ABSTRACT

SMITH, HAYLEY JOYELL. What do Students Find Relevant in an Introductory Geology Course? Implications for Changing Students' Attitudes About the Relevance of Geoscience in Society. (Under the direction of Dr. David McConnell.)

Geoscience education plays a vital role in achieving the goal of cultivating a scientifically literate citizenry that can make informed decisions for a sustainable future. This study investigated undergraduates' attitudes about and perceptions of the relevance of geoscience in society. Using a mixed-methods approach, data were collected over the course of a semester in an active-learning introductory geology courses. Course structure, instructor pedagogical practices and student demographic profile characteristics were described. Students' (n=144) attitudes in three section of MEA 101 were quantitatively measured with the Changes in Attitudes about the Relevance of Science (CARS) instrument. There was no significant difference in students' attitudes about the relevance of science among sections. Statistical analysis provided evidence that student's average CARS scores significantly increased ($p=0.018$) over the course of the semester. This signified that students were increasingly more agreeable to statements about the application of science in daily decision-making. Students' change in CARS scores showed a significant positive relationship with two of the three performance measures. The strongest relationship ($R^2=0.16$, $p<0.001$) was with a short-answer score that assessed students' ability to describe the application of geoscience content in society. Qualitative data from open-ended questions provided insight into students' perceptions of the relevance of geoscience in society. Analysis of responses showed that students identified similar geoscience concepts relevant to society as described by the Earth Science Literacy Principles human-Earth related Big Ideas. These concepts included topics related to natural hazards, water and energy resources, and climate change. Student responses revealed the link between perception of relevance and application of the geoscience content in a real-world situation.

What do Students Find Relevant in an Introductory Geology Course? Implications for Changing Students' Attitudes About the Relevance of Geoscience in Society

by
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DEDICATION

I dedicate this thesis to the one who initially sparked my curiosity of Nature. To the one who took me fossil hunting as a child, worked on science projects late into the night as a girl, taught me how to create art as a teenager, and sent me to college with a toolbox and the encouragement to always give things a try. I dedicate this to the person who instilled a sense of questioning, work ethic, and love of the sun. This thesis is for the one who cultivated my curiosity into a way of living with a sense of openness to wonder and gratitude. I dedicate this personal life achievement to the one I hold in my heart and miss everyday, my father, Brant Smith.

BIOGRAPHY

I was born and raised in Anderson, Indiana. Fortunate to be surrounded by family, my childhood was one of a typical Midwest middle class suburban family. However, my parents embodied a unique appreciation for openness to various foods, cultures, music, and life experiences. This shaped my perspective on people and resulted in growing up with lots of friends from many different backgrounds. I. middle school I became interested in humanitarian and environmental issues. This continued through high school, where I started a city-wide recycling project, completed outdoor adventures, and began considering the way in which lifestyle affected the environment.

Attending a small private liberal arts college in Southern Indiana was the place that fostered my drive to read and learn. I double majored in Philosophy and Geology and completed my thesis about the impacts of the Three Gorges Dam on the people and environment along the Yangtze River, China. I was lucky to have a suite of brilliant professors that introduced me to new ways of thinking and using resources. I pursued geology because I loved being outdoors and the knowledge of the landscape fueled my curiosity of the natural world. Furthermore, I found the scientific method a fascinating ontology that complimented my philosophical perspectives.

Following Hanover College, I moved to Asheville where I worked with clay and later began teaching middle-school science. Afterward, I began traveling in developing countries where it became clear to me that the complexities of Earth's systems are more than mind candy; they were the systems that determined our livelihood. The relevance of geoscience was abundantly clear after witnessing communities that depended on their surrounding local ecosystems instead of the global resources, individual suffering from water borne illnesses, and displaced families after an earthquake crumbled the village of adobe homes. These experiences lead me to decided to further my own education and to research the way that others perceive the relevance of geoscience in society.

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INTRODUCTION

The call to cultivate citizens who can address global sustainability challenges echoes through environmental grassroots organizations (Pastakia, 1998), universities (Rowe, 2002), and global institutions (Jickling and Wals, 2008). These efforts share a broad goal to educate a scientifically literate citizenry that understands the connection between humans and environmental health and possesses skills that foster informed decision-making for a sustainable future. Geoscience education plays a vital role in achieving the goal of sustainability as environmental health is inherently rooted in Earth systems. While students have years of experience exploring societal dynamics through their day-to-day interactions with other citizens, they may lack the knowledge or awareness of their interaction with the Earth system. Many US undergraduates enroll in introductory geology courses that fulfill the physical science general education degree requirement. This provides an opportunity to address science literacy and teach geoscience content that students will need to make informed decisions for a sustainable future (Bralower et al., 2008).

The geoscience community has acknowledged the need to address global sustainability and to connect the geosciences to societal issues. A prime example is the recently published Earth Science Literacy Principles (ESLPs; Wysession et al., 2012). The ESLPs highlight the role geoscience plays in the facilitation of sustainable choices made by individuals and communities by outlining the ways in which humans: 1) depend on Earth's resources; 2) are impacted by natural hazards; and 3) alter Earth's systems. The role geoscience plays in the sustainability of the planet is obvious to geoscience experts and educators, who have a firm grasp of topics such as water systems, formation of fossil fuels, and plate tectonics. However, do undergraduates in an introductory geology course perceive geoscience as relevant for a more sustainable future? Does their experience in an introductory geology course impact their attitude about the relevance of science for decision-making in their daily lives? Furthermore, if students recognize geoscience content as relevant, do they foresee how to apply the information in a societal context? If the community of geoscience educators aims to contribute to the cultivation of future citizens capable of making informed decisions for a sustainable future, then these questions need to be addressed.

