tutorials are the most useful. Their analysis charts student improvement on an assessment test. On a pre-test, before any group had had lectures or tutorials, there was a range of scores from ~50%-~20%. Assessed performance from all groups improved as the course went on, however the groups that had at least one computer tutorial prior to lectures showed significantly more improvement. Furthermore, the group that used the computer tutorial first, before any lectures at all, demonstrated the greatest improvement and, ultimately, the highest test scores. While all three groups covered the same material in the same amount of time, the order in which the material was presented made a significant difference – students who apply information, in the forms of tutorials or otherwise, are better able to process that information later, both in test and lecture situations.

As shown by Frith et al. (2004), early exposure to interactive lessons and demonstrations can improve student performance. By providing students with practical applications for and demonstrations of even the most difficult or esoteric information, the instructors can significantly improve student performance and increase student learning. The introduction of this material at the beginning of a course, rather than at the end, provides students with a framework for understanding and contextualizing the material, and ultimately encourages learning at a higher level.

Personal response systems, or "clickers," can also be an extremely effective tool for classroom instruction. In a clicker-equipped class, each student is issued a handheld device with a keypad attached. Intermittently throughout the lecture, professors present multiple choice questions and ask the students to enter the correct answer on their keypads. The answers are transmitted, via infrared beams, to a receiver, where signals are complied and projected onto a screen in the front of the room (Len, 2006). This system has significant advantages: professors can use the clickers as a real-time assessment tool, and students feel engaged in the learning process (CAPT, 2006). With regular feedback from students, professors can determine how well students are understanding the lectures, and which subjects need further explanation. The clicker system can also lead to less wasted class time, since professors can quickly and easily determine how well students understand course materials.

The clicker systems can also be used to evaluate individual students' performance. Some systems allow professors to keep records of each student's answers throughout an entire course, which can then be incorporated into a classroom participation grade, or even a quiz grade. This not only gives students an increased sense of involvement in the lecture, it also provides professors with an excellent means for tracking student performance in a lecture scenario. Some students suffer from test anxiety or are poor essayists, and their performance on traditional assessment pieces may not reflect their understanding of the course material. For these students, a clicker system can be a significant boon, both as proof to professors of the students' effort and classroom attentiveness, and as a tool for reinforcing for students what material is most likely to be covered on tests and quizzes (Wieman and Perkins, 2005).

Technology can be a powerful tool in the classroom, but only in the hands of a professor who uses it well; the benefits of technology are purely aesthetic unless accompanied by a significant change in teaching style (Goldenberg, 1995; Szabo et al., 2000). What we really require is the introduction of a teaching style that incorporates curriculum materials, current technology, and perhaps the multiple ways students learn (McNulty et al., 2000; Guthrie and Carlin, 2004; Miller, 2004).

CASE STUDY: RUTGERS UNIVERSITY OCEANOGRAPHY

Introductory-level courses in the Rutgers University oceanography department, as in other university departments, are designed to both provide students with a general overview of the subject material and also to draw in potential majors. While we acknowledge that many students take the introductory oceanography courses purely to fulfill general education requirements, we do not see this as a reason to believe that these students will not successfully learn and retain the course material. Rather, there is a great advantage to this sort of course: it may be that introductory, general education-style courses contribute significantly to SL (Schmidt et al., 1997; Miller, 2004). In the US, the majority of university graduates are required to take science courses, even if they are not studying scientific disciplines. Similarly, American adults have slightly higher levels of SL than do EU or Asian adults. Miller et al. (1997) and Miller and Pardo (2000) say that this isn't a coincidence: rather, the general education courses expose undergraduates to science at a higher level, encouraging those students in the development of SL (Schmidt et al., 1997, Ryder et al., 1999). If even an averagely effective introductory science course can increase an individual's SL, then we posit that an extremely well-crafted, high-quality course has the potential to result in dramatic shifts in the understanding of and appreciation for science. In this section, we will review the student-reported effectiveness of a single introductory oceanography course at Rutgers University, then propose a series of assessments which will allow us to better evaluate student SL before and after the course. Finally, we will propose methods for altering the course to encourage the development of student SL.

Student learning in an introductory oceanography course

At Rutgers University, the general education program requires undergraduate students to take six credits of writing, six of quantitative reasoning, six of natural science, 12 of social science and interdisciplinary courses, three in a diversity field, and three in a global awareness field (Alvarez, 2007). Each field contains some courses which could lead to increases in student SL (Appendix 1), however, that there is a required natural science field suggests that some students are likely to take introductory-level natural science courses because of the requirement rather than as a result of a strong prior interest in the subject.

In this case study, we will focus on Oceanography 204, The Water Planet, a large and popular introductory course. In this course, an average 34% of students over four years self-report a "strong prior interest in the course" (Appendix 2). This can be a negative (in a class with fewer interested students, the entire tone of the classroom can be affected, and the learning for the entire group can be undercut, but can also have positive results – students who may otherwise have never taken a science course at all may discover a strong, previously unrecognized interest in and aptitude for the subject (Miller and Pardo, 2000).

While an average of 34% of students reported prior interest in the course material, after completion of the course 62% of students reported having "learned a great deal" (Appendix 2). This reflects a near-doubling in students' interest in the course material, and reflects positively on students' SL having improved as a direct result of taking the class. The student SL likely improved in two distinct ways: first, simply by learning the course material – as discussed in Miller (2004), the simple act of learning even the most basic facts does indeed result in an improvement in SL. A majority of students reported having learned the course materials, and, based on an average assessed course grade of a B+, it does indeed appear that the students successfully learned the course basics. Second, student SL improved as a result of their improved interest in the course materials – that is, as addressed by Miller (2004), a component of SL is the individual's use of informal science resources – books, television shows, etc. If students' have gained an enhanced interest in the course material, which we can assume happened if a majority of students report having learned a significant amount from the course, then we can also assume that these students will be more likely to take an active interest in and to seek out additional scientific material in the future, whether by reading oceanography-related articles in the newspaper or watching televised specials.

While the student assessment forms can give us mostly positive feedback, there are still significant concerns. While the 62% of students did report having learned a great deal in the course, 32% reported a neutral response and 6% disagreed, and reported that they had *not* learned a great deal. In any class, there is likely to be a certain percentage of students who, due to circumstances out of our control, will report having not learned a significant amount in a given class. However, we are interested primarily in the 32% of students who report a neutral feeling regarding their in-class learning – those who were not "reached" by the course material.

In assessing student learning in an introductory course, there is the problem of identifying what students actually did and did not learn in the course. While a self-assessment is an excellent first step, students' egos (large or small), as well as their desire to please (or punish) the professor, have the potential to alter the results gleaned from the surveys. Hence, as we see in other studies of SL and science education we must develop an effective method for assessing student learning in a course situation, which will allow us to evaluate student knowledge before the course, as well as upon course completion. An additional assessment method would also let us confirm (or disprove) our assumptions: that increased interest in the course materials will lead to increased SL.

A proposed assessment method for oceanography students

To evaluate the effectiveness of introductory undergraduate oceanography programs, we must first find a way to evaluate student knowledge prior to the course – we must establish a baseline level of knowledge. To do this, we will use the three-pronged test proposed earlier in this thesis, evaluating students' factual knowledge about the subject matter, ability to apply course materials to real-world situations, and attitudes towards climate science and oceanography. We propose assigning this quiz as a brief, in-class assignment on both the first and last days of the class, in order to best determine precisely what material was learned during the duration of the course. While these quizzes will not take into account students' learning outside of the class itself (for example, if students took classes during the same semester which taught similar information), they will effectively evaluate what material the students learned during the semester in which they took the course.

Our first step must be the evaluation of students' factual knowledge. In order to do this, we will provide students with a brief series of questions, each of which will address material that will later be covered in the course itself (Appendix 3). The quiz we propose includes questions regarding greenhouse gases, precipitation, volcanoes, winds, the preservation of natural resources and other course topics (Appendix 4).

For the application-based portion of our assessment, we will provide students with a series of introductory paragraphs from chapters in the course textbook, The Blue Planet (Skinner et al., 1999). Each chapter begins with a page-long summary of an application of the textbook material (a summary of Krakatau preceding a chapter on volcanoes, a summary of the Glen Canyon Dam's environmental impact preceding a chapter on stream flow, etc.). We will then request that students read the paragraphs, then write a brief summary, including at least two questions which may help them better understand the material (Appendix 5). We will evaluate these questions using a rubric derived from Korpan et al. (1997) (Appendix 6). Each question will be classified into one of nine categories, based on the types of information requested and on their demonstrated understanding of the subject. As addressed in Korpan et al. (1997) and Tytler et al. (2004), the ability to ask questions whose answers are not explicitly addressed in the provided material is an excellent indicator of student learning and comprehension.

The third component of our assessment will examine students' personal feelings about science and scientific research. We will provide students with a series of questions, asking them to rank their feelings on the subject, using a simple numerical evaluation scale (Pooley and O'Connor, 2000; Halloun, 2001) (Appendix 7).