It is expected that some of the instructors described in this study will employ new curricula developed to incorporate the ESLPs and relevance of geoscience in society. The curricula are the outcome of the Interdisciplinary Teaching about Earth for a Sustainable Future (InTeGrate) project (http://serc.carleton.edu/integrate/). This multi-institutional project funded by the National Science Foundation, is leading the effort to promote the development of geoscience curricula in the context of societal issues (Gosselin et al., 2013). The findings from the current study will serve as a point of comparison to measure the impact of the InTeGrate curricula on student attitudes about the relevance of science in everyday decision-making and their perception of the relevance of geoscience content in society.

This study sought to establish a baseline that characterized student perceptions of the relevance of specific geoscience content as it related to individuals and communities around the world. Open-ended questions were used to address the following research question:

RQ: How do undergraduates' perceptions of the relevance of geoscience emerge from student writings on geoscience content in the context of society?

This study also endeavored to investigate undergraduates' attitudes about the relevance of science in an introductory physical geology course. We used a survey instrument to measure the degree of change in students' attitudes about using science for daily decision-making to address the following hypotheses:

$H_0$1: There is no difference in undergraduates' attitudes about the relevance of science among sections of MEA 101.

H2: Exposure to geoscience content changes students' attitude about the relevance of science.

H3: There is a relationship between student changes in attitude about the relevance of science and performance.

LITERATURE REVIEW

Science Literacy

The topic of science literacy entered the United States education scene in the early 1900's when scientists began explaining the relevance of science in individual and societal life (Deboer, 2000). Since then, scientists and education researchers alike have cited increasing changes in technology and the unpredictable nature of the world as reasons for emphasizing scientific literacy (Gogolin and Swartz, 1992; Holbrook and Rannikmae, 2009). Advocates for a scientifically literate citizenry claimed that comprehensive knowledge of the natural world is essential for cultivating a sustainable planet (Mayer 1997; Liu 2013). However, one challenge with the broad goal of science literacy was in discerning what exactly constitutes a scientifically literate person. For example, did an individual need to be able to illustrate the hydrologic cycle, describe the theory of plate tectonics, or identify certain rocks and minerals to be considered scientifically literate? Another challenge was epistemological; what value did knowledge possess if it could not be applied in a real life situation (Klotz, 1992)? For instance, was knowledge that water facilitates the metamorphosis of rocks equal in value as knowledge that water facilitates the transportation of minerals and pollutants? Furthermore did it matter if an individual possessed the knowledge but did not know how to apply it to prevent or solve a problem? Instead of focusing on content knowledge that defines a field of study, Klotz (1992) argued that focusing on content that pertained to one's own life and fostering an ability to use scientific knowledge for sound decision-making was of greater importance. Over the past few decades various scientific disciplines have attempted to identify the knowledge a person should possess for every day decision-making.

Environmental literacy laid the foundation for other discipline-based science literacy goals and was the first to make its way into public vocabulary. Charles Roth coined the term "environmental literacy" in 1968 in an article published in the Massachusetts Audubon (Roth, 1968) that was reprinted in the New York Times (Faust, 1969) and shortly afterward popularized by President Richard Nixon. President Nixon first referenced environmental literacy in an address to Congress and continued using the term during his promotion of environmental quality as a national priority (Nixon, 1970). At that point the term "environmental literacy" was vague and undefined. Shortly after, Roth and the Liberty Council of Schools Environmental Project worked to create a clear definition and framework for environmental literacy. Under the premise that "A major purpose of education is to provide people with the knowledge and skills to allow them to live successful, productive lives and to function as responsible citizens within society" (Roth, 1992, pp. 10), an environmental literacy framework was adopted by the National Environmental Education Act of 1970 that stated:

1. All sustainable human activities are dependent upon a clean, healthy, and productive environment.
2. It is the environment that provides the materials and energy to meet our basic needs and desires.
3. The nature of particular environments set the parameters and risks for many human activities.
4. All human activities have consequences for the environment, both positive and negative.
5. The quality of our environment at any given point in time is the net sum of the consequences of individual and group actions.
6. People have the capacity, and generally the opportunity, to make individual and group choices among alternative behaviors and technologies and to assess and affect the risks.
7. Much of the environmental degradation that has occurred in the past, and continues today, is the result of the failure of our society and its educational systems to provide citizens with the basic understanding and skills needed to make informed choices about people/environment interactions and interrelationships.
8. Environmental degradation is often the result of thoughtless activity of most economic systems operative today.
9. Environmental literacy is essentially the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or

improve the health of those systems.

10. Developing environmental literacy is the primary goal of environmental education, with the objective of fostering productive and responsible citizens of this planet and of our society.
11. A major objective of schools is the preparation of students to be productive and responsible citizens in our society.

Recently published science literacy documents described similar goals of establishing an overarching understanding of the interconnectedness of Earth systems and identifying the role humanity plays in the health and sustainability of the planet: atmospheric literacy (Johnson et al., 2007), climate literacy (NOAA 2009), earth science literacy (Wysession et al., 2012), and ocean literacy (Aldredge et al., 2013). Many of these documents also highlight content knowledge that can be applied in the daily lives of citizens.

Aspects of the Earth Science Literacy Principles (ESLPs) are the focus of the current study. The ESLPs were developed through multiple iterations during 2008 and 2009. Funded by the National Science Foundation, the Earth Science Literacy Initiative (ESLI) was spearheaded by both educators and scientists. The process of composing the documents consisted of online and in-person workshops, presentations at professional meetings, and alignment with the National Science Education Standards (LaDue et al., 2007). In all, over 700 people contributed or reviewed the ESLPs document (Wysession et al., 2012).

There were nine total ESLPs described by the Earth Science Literacy Committee (ESLC) as the “Big Ideas” (Wysession et al., 2012). Each Big Idea was divided into several supporting concepts. Each of the supporting concepts included a brief description and examples of the content covered by the concept. See Table 1 for an example.

Table 1. Example outline ESLP with Big Idea, Supporting Concept, and Description

Big Idea 8	Supporting Concept 8.7	Description
Natural Hazards pose risks to humans	Humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts.	Loss of life, property damage, and economic costs can be reduced by identifying high-risk locations and minimizing human habitation and societal activities in them, improving construction methods, developing warning systems, and recognizing how human behavior influences preparedness and response.

The current study focused on three of the nine Big Ideas that discuss specific connections between geosciences and humanity, therefore making it more relevant to the reader (Appendix A; Wysession et al. 2012). The three human-Earth Big Ideas and an overarching description of the supporting concepts as described by the ESLC are as follows:

- Big Idea Seven: Humans depend upon Earth for resources.

  Earth is our home; we depend upon it for our subsistence. The availability of natural resources has determined where cities and civilizations have arisen. The supplies of many resources—water, soil, minerals and metals, and fossil fuels—are unevenly distributed and globally limited and have long been a source of political and social turmoil.

- Big Idea Eight: Natural hazards pose risks to humans.

  Many natural Earth science–related processes are extremely destructive to life and property, and the natural history of severe geologic events has shaped the course of human history. Though we cannot stop these hazards, we can attempt to determine when and where they might occur, reduce activities that exacerbate their impacts, and take actions to reduce the likelihood of some hazard types.

- Big Idea Nine: Humans significantly alter Earth.

  Human activities now cause environmental changes in many areas at a rate faster than that of any other geologic process, significantly altering the atmosphere, ocean, biosphere, climate, and land surface. Increases in both human populations and levels of industrialization are causing a rapid rise in the magnitude of human impacts on Earth.

These three Big Ideas and the original environmental literacy framework share a common theme in the promotion of science literacy as a way to both highlight the interconnectedness of society and Earth's resources and to foster thoughtful decision-making about human-Earth interactions. At the time of this research there were no published studies that specifically examined the integration of ESLPs in an undergraduate classroom.

Students' Perceptions and Attitudes about the Relevance of Science

No published research was found on student perceptions of or student attitudes about the relevance of geoscience in society. Therefore, this literature review addresses both research on students' attitudes about science and perceptions of the relevance of science across multiple disciplines.

Research on students' attitudes and perception of science have considered demographic characteristics, with the most common being gender. Undergraduate males had significantly more positive attitudes toward the use of science (Weinburgh, 1995) and space exploration (Cook et al., 2011). However, there was no significant difference between genders with regard to undergraduates' perceptions of the relevance of biology content to everyday life (Himschoot, 2012), attitudes toward climate change (Sinatra et al., 2011), or perceptions of Earth and ocean science in introductory courses (Jolley et al., 2012).

Another area of demographic research included differences between science or science, technology, engineering, and math (STEM) majors versus non-science or non-STEM majors. Gogolin (1992) found that science majors had significantly more positive attitudes towards science than non-science majors at the beginning of the semester and showed significantly greater gains in attitudes by the end of the semester. Science majors had an overall more favorable perception of Earth and Ocean science than non-majors (Jolley et al., 2012). Others found no significant difference in attitude toward science in general or space exploration between science and non-science majors (Cook et al., 2011).

Student attitudes towards an aspect of science are related to individual value systems (Milfont and Gouveia, 2006; Marlos, 1999; Liu et al., 2011). Value systems are closely related to social behavior, which impacts students' attitude toward science (Gogolin and Swartz, 1992). Students with a higher value of nature also have a higher degree of concern for the health of the environment (Wesley and Schultz 2001). Wesley and Schultz (2001) found a positive relationship between students' perception of interconnectedness with nature and attitude toward science. Students who identify being part of a community that use science have more positive attitudes toward the relevance of science (Unsworth et al., 2012).

A student's perception of whether the course instructor or content provide essential information that could be applied in real life situations is an underlying factor in students' perceiving content as relevant (Keller, 1987). Students' perceptions are defined as internally or externally relevant (Newton, 1988). Internal relevance include students' perception of science content as important for understanding other science concepts or doing well in a course. In contrast, external relevance is perceived as applicable to a student's personal life or real world situation outside of the classroom (Newton 1988). For example, a student in a geology course may perceive learning mineral properties as internally relevant for identifying rocks on a test but as externally relevant for the purpose of selecting a material for a personal art project. Undergraduates' appreciate and information being applicable outside of the course and have expressed the desire to learn more about "topics that were relevant to their world" (Himschoot, 2012, p. 116). The significant of students perceiving content as externally relevant is that when they recognize content as relevant to their own lives they are more motivated to examine the details of the information, which contributed to the learning process (Sass, 1989; Frymier and Shulman, 1995).

The majority of quantitative research on attitudes toward science has focused on using survey instruments to assess the role of instructors or curricula (Osborne, Simon, and Collins 2003). Several validated instruments have been used to investigate student's attitudes and perceptions about different aspects of science (Moore and Sutman, 1970; Gogolin and Swartz, 1992; Adams et al., 2006; Barbera et al., 2008; Blalock et al., 2008; Aikenhead and Ryan, 1992). Jolley (2012) developed the Student Perceptions about Earth Science Survey (SPESS) that measures change in perception of Earth Science from the beginning to the end of a semester. The SPESS is a multidimensional scale that assesses: Memorization, Science and Society, Mathematical Problem Solving, Personal Interest, Skeptical Reasoning, Conceptual Problem Solving, and Human-Science Interaction. Results showed that there was an overall shift to more favorable (positive) perceptions of Earth and ocean science over the course of the semester (Jolley et al., 2012). While Jolley included some survey items that addressed student perceptions about the application of science, such as "Learning Earth and Ocean Sciences helps me understand the impacts humans have on the environment" and

“Knowing about how the Earth works is useful in making some decisions in life,” but measuring perception of relevance was not the primary objective of the study.