We will consider the difference in student scores between the beginning and the end of the course the shift in student SL resulting from having taken Oceanography 204. In an ideal world, we could also revisit the class cohort a year or more later and present them with the same quiz, the results of which we could use to determine the degree to which the students retained information obtained in the course.

Improving student learning in large classes: Small changes with large results

Introductory courses at Rutgers University are quite large, with an average student enrollment of approximately 200 students in the Water Planet. Thus, in order to cover a large amount of material over the course of a single semester, many professors choose to base their courses on lectures to large groups. This instructional style is widely popular in a great number of science courses, because of its comparative efficiency in passing large amounts of information in a relatively short amount of time (Cooper and Robinson, 2000; Dehaan, 2005). McKeachie (1980) suggests that large lecture courses are not significantly less effective than smaller lecture classes, if we use multiple-choice achievement tests. However, students in larger lecture classes do perform less well than their peers in smaller classes on assessments of ability to evaluate and apply course materials (Benjamin, 1991). In addressing education in large introductory classes, we must work towards the delicate balance between quantity of students taught and quality of information transferred.

Gardner (1993) proposes that, in a given group of science students at an introductory level, it is unlikely that a significant majority will have a strong natural aptitude for the material, hence the professors must teach not only to the students with great interests in the material but also to the students who require extra assistance. For professors, teaching to the students who are less interested in course material can improve learning and retention for all the students – students learn a subject more thoroughly when the instructor uses not only traditional methods but also spends class time addressing social applications of the material, as well as visual, artistic, kinesthetic, and other methods for examining the data (Gardner, 1993; Lerch, 2006).

One method for improving student learning is the increased use of assessment techniques (Black and William, 1998). Regular assessment in a classroom setting provides students with a clear picture of what course material they should learn, as well as to what depth they must learn it. Assessments which address simple vocabulary and concepts effectively "tell" students that they need only learn material at a superficial level, whereas regular, high-level questions tell students that they are expected to develop a strong grasp of the material (Boud, 1995). While it is difficult to provide high-level homework assignments to a large class on a regular basis, Thalheimer (2003) suggests that asking students questions during class, and then simply providing them with a few minutes to write down brief answers, is just as effective a method of ensuring information transfer as are the institution of regular homework assignments or quizzes. Hence, one simple technique for improving student learning in a large class is the regular posing of high-level questions in class. The assignments can be collected at the end of the class period, or regularly throughout the semester, in order to prevent the "hitchhiker" problem – students present for but refusing to participate in class work because it is not collected.

Clicker systems are also especially useful in larger classes. In a large class, students often report a lack of involvement in the classroom, which results in a loss of interest in the course material (Len, 2007). The addition of regular clicker-based questioning, especially when question results are displayed via projector and are immediately addressed by the professor, can increase individual student involvement.

Furthermore, when students do *not* understand the subject material, the professor can quickly address sources of confusion, even if the students are too embarrassed or proud to ask the professor for clarification.

Additionally, clicker systems can be used for both introductory and review questions, which can serve both to steer the course of lectures and to clarify for students the “take-away” message of the lecture (CAPT, 2006). Therefore, these systems can help improve student learning, even in situations in which regular, intensive one-on-one interaction with the professor does not take place.

Another simple change which instructors may find extremely effective is the removal of key terms from PowerPoint presentations. When all relevant information is printed onscreen in a PowerPoint presentation, and especially when those presentations are available for students to download, students lose motivation to pay attention and to take notes during class. The availability of full sets of lecture notes on the internet results in decreased student motivation to attend class, as well as in increased absenteeism (Sipress, 1995; Szabo 2000; James et al., 2006). Rather than providing all necessary course material in PowerPoint presentations, professors should instead heavily edit course materials. While putting charts and figures into PowerPoint presentations can be quite helpful to students, the removal of the bulk of the text from these presentations will benefit professor-student interactions in two ways: it will demand more attention from students during lecture periods, improving student engagement and comprehension, and it will make class attendance a greater priority for many students.

A third technique for improving student learning in a large-lecture-based course is the incorporation of small group discussion sessions. While it may be difficult to successfully orchestrate such events, they result in improved student attendance, as well as student-reported improvements in learning and critical thinking (Cooper and Robinson, 2000; Yuretich et al., 2001). In a small group, students work together to "construct knowledge," shifting from passive to active roles, which significantly contributes to information retention (Garfield, 1993). One potential way to easily incorporate group work is through use of "think/pair/share" exercises (Lyman, 1981). In this type of work, individual students are asked to formulate a short, written response to an open-ended question, then to compare their responses with a partner. This method of instruction is quick, and requires minimal set-up on the part of the instructor, but also provides students with the chance to hone their analytical skills by discussing course material with peers. Another potential method for student involvement requires a shifting in the course schedule: by reorganizing class periods so that smaller groups (~20 students) meet for shorter classes – for example, ¼ of the class can come to the first 20 minutes for a discussion; after 20 minutes the next ¼ arrives for a discussion, etc. This method fosters enhanced student-faculty interaction, and, while it may result in less in-class time for each individual student, it ensures that students are actively engaged for the duration of the abbreviated period (Yuretich et al., 2001).