The instrument selected for the current study measures how student attitudes about the relevance and application of science for decision-making in everyday life changes over a semester-long course (Siegel and Ranney 2003). Siegel and Ranney (2003) developed and validated the Changes in Attitude about the Relevance of Science (CARS) instrument. The CARS instrument is composed of 59-items that are divided into three questionnaires. To avoid repeated test effect, each questionnaire includes 17 unique items and 8 repeated items. The three CARS questionnaires are completed at different times throughout a semester. CARS uses statements and provides responses using a five-point Likert scale that ranges from strongly disagree, disagree, neutral, agree, to strongly agree. CARS was piloted with upper-level high school students. Student responses were assessed and statements were adjusted based on their fit in the Rash model. The Rash model determined an internal consistency of 0.80 for each of the three CARS questionnaires, and was 0.91 for the overall 59-item CARS instrument (Siegel, 1999). This reliable consistency represented attitudes toward the relevance of science as it relates to decision-making in everyday life situations.

Siegel (1999) investigated students’ attitudes in two high school biology classrooms using different active-learning pedagogies. The CARS instrument was given as a pre-survey during week one of the semester, during week 15, and then week 18 at the end of the semester. The researcher assigned a number scale (0-4) to the responses and averaged student scores for each of the three CARS iterations. Siegel found that both classes’ average CARS scores significantly increased over the course of the semester (0.32 increase; $p=0.01$ and 0.35 increase; $p=0.002$). Analysis of the repeated questions was not reported but it was noted that some statements showed students tended to more strongly agree with over the course of the semester whereas other statements students tended to more strongly disagree. Overall, students started out with a neutral attitude toward science being relevant to decision-making in their personal life and moved to a more positive attitude toward the end of the semester. Siegel (1999) did not investigate the role of attitude about the relevance of science and learning gains or if demographic characteristics impacted students’ CARS scores.

METHODS

Mixed-methods were used to investigate the attitudes of undergraduates enrolled in MEA 101 about the relevance of geoscience. Quantitative and qualitative data were collected in-class and online during fall semester, 2013. The quantitative component of the study involved: 1) Scores on the Changes in Attitude about the Relevance of Science (CARS) survey that provided numerical descriptions of attitudes about the relevance of science; 2) Pre- and Post-totals on the Geoscience Literacy Exam (GLE) that measured learning gains; 3) The final course grade that represented overall performance; and 4) Score on a short answer response from the final exam that specifically measured students ability to describe applications of geoscience content in society. The purpose of the qualitative component of the study was to provide context for the characterization of student perceptions in MEA 101about relevance of geoscience in society. Qualitative data (in the form of open-ended responses) were collected from a repeated short-answer question administered online at the end of each module and a different short answer question completed on the final exam. Both of the short answer question formats were created to investigate students' perceptions of the relevance of geoscience content in a societal context.

Sampling Procedures

A sample of convenience from three sections of the MEA 101 course were included in this study. Final enrollment in each section was as follows; Section 1: 94 students, Section 2: 40 students, and Section 3: 133 students. During the second week of the semester, the researcher visited each class and gave a brief explanation of the research and students were given the opportunity to consent to participate in the study (Appendix B). Data were collected from students who voluntarily signed the informed consent document. A majority of students in each section (83% - 91%) chose to participate in the study. The total number of initial participation was 233 students but incompletion of surveys resulted in decreased sample size. Students who completed all CARS surveys and the demographic profile yielded a total sample size of 144 students. This sample represented 56% of the total number of students enrolled in the three sections of MEA 101 at the end of the semester.

Structure of Coursework

Undergraduate students in introductory physical geology courses (MEA 101: Geology I: Physical) at NC State were presented with a variety of geoscience topics throughout the semester. Related topics were grouped together into eight modules. Reflecting the content covered, the eight modules were:

Module 1: Geology and the Scientific Process
Module 2: Plate Tectonics
Module 3: Rocks and Minerals
Module 4: Volcanoes vs. Earthquakes
Module 5: Geologic Time
Module 6: Earth’s Climate Past
Module 7: Water and Society
Module 8: Energy Resources & Earth’s Climate Future

The quantity of time and topic-based material varied from module to module. With the exception of the first module, the amount of time devoted to each module ranged from two to four 75-minute lecture periods or three to six 50-minute lecture periods. Textbook reading assignments also varied depending on the module, which ranged from 13 to 52 pages per module. The number of pages assigned was not directly related to the number of lecture periods allotted for the module.

Students in all sections were assigned the same textbook, reading assignments and learning objectives. They were also given similar daily homework assignments, completed the same online quizzes, and administered tests that included many common questions. With the exception of adding or subtracting a few slides from lecture presentations, the instructors used similar PowerPoint slides, conceptests, and other in class activities. Differences in the sections were the number of students in the lecture and amount of time per lecture period

(Table 2). While there was some variation in the details and order of material presented across the sections, the instructors shared a common structure of course materials and active learning lecture format.

The cornerstone of the course structure was the module learning objectives that outlined the content discussed in the work to be completed in and out of the class. The level of complexity of the learning objectives spanned from lower order skills such as defining a vocabulary term to higher order thinking that required a student to interpret or make predictions. The number of learning objectives in each module ranged from 9 to 20. The researcher identified that 20% of the total module learning objectives aligned with the human-Earth related Big Idea supporting concepts. At the beginning of each class lesson, instructors presented these objectives and they also provided students with online access to lecture slides and other documents that stated the module learning objectives.

Multiple assessments associated with the learning objectives were created to support student content learning gains. Assessments in the form of online assignments or quizzes, in-class conceptests, and other activities provided students opportunities to earn points toward their final grade. In addition, these assessments allowed students to practice recalling information from the reading assignments and lectures. Summative assessment exams tested students on content and concepts connected with the learning objectives. Students' cumulative end-of-semester grades were used as performance measures for data analysis in this study.

Table 2. Characterization of MEA 101: Geology I: Physical

Classroom Characterization				Instructor Characterization		
MEA 101 Section	Number of lecture periods per week	Amount of time per lecture period	Number of students enrolled at the end of the semester	Age	Gender	Undergraduate Teaching Experince
1	2	75 minutes	94	55	Male	26 Years
2	3	50 minutes	40	31	Male	> 1 Year
3	3	50 minutes	133	29	Female	2 Years

Instructors

The three participating instructors of MEA 101 sections were in the Geoscience Learning Process Research (GLPR) group at North Carolina State University (NCSU) and their courses shared resources and featured several common characteristics. The three instructors had varying amounts of teaching experience (Table 2).

Instructors' pedagogical practices were observed by members of the GLPR group, who used the Reformed Teaching Observation Protocol (RTOP) to measure the degree of "reformed" teaching per class. The RTOP instrument was developed by the Arizona Collaborative for Excellence in the Preparation of Teachers (Piburn and Sawada, 2002). The RTOP scores instructors on 25 different teaching items, each with a score range of 0 (not observed) to 4 (very descriptive), for a maximum possible score of 100. A higher score indicates a more reformed and thus student-centered classroom. The RTOP tool measured the degree of reformed teaching practices in regard to lesson design and implementation, presentation of content, and the classroom culture students experienced. The scoring rubric developed by Budd et al. (2013) was used because is allows for a higher inter-rate reliability (Budd et al., 2013). Three RTOP trained GLPR group members completed nine classroom observations. Each instructor's class was observed three times during the semester. The observations were scheduled so that instructors were teaching similar topics. The classroom observation notes and RTOP scores were generally consistent (Table 3). The sole purpose of using this instrument was to determine if students were receiving a similar learning environment in the classroom. While it is possible that instructors may have affected student attitudes, the extent of those effects were not explored in this study.

Table 3. Instructor's RTOP Scores

	RTOP Scores				
	Module 4	Module 6	Module 8	Average	Std. Dev.
Section 1	46	50	51	49	2.65
Section 2	43	53	48	48	5.00
Section 3	47	52	31	43	10.97

Demographic Profile Survey

A demographic profile (Appendix C) was designed to characterize the sample population and incorporate questions related to students' perceptions and behavior. During a lecture period in the second half of the semester, the 9-item demographic profile was administered and collected by the researcher in all three sections of MEA 101. Study participants who attended class on the day of administration totaled 144 students.

The preparation for data analysis consisted of entering the hand-written profile answers into a digital file and converting the responses into numerals. The student's name allowed the self-reported demographic information to be matched with the other data but were not considered a demographic profile item. The first three items were write-in format: 1) intended major, 2) age, and 3) gender. Students' intended major was categorized based on the College Affiliation at NC State University. College affiliation was then divided into STEM or non-STEM. Age was recorded as a raw number. Responses for gender were recorded and then coded into numerals; 1: male and 2: female. These characteristics were used to describe the sample population, compare sections of MEA 101, and determine relationships with other parameters.

Students were instructed to circle one of the options provided for Items 4 through 7. Item 4; "What is your current class standing?" was included to determine the percentage of undergraduate freshmen, sophomores, juniors, or seniors. Item 5 asked students "Which description best fits the environment in which you lived during childhood through high school?" Students were given the options of: rural, suburb, urban or other. If a student selected “Other” they were asked to specify the environment. Student responses were coded into numerals for nominal representation of the environment. Item 6 on the demographic profile was a behavioral question that asked students “How often do you talk to your friends and family about ways that you affect the environment”. Five possible options were presented in a Likert-response format ranging from “a lot” to “not at all.” Student responses were coded into numbers one through five and marked as ordinal data.

Item 7 was called the Inclusion of Self in Nature (ISN) that aimed to capture students’ perception of their relationship with the natural environment (Schultz, 2001). This question presented students with seven gradations of Venn diagrams that had the word “Self” in one circle and “Nature” in the other. Students were asked to “Please circle the picture below which best describes *your relationship with the natural environment*. How interconnected are you with Nature?” Each Venn diagram was given a number that ranged from one that represented no overlap of the two circles to seven that represented no separation between self and nature. Data from the ISN was labeled as ordinal because it signified the degree to which students perceived a connection with the natural environment.

For the profile items 8 and 9, students were instructed to circle all responses that applied to the question. Item 8 asked: “What were your reasons for taking the class?” The response options included: “It is a major requirement”, “It was one of my options to fulfill the University science requirement”, “It sounded interesting”, “Friend recommended the course”, and “Something else (please specify)”. Since students were allowed to circle more than one answer, the number of possible reasons for taking the course was greater than the number of students whom completed the profile form. Item 9 inquired about the student’s ethnicity. Students were given a list of six ethnic descriptions or could select “other”.