Geske (1992) proposes a method for avoiding this problem: he invites guest lecturers to provide a short lecture followed by a discussion session, offering extra credit for students who attend and participate. While this method does not specifically address all students in the classroom, it does indeed provide students with opportunities to engage with course materials on a personal level.

By using active, student-based instructional methods in large, introductory classes, we can see significant shifts in student performance (Garfield, 1993; Boud, 1995; Cooper and Robinson, 2000; Yuretich et al., 2001). Here, we propose three simple methods for improving student involvement without significantly straying from the large-lecture format of most university's introductory science courses. By making these few shifts, it is possible to improve student learning and to greatly increase the development of SL.

Conclusions

The American public's interest in science has shifted and evolved in response to developments in politics and social movements (DeBoer, 2000). In the United States today, there is an overwhelmingly positive public perception of science and technology; however, there remains a very low level of public understanding of basic scientific principles and applications (Ryder et al., 1999; Gambro and Switzky, 1996, Korpan et al. 1997). There is a strong correlation between SL and courses taken at the university level, so the university system must respond to this low level of public understanding of science by examining and improving methods of education (Miller, 2004).

After comparing a suite of definitions and assessment methods for SL, we proposed a three-part definition, combining fact-based, application-based, and emotion-based assessment methods into a single method. After a review of the structure of large science classes at Rutgers University, we propose a method for assessing student learning in an introductory oceanography class, Oceanography 204, The Water Planet. By assessing student understanding of the fundamental concepts of oceanography before and after the course, we can determine whether student learning is taking place, and whether students are developing analytical skills as well as factual knowledge. Finally, with a series of techniques for altering the structure of The Water Planet, we suggest methods for increasing student learning in a large lecture-format class, which could increase student interest and involvement.

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APPENDIX 1

Summary of general education requirements at Rutgers University, and list of courses fitting those requirements that may also result in increased SL (Alvarez, 2007).

Writing Requirement: Expository Writing 101 and one course, credit-bearing and worth at least 3 credits, from a list of approved courses. Such courses are above the 100 level, require 15 pages or more of writing in English (excluding exams), including at least one sustained piece of analytical or interpretive prose, and provide regular detailed feedback on writing.

01:355:302	Scientific and Technical Writing
01:355:312	Writing for Biology and Natural Science
01:355:315	Writing Grant Proposals
01:355:322	Writing for Engineers
01:355:342	Science Writing
01:355:352	Writing as a Naturalist
01:447:484	Behavioral and Neural Genetics
01:450:330	Geographical Methods
01:450:413	Climate System and Global Climate Change
01:450:419	Advanced Conservation of Natural Resources
01:450:470	History and Theory of Geography
01:450:491,492	Geographic Problems
01:460:341	Stratigraphy
01:460:408	Geomorphology
01:460:410	Field Geology
01:694:489, 490	Literature Research in Molecular Biology and Biochemistry
01:920:434	Social Science & Public Policy

Quantitative Reasoning Requirement: 2 courses, each credit-bearing and worth at least 3 credits, consisting of 1 course in Mathematics (640) and 1 course in mathematics or some discipline specific course strongly emphasizing either analytic or quantitative methods.

01:450:319	Quantitative Methods in Geography
01:450:320	Spatial Data Analysis
01:450:330	Geographical Methods
01:730:201	Introduction to Logic
10:762:395	Research Methods
01:160:251	Analytical Chemistry
01:450:319	Quantitative Methods In Geography
01:450:320	Spatial Data Analysis
01:450:330	Geographical Methods
11:115:413	Experimental Biochemistry

Natural Sciences Requirement: Two courses, each credit-bearing and worth at least 3 credits, chosen from: Biological Sciences (119, 146, 447, 694), Chemistry (160), Geological Sciences (460), Marine and Coastal Sciences (628), Meteorology (670), and Physics (750), plus a list of select courses noted below. Independent study, internships, and research courses may not be used to fulfill this requirement.