Changes in Attitude about the Relevance of Science Instrument

The Changes in Attitude about the Relevance of Science (CARS) instrument (Appendix D) was used to measure undergraduates’ change in attitude about the relevance of science and geoscience in three sections of MEA 101. Ten of the fifty-nine items were modified to reflect a geoscience course instead of a biology course. See Appendix D for modifications, which are specifically identified in bold. The CARS instrument was administered at the beginning, middle, and end of the semester. The instrument was completed through an online interface where students read each statement and selected the response that best represented their attitude about the statement. The five possible responses included: strongly disagree, disagree, neutral, agree, and strongly agree. Responses were recorded in the online classroom management system and then exported as an excel spreadsheet. Responses were then transformed into representative numerals. Numerals from negative statements were reversed to represent the students' attitude as though the questions were stated in the affirmative. For example, a student who "agreed" with the statement, "Things I do in science have nothing to do with the real world" would initially be transformed into the numeral four and then reversed into a two. This method allowed an average CARS score to represent a students' overall attitude about the relevance of science, with larger values indicating more positive attitudes.

Statistical analyses for differences in CARS scores between sections and over the course of the semester were completed using Statistical Programing for Social Sciences (SPSS). To investigate differences across sections, sets of T-tests were performed with the average CARS score as the test variable and section number as the group variable. T-tests were run for each of the three CARS iterations. An additional set of T-tests were run within each class section to evaluate the change in CARS score from iteration one at the beginning of the semester to iteration three at the end of the semester. This dataset was used to determine if the amount of change in attitude was statistically different among sections of MEA 101. Change in students' average CARS scores over the course of the semester were evaluated using ANOVA, and T-tests. These tests were run with the assumptions that the sample was a normal distribution and a homogenous sample. These assumptions were met. The level of significance was set to 0.05.

CARS Repeated Statements

The original CARS had eight repeated items. Due to human error, there was a typo in one of the repeated questions for CARS iteration 2. Thus, there were only seven items on the

CARS instrument that were asked on all three iterations. Each of the items was individually evaluated for changes during the semester. The repeated statements included:

1. Much of what I learn in Geology class is useful in my everyday life today.
2. Learning science can help me when I choose when to buy a house.
3. Caring about people is part of making a scientific choice, such as whether to use pesticides on plants.
4. Science helps me make sensible decisions.
5. Things I do in science have nothing to do with the real world.
6. Science helps me to make decisions that could affect my natural environment.
7. Making decisions can be difficult without reliable evidence.

Each item was assessed using raw numbers to determine changes in overall students' average scores on the repeated statements. This method allowed a finer-grained assessment of the timing of change in attitude about specific items on the CARS survey.

Performance Measures

Overall attitude about the relevance of science was measured with the average CARS scores from all three iterations. The amount of change in attitude about the relevance of science was measured by the change in average CARS scores from Iteration 1 and 3. Relationships between the change in CARS scores and performance were determined using linear regression analysis. Assumptions of normality were met. The level of significance used for evaluation was set to 0.05.

<u>Geoscience Literacy Exam</u>

Students in Sections 1 and 2 (n=66) completed a Geoscience Literacy Exam (GLE) pre-test during the second week of the semester and the post-test during the last week of the semester. The pre- and post-tests consisted of eight weighted multiple-choice questions, some of which required students to select a combination of answers to earn full credit (Appendix E). The maximum possible score a student could earn was twelve points. Scores were recorded in a spreadsheet with the corresponding student research ID number. Two of the eight questions aligned with content related to the human-Earth Big Idea Supporting Concepts.

Statistical analysis utilizing the GLE scores was used to determine any disparities between students' incoming content knowledge and learning gains in two of the three sections. Because an independent T-test showed no significant difference between the average pre ($p=0.094$) or post ($p=0.76$) GLE scores between MEA 101 sections 1 and 2; the two sections chosen to address the relationship between student CARS scores and performance.

Comparison of pre- and post-test score was used as a performance measure for content learning gains over the course of the semester. A regression analyses was utilized in the investigation of the relationship between students' change in average CARS scores from iteration 1 to iteration 3 and change in GLE pre- to post-test scores. Change in average CARS score was set as the predictor of change in GLE score. These analyses facilitated the evaluation of students learning geoscience content and any associations with attitudes about the relevance of science.

Final Course Grade

Students' final course grades from three sections of MEA 101 were used as an overall course performance measure. Students' final grades were comprised from homework assignments, four exams, and in class assignments. Participating students' ($n=144$) final grades were paired with their CARS and demographic profile. Average course grades varied across sections: Section1: 83%; Section 2: 77%; Section 3: 85%. ANOVA showed that the differences in final course scores was not statistically significant ($p=0.682$). Therefore, the sections were compiled and regression analysis was conducted with student's average CARS data.

Final Exam Short Answer Score

Scores on a final exam short answer question given in MEA 101 sections 1 and 2 were used as a performance measure. Students were given the following prompt:

> “From the information presented in MEA 101, what do you think are the two most important concepts citizens need to comprehend in order be considered an Earth-science literate person who can make sound decisions for a sustainable future? (*A sustainable future ensures the long-term preservation of natural environments while providing for economic and social well-being of Earth’s population*.) In a minimum of 3 complete sentences, describe two concepts and how citizens can apply the knowledge. There are multiple ‘right’ answers. Your response will be graded on the quality of your explanation.”

A rubric was developed and applied for the grading of the final exam short-answer responses (Appendix H). Each response could receive a maximum score of seven points. Responses from students who completed all three iterations of CARS and the demographic profile were selected for analysis (n=75). The rubric score was then used as a performance measure and set as the dependent variable in a regression analysis with CARS data. There was no significant difference (p=0.112) between final short answer scores from MEA 101 section 1 and 2, with average scores of 5.3 and 4.9 respectively.