01:105:ALL	Department of Astrophysics
01:119:ALL	Department of of Biological Sciences
01:146:ALL	Cell Biology and Neuroscience
01:160:ALL	Department of Chemistry and Chemical Biology
01:447:ALL	Genetics
01:460:ALL	Department of Geological Sciences
01:628:ALL	Department of Marine and Coastal Sciences
01:670:ALL	Department of Meteorology
01:694:ALL	Molecular Biology and Biochemistry
01;750:ALL	Department of Physics and Astronomy
01:070:102	Introduction to Human Evolution
01:070:212	Survey of the Living Primates
01:070:213	Environment and Human Evolution
01:070:215	Survey of Fossil Primates
01:070:240	Introduction to Molecular Evolution
01:070:325	Evolution & Culture
01:070:348	Primate Socioecology
01:070:349	Advanced Physical Anthropology
01:070:350	Primatology and Human Evolution
01:070:354	Functional and Developmental Anatomy of the Primate Skeleton
01:070:356	Human Variation
01:070:358	Introduction to Human Osteology
01:070:390	Plio-Pleistocene Hominid Anatomy
01:070:402	Theories in Physical Anthropology
01:070:420	Evolutionary Genetics: Humans and Other Primates
11:375:101	Introduction to Environmental Sciences
11:375:102	Soils and Society
11:375:103	Introduction to Environmental Health
01:185:201	Cognitive Science: A Multidisciplinary Introduction
01:185:411	Advanced Topics in Cognitive Science 1
01:185:412	Advanced Topics in Cognitive Science 2
01:185:495-496	Research in Cognitive Science
01:377:213	Functional Human Anatomy
01:377:303	Neuromechanical Kinesiology
01:377:350	Biomechanics
01:377:370	Exercise Physiology
01:377:381	Biochemistry of Exercise
01:377:410	Exercise Testing and Prescription
01:377:454	Advanced Exercise Physiology
01:447:ALL	Department of Genetics

01:450:101	Earth Systems
01:450:102	Transforming the Global Environment
01:450:140	The Greenhouse Effect (also 160:140, 556:140, 750:140)
01:450:370	Global and Regional Climate Change
01:450:403,404	Advanced Physical Geography
01:450:413	Climate System and Global Climate Change
01:450:417	Coastal Geomorphology
01:556:101	Study BioMed Science
01:556:201	Study BioMed Science
11:067:142	Animal Science
11:704:351	Principles of Ecology
11:776:170	Plants and People

Social Sciences, Humanities, and Interdisciplinary Requirement: Four courses, each credit-bearing and worth at least 3 credits, in the Humanities and Social Sciences, with at least 3 credits from each of the three subdivisions shown below:

a. Social Science

01:070:ALL	Anthropology
01:450:ALL	Geography
01:790:ALL	Political Science
01:10:762	Planning and Public Policy
01:10:832	Public Health
01:556:220	Intro to Science, Technology, & Society
01:556:404	Topics in Science, Technology, & Society

b. Humanities

none

c. Interdisciplinary Humanities and Social Science

01:450:ALL	Department of Geography
01:762:ALL	Department of Planning and Public Policy
01:832:ALL	Department of Public Health
01:070:205	Evolution & Culture
01:070210	Approaches to Human Nature
01:070:220	Food & Culture
01:070:302	Environmental & Cultural Behavior
01:070:307	Medical Anthropology
01:070:317	Method and Analysis in Cultural Anthropology
01:070:326	Pleistocene Hominid Adaptations
01:070:334	Field Study in Archaeology
01:070:335	Analysis of Archaelogical Data
01:070:392	Faunal Analysis in Archaeology
01:070:394	Microstratigraphic Analysis in Archaeology
01:070:395	Quanification of Archaelogical Data

01:070:396	Geochronology
01:070:404	Advanced Seminar in Archaeology
01:070:412	Topics in African Prehistory and Paleoanthropology
01:070:414	Topics in European Prehistory and Paleoanthrpology

Diversity Requirement: One course, credit-bearing and worth at least 3 credits, from an approved list of courses. Courses fulfilling this requirement engage students in theoretical issues and political debates pertaining to questions of "diversity," namely race, ethnicity, language, migration and diasporas, gender, and sexualities. These courses must juxtapose two or more visions or methods which would enable an understanding of an increasingly globalized world. Sample topics include the following: histories of religion, social movements, cultural conflicts, racial tensions, visual culture and representation of transnational identities and differences, international feminisms, and sexual prejudice. Study abroad does not ipso facto satisfy this requirement, although individual courses taken abroad may qualify.

04:192:446	Communication and Social Change
01:450:100	Global Perspectives on Culture, Society and Environment
01:450:103	Human Geography: Space, Place and Location
01:450:262	Geographic Background to Current World Affairs
01:450:363	Geography of Development
01:450:470	History and Theory of Geography
01:512:121	Health and Environment in America

Global Awareness Requirement: One course, credit bearing, worth at least 3 credits, from an approved list of courses. The Global Awareness requirement promotes enhanced knowledge of the interconnectedness of the world's peoples, cultures, environments, regions, or nations whether historically, politically, economically, socially, linguistically, technologically, ecologically, or epidemiologically. Courses in this category deepen area based knowledge and encourage analysis of global or transnational processes. They help students to recognize the need for an understanding of local, regional, international, transnational and/or global dynamics that inhibit or promote solutions to contemporary world problems. Introductory language courses do not fulfill this requirement.

01:070:305	Anthropology of Development
01:160:127	Impact of Chemistry
04:192:446	Communication and Social Change
04:567:420	Global News
04:567:475	International Media
01:450:100	Global Perspectives on Culture, Society and Environment
01:450:101	Human Geography: Space, Place and Location
01:450:262	Geographic Backgrounds to Current World Affairs
01:450:311	Natural Hazards and Disasters
01:450:363	Geography of Development
01:450:370	Global and Regional Climate Change
01:450:380	Medical Geography

01:556:140	Greenhouse Effect
01:790:317	Globalization and the Non-Western World
01:790:350	Environmental Politics-U.S. and International
01:940:462	Environment and Literature in Hispanic Culture

APPENDIX 2

Student course evaluation data from Oceanography 204: The Water Planet. Students filled our multiple-choice surveys voluntarily on the last day of class.

			Response			Average Response		
		Year	Positive	Neutral	Negative	Positive	Neutral	Negative
1	The instructor was prepared for class and presented the material in an organized manner	2006	0.985	0.015	0.000	0.910	0.069	0.021
		2004	0.827	0.106	0.067			
		2003	0.860	0.123	0.018			
		2001	0.969	0.031	0.000			
2	The instructor responded effectively to student comments and questions.	2006	0.957	0.043	0.000	0.885	0.084	0.031
		2004	0.784	0.127	0.088			
		2003	0.895	0.070	0.035			
		2001	0.906	0.094	0.000			
3	The instructor generated interest in the course material.	2006	0.783	0.159	0.058	0.692	0.211	0.098
		2004	0.559	0.275	0.167			
		2003	0.800	0.127	0.073			
		2001	0.625	0.281	0.094			
4	The instructor had a positive attitude toward assisting all students in understanding course material.	2006	0.970	0.030	0.000	0.892	0.094	0.014
		2004	0.786	0.175	0.039			
		2003	0.875	0.107	0.018			
		2001	0.938	0.063	0.000			
5	The instructor assigned grades fairly.	2006	0.924	0.076	0.000	0.835	0.136	0.028
		2004	0.660	0.280	0.060			
		2003	0.821	0.125	0.054			
		2001	0.935	0.065	0.000			
6	The instructional methods encouraged student learning.	2006	0.706	0.265	0.029	0.610	0.323	0.067
		2004	0.480	0.353	0.167			
		2003	0.691	0.236	0.073			
		2001	0.563	0.438	0.000			
7	I learned a great deal in this course.	2006	0.739	0.246	0.015	0.620	0.321	0.059
		2004	0.525	0.327	0.149			
		2003	0.655	0.273	0.073			
		2001	0.563	0.438	0.000			

8	I had a strong prior interest in the subject matter and wanted to take this course.	2006	0.448	0.239	0.313	0.342	0.368	0.272
		2004	0.330	0.320	0.350			
		2003	0.309	0.382	0.236			
		2001	0.281	0.531	0.188			
9	I rate the teaching effectiveness of the instructor as	2006	0.896	0.090	0.015	0.805	0.166	0.029
		2004	0.636	0.263	0.101			
		2003	0.821	0.179	0.000			
		2001	0.867	0.133	0.000			
10	I rate the overall quality of this course as	2006	0.797	0.188	0.014	0.708	0.248	0.044
		2004	0.525	0.366	0.109			
		2003	0.778	0.204	0.019			
		2001	0.733	0.233	0.033			

APPENDIX 3

Syllabus from Spring 2007 class for Oceanography 204, The Water Planet.