Open-ended Responses

<u>End-of-Module Responses</u>

Qualitative data from the end-of module short answer questions were collected from daily online homework assignments from MEA 101 section 1. Students responded to an open-ended question at then end of each of seven modules that asked: “How relevant do you think the information in the [inserted recent module title] module is to individuals and communities around the world?” Students were instructed to write at least three complete sentences and include any concepts or examples that would provide context for their answer. Students were informed with the statement: “There are multiple right answers and responses are graded on the quality of the explanation.” Throughout the semester student responses were given full credit if they provided the minimum of three sentences. These responses were compiled into one datasheet.

A convenience sample of students who completed all seven end-of-module questions was selected from MEA 101 Section 1. This sample (n=34) was representative of the larger sample (n=144) used in the CARS analysis from the three sections of MEA 101. See

Appendix J for comparisons of demographic characteristic proportions. It became apparent to the researcher that 238 open-ended end-of-module responses forming the representative sample was sufficient for establishing patterns of students' perceptions for the baseline study. It was likely that further analyses of the open-ended responses would have resulted in a saturation of data and yielded repeated themes in responses (Feig, 2011).

Qualitative analysis consisted of developing a characterization sheet that accounted for three components of each student response: 1) Who the content was relevant for; 2) Why the content was relevant; 3) What content was relevant (Appendix H). Who the content was relevant for depended upon the individuals or groups the student mentioned in the response. Why the content was relevant depended upon if the student suggested the content as being relevant for the sake of knowledge or cited a way to apply the content knowledge. What content was relevant, was categorized on the basis of concepts or examples of content that students described as relevant.

The end-of-module prompt aimed to determine whom students thought the information was relevant for and student responses were categorized in one of four ways:

1) All communities or individuals

   Student examples: "The information in this module is relevant to communities and individuals" and "Communities should understand where fresh water locations are." "People need to know what type of area they live in to be aware of earthquakes."

2) Includes self with communities

   Student examples: "We need to know where to find clean water, and how to keep it clean." "It also talks about alternative sources of energy which is going to be one of the biggest concerns for our generation in the world."

3) Specific community or individual

   Student examples: "This information is important to people born or living in North Carolina." "Knowing how to prepare for a volcanic eruption is only relevant for communities who live on a convergent boundary" or "Dating rocks would not be that relevant or important to the everyday lives of individuals unless they were geologists."

4) Does not address who would find the content relevant

> Student example: "It is important to realize that everything that happens on Earth affects the future of the Earth and life on Earth. It is also critical to understand the concept of geological time to gain an understanding of Earth's past."

If a student response included more than one type of person(s) in the description of why content was relevant, the person(s) identified in their description determined the category marked. For example, a response began with "Individuals and communities around the world" and went on to explain reasons why "communities on convergent boundaries need to be aware of the location of fault lines" was categorized as specific communities or individuals.

A students' response as to "why geoscience content is relevant" was categorized as application or knowledge. Application responses referred to information in the module as being relevant and then described how it could be applied. Examples of common active phrases such as "use the knowledge of… to prepare", "understanding…will help to locate a valuable resource", or "information can be vital in making decisions on where to live", indicated that students could demonstrate the application of content knowledge in real-life situations. For example:

> I believe that the information is quite relevant. Water is essential for the survival of individuals and communities. Knowing where water is and how it can be effectively utilized through dams and wells is important for survival. Not only is water necessary for life, but it can also be a destructive force. Communities should use information to invest in flood preparation because it can take up large amounts of resources if they are not aware of their risk. As a result, it is necessary to understand how it helps and hurts individuals and communities.

Because this response refers to using the content knowledge for the utilization of water resources and preparation for potential flooding it was categorized as application.

Conversely, knowledge responses cited the content as not relevant or relevant for the benefit of general understanding or gaining knowledge. These responses included example phrases such as "information tells us why things are the way they are", "need to know…so that they will know" or "without understanding that, individuals cannot fully understand the ways in which water helps give life”. While knowledge responses identified content as relevant, they lacked examples of situations or explanations of how the information in a module could be applied.

Relevant content was based on the topics or examples students described in their response. The ESLP’s human-Earth related Big Ideas were used as a guide to categorize content discussed in student responses. If students mentioned a topic that aligned with one of the ESLPs it was categorized into one of the three Big Ideas (Appendix A):

Big Idea 7: Humans depend on Earth for resources

Big Idea 8: Natural hazards pose risks to humans

Big Idea 9: Humans significantly alter the Earth

If a student included more than one theme, all additional themes were accounted for in each response. A response that stated the content was not relevant was categorized as “not relevant”. For example, “I don’t think this module is that relevant. I think the fact that you can tell how a rock formed or where it came from is interesting but does not help a community or an individual in anyway.” A response that did not include a clear description was categorized as “vague”. For example, “I think that the information in this module is very relevant to the lives of individuals and communities around the world. It is very important that we understand how the foundation of the land we live on was created. We cannot just live our lives oblivious to how the world around us works.” This response stated that the module was relevant but did not give a clear enough description or an example to categorize.

A student response that included an explanation that did not align with one of the human-Earth Big Ideas was categorized as “other”. For example, “It is somewhat relevant to the lives of individuals and communities around the world. The information in the module can help people determine when rocks were formed and date them. It can also help people date fossils found in rocks. Dating rocks can help us determine how old the Earth is and how long it has taken to change.” This response clearly explained that dating rocks was the relevant content from the module and provided an example of how to apply the content knowledge. However, this example did not align with one of the human-Earth Big Ideas but it did align with one of the other Big Ideas not assessed in this study. Therefore it was categorized as “other”.