Date	Day	Topic	Reading
16-Jan	T	The Earth system	ch 1
18-Jan	TH	The planetary system	ch 2
23-Jan	T	The sun, giver of life	ch 3
25-Jan	TH	Plate tectonics	ch 4
29-Jan	T	The Earth's evolving crust	ch 8
1-Feb	TH	The properties of water	
6-Feb	T	Water on land	ch 9
8-Feb	TH	Groundwater	
13-Feb	T	The world of snow and ice	ch 10
15-Feb	TH	The world ocean I	ch 11
20-Feb	T	The world ocean II	
22-Feb	TH	The world ocean III	
27-Feb	T	The Atmosphere	ch 12
1-Mar	TH	Winds, weather and deserts	ch 13
6-Mar	T	A planetary perspective on life	ch 15
8-Mar	TH	*Mid-term*	*problem set due 3/20/07*
13-Mar	T	**Spring break**	
15-Mar	TH	**Spring break**	
20-Mar	T	Biogeochemical cycles I	ch 16
22-Mar	TH	History of the biosphere I	ch 17
27-Mar	T	History of the biosphere II	
29-Mar	TH	The Earth's changing climate I	ch 14
3-Apr	T	The Earth's changing climate II	
5-Apr	TH	Earth's resources I	ch 18
10-Apr	T	Earth's resources II	
12-Apr	TH	Global Change I: the atmosphere	ch 20
17-Apr	T	Global Change I: cont.	
19-Apr	TH	Global change II: the hydrosphere	
24-Apr	T	Global change III: the biosphere	
26-Apr	TH	Concluding session	
8-May	T	*Final Exam 8am – 11am*	

APPENDIX 4

Sample assessment quiz for factual-based SL assessment for Oceanography 204, The Water Planet. Based on quizzes from Lightman and Miller (1989), Gambro and Switzky (1996).

1) List the order of the planets of the solar system (closest to the sun to furthest from the sun).

2) What is the chemical composition of water?
   a. O_2
   b. H_2O
   c. NH_4
   d. CO_2

3) The burning of fossil fuels has increased atmospheric carbon dioxide concentration. What immediate results do we expect to see?
   a. an increase in severe earthquakes
   b. a decrease in volcanic eruptions
   c. a cooler climate
   d. a warmer climate

4) What type of water is denser? Warm, fresh water or cold, salty water?

5) Name two major elements in sea salt.

6) Which of the following is *not* a renewable source of energy?
   a. Fossil fuels
   b. Solar power
   c. Hydroelectric power
   d. Wind power

7) What percentage of Earth's water is contained in the oceans?

8) Where in the ocean does the bulk of the deep water form?

9) With increasing depth, does water become warmer or cooler?

10) What is a word for the type of rock that is formed by volcanoes?

Answers:

1) Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto

2) b

3) d

4) Cold, salty water

5) Sodium, chloride, sulfate, magnesium, calcium, potassium

6) a

7) ~98%

8) The North Atlantic

9) Cooler

10) Igneous

APPENDIX 5

Sample application-based assessment for Oceanography 204, The Water Planet. Critical reading sections are taken from *The Blue Planet* (Skinner et al., 1999).

Instructions: Read the following selection, then write a short one-paragraph summary. Your summary should address the major topics of the selection. Write at least two questions that would help you develop a stronger understanding of the material.

Selection 1:

Phosphorus is one of the essential building blocks of life. Unlike the other essential building blocks – carbon, hydrogen, nitrogen, oxygen, and sulfur, all of which occur as gases in the atmosphere – phosphorus is difficult to obtain in nature. The original source of phosphorus is the rocks of the solid Earth, from which phosphorus containing soils are derived and from which in turn plants get their phosphorus, and animals, by eating plants, satisfy their needs. But agriculture removes phosphorus from the soil, an for good crop production phosphorus fertilizers are often needed. When the Indians showed the Pilgrims how to plant crop seeds with fish bones, they were teaching them a lesson in fertilizing; fish bones are rich in phosphorus.

Some soil phosphorus is carried away by groundwater and is eventually deposited in the sea. There, under rare and special circumstances, it may be concentrated into deposits that can be mined for the needed fertilizers. One of the most unusual circumstances of phosphorus concentration involves seabirds.

For centuries, phosphorus fertilizers were gathered on small coastal islands along the western coasts of South America. The "ores" were layer upon layer of whitish bird droppings – guano – left by millions of nesting sea birds over many years. When guano began to be exported to the northern hemisphere the harvesting of guano exceeded its creation. In addition, mining practices destroyed nests and bird populations on the islands were diminished.

Birds that nest on the guano islands obtain phosphorus by eating fish. The fish in turn feed on plankton, the floating "soup" of microscopic animals and algae in the upper layer of the ocean. The plankton get their phosphorus from seawater, and the places where plankton are most numerous are along coasts where deep, phosphorus-rich waters well up to the surface such as along the western coasts of South American and Africa.

Upwelling currents, plankton, fish, and birds are only part of the story. Guano is soluble and washes away in the rain. Guano can only accumulate in large amounts in dry climates. Thus, formation of a major source of guano requires a particular climate, a particular geography, and a particular set of fish and bird species. Occasionally, the relationships are disrupted; sometimes the upwellings fail because of the El Niño events, the plankton disappear, fish die or swim away, and birds die in vast numbers.

Selection 2:

When John Wesley Powell and his companions made the first transit of the Grand Canyon by boat in 1879, the Colorado River was a mighty through-flowing stream with a series of dangerous rapids. The far-sighted Powell envisaged dams across the river that someday would provide abundant water to the arid lands of the American Southwest. Today, like most western rivers, the Colorado is no longer entirely free-flowing. In 1963, the federal government built the Glen Canyon Dam, designed to provide bother water and electrical energy to nearly 20 million people. In the years before the dam was raised, the river annually carried millions of tons of sediment into the Grand Canyon where it created bars and beaches that supported the vegetation on which myriad animals depended for food.

Like other dams built across rivers throughout the continent, the Glen Canyon Dam disrupted the natural aquatic habitat. It halted the supply of fresh sediment from upstream, reducing the sediment load that led early settlers to claim that the river was "to thick to drink, and almost thick enough to plow." Furthermore, until recently, release of the impounded waters was timed to accommodate the fluctuating needs of consumers for power to run air conditioners on hot afternoons, or to turn on electric stoves and ovens for the evening meal. Aquatic populations find it difficult to adjust to frequent highly variable changes in water level, and it is not surprising that the river became biologically poorer.

Alarmed by the serious changes in the ecosystem resulting from the dam, and alert to studies that emphasized the need of riverine ecosystems to have a sustained natural flow of water, scientists proposed that an experimental flood be released to assess its effect in restoring natural conditions along the stream systems. In the spring of 1996, a week-long release of water from the reservoir created an artificial flood. By autumn, the government reported that several major waterways and former beaches had been restored and that nutrient-rich sediment had been made available to plants and animals. Based on these studies, the government has released new guidelines for government-managed damns designed to allow water to flow more naturally.

APPENDIX 6

Category:	Requests involve:	Examples:
Social context	Social factors that may influence the study; credentials of researchers; sources of funding; where research is published	Where was the research done? Who funded it? How qualified are the researchers? In which journal was the study published?
Agent/theory	The agent involved in the experiment; possible causes for observed results	Why is salty water denser? How does sea ice form? How do submarines work?
Methods	Research methods, procedures, replicability, and control groups.	What was the experimental procedure? Where was the experiment done? What control group was used?
Data/statistics	Statistical analyses used, explicit requests for the data themselves.	What is the statistical significance of the results? Are the conclusions proven?
Related research	Similar studies, relationships among these findings and those from similar experiments.	Have similar experiments been done before? By whom? What were their results?
Relevance	Social context of findings, potential impacts of research	How broadly applicable are these results? How should society respond?
Other	Information that is relevant to the subject but not covered by any of the above categories	Where is the Sargasso Sea? Who discovered AABW?
Ambiguous/relevant	Information that falls into more than one of the above categories	Why did this group study this topic? What is the history of this problem?
Off-task/irrelevant	Information that is inappropriate or does not show understanding of concepts	Where is the ocean?

APPENDIX 7

Sample assessment quiz for emotion/belief-based SL assessment for Oceanography 204, The Water Planet. Based on assessments frm Pooley and O'Connor (2000).

Instructions: Read the following list of concepts/behaviors, then circle your emotional responses. Use the following scale:

Unfavorable			Neutral		Favorable	
-3	-2	-1	0	1	2	3

1. Logging national forests	-3	-2	-1	0	1	2	3
2. Restricting carbon dioxide emissions	-3	-2	-1	0	1	2	3
3. Eating organic food	-3	-2	-1	0	1	2	3
4. Driving a large sport-utility vehicle	-3	-2	-1	0	1	2	3
5. Increasing the use of nuclear power	-3	-2	-1	0	1	2	3
6. Recycling	-3	-2	-1	0	1	2	3
7. Drinking bottled water	-3	-2	-1	0	1	2	3
8. Fertilizing your lawn	-3	-2	-1	0	1	2	3
9. Washing laundry on the coldest setting	-3	-2	-1	0	1	2	3
10. Buying local produce	-3	-2	-1	0	1	2	3