Final Exam Short Answer Responses

In addition to the scoring of student responses to the final exam short answer question, the two concepts students stated that citizens need to comprehend in order be considered Earth-science literate were recorded. If a student described an overall concept, (e.g., climate change), and then described two different components of that concept, the two sub-concepts were recorded as two separate concepts. For example, a student that stated climate change was important for citizens to know and then described “understanding the greenhouse effect” and “humans burn fossil fuels that contribute to greenhouse gasses”. Concepts were coded and grouped into themes. For instance, the following were all grouped under water resources: “information about groundwater can help individuals and government organizations decide where to locate an area for an efficient groundwater well, which provide access to clean water”, “in order to sustain ourselves it is important to know how to prevent water contamination”, “need to know about the water cycle so that can understand how different part of the water systems are connected”, or “need to realize that freshwater is a limited resource…should work to conserve this valuable resource for future generations” . Responses were not analyzed beyond noting the concepts students cited as being relevant for citizens to be considered an Earth science literate person. The analysis did not directly assess student responses in the context of the ESLPs human-Earth Big Ideas.

RESULTS

Nature of the Sample

Results for the sample of undergraduate students enrolled in all three sections of MEA 101 (n=144) are reported in the order of the demographic profile items on the survey (Table 4; Appendix C). The sample included roughly equal portions of STEM (46%) and non-STEM (54%) majors along with equal portions of males (49%) and females (51%). Reported ages ranged from 18 to 32 years, with the most common (42%) student age being 18 years old. More than half (52%) of the population was composed of freshman. Most of the students in the sample (56%) reported their home environment during childhood through high school as suburban. Most of the students (67%) reported either talking about the way they affect the environment "only a little bit" or that they "may have mentioned it once or twice". The majority of students (79%) selected Inclusion of Self in Nature (ISN) Venn diagrams that illustrated more than 10% to less than 50% overlap. The extreme Venn diagrams representing no overlap or no separation were the least selected with 3% and 1% respectively. The remaining 17% of students selected an ISN Venn diagram that represented ~50% overlap to ~75% overlap. The reported ethnicities were: Caucasian (85%), African Americans (6%), Hispanic (6%), and Asian (3%). A majority (74%) of the students reported enrolling in the course because it fulfilled a university physical science requirement.

Table 4 also shows that results from analysis of the initial, final and change in CARS scores for the following six demographic profile items: intended major, gender, class standing, childhood environment, amount students talk about affecting the environment, and ISN Venn diagram. There was no significant difference in initial or final average CARS scores dependent upon five of the six items listed above. The amount students talked to friends and family about ways they affect the environment showed a significant difference among groups. For the initial CARS survey, a Bonferroni test showed that the significance derived from the difference between students who selected "Not at all" and those who selected "Only a little bit" (p=0.004). For the final CARS survey, the Bonferroni test suggested significant differences between students who selected “Not at all” or “May have mentioned it once or twice” ($p=0.031$) and “Not at all” or “Only a little bit” ($p<0.001$). There was no significant difference in the change in average CARS scores in any of the six demographic profile items (Table 4). Results from analyses of the demographic profile items increased the confidence that observations from the CARS data were not due to the students' demographic profile items included in this study.

Table 4. Results from Demographic Profile Items from MEA 101 Sections (n=144)

Demographic Item and Item Options		n	Initial CARS Scores Mean	Initial CARS Scores Std. Dev.	Initial CARS Scores Sig.	Final CARS Scores Mean	Final CARS Scores Std. Dev.	Final CARS Scores Sig.	Change in CARS Scores Mean	Change in CARS Scores Std. Dev.	Change in CARS Scores Sig.
Intended Major	STEM	66	3.54	0.314	p=0.441	3.73	0.481	p=0.130	0.171	0.377	p=0.338
	Non-STEM	78	3.5	0.383		3.59	0.59		0.105	0.419	
Gender	Male	71	3.53	0.364	p=0.662	3.66	0.544	p=0.539	0.096	0.423	p=0.211
	Female	73	3.51	0.369		3.68	0.45		0.179	0.179	
Class Standing	Freshman	76	3.54	0.345	p=0.843	3.62	0.542	p=0.467	0.082	0.385	p=0.151
	Sophomore	42	3.58	0.411		3.63	0.612		0.153	0.413	
	Junior	12	3.51	0.381		3.84	0.478		0.333	0.311	
	Senior	14	3.55	0.344		3.78	0.385		0.232	0.437	
Childhood Environment	Rural	44	3.54	0.341	p=0.986	3.66	0.524	p=0.806	0.114	0.381	p=0.079
	Suburb	81	3.53	0.374		3.63	0.57		0.106	0.381	
	Urban	16	3.42	0.405		3.76	0.532		0.341	0.504	
	Other	3	3.56	0.327		3.83	0.3		0.267	0.062	
Amount Students Talk about Affecting the Environment	Not at all	23	3.29	0.514	p=0.009	3.26	0.794	p=0.001	-0.0393	0.486	p=0.071
	Mentioned once or twice	48	3.54	0.322		3.65	0.478		0.113	0.401	
	Only a little bit	49	3.62	0.292		3.83	0.435		0.204	0.374	
	A fair amount	20	3.51	0.339		3.69	0.383		0.182	0.28	
	A lot	4	3.38	0.361		3.81	0.537		0.43	0.241	
ISN Venn Diagram	1	4	3.16	0.712	p=0.334	3.04	0.705	p=0.108	-0.12	0.27	p=0.154
	2	36	3.51	0.299		3.62	0.62		0.11	0.44	
	3	35	3.57	0.276		3.67	0.49		0.1	0.38	
	4	43	3.58	0.414		3.76	0.42		0.18	0.31	
	5	16	3.43	0.362		3.48	0.64		0.05	0.48	
	6	8	3.45	0.198		3.91	0.49		0.45	0.26	
	7	2	3.42	0.366		3.8	1.13		0.38	0.93	

Student scores (n=66) on the Geoscience Literacy Exam (GLE) from both sections were combined to determine overall change and distributions between the GLE pre- and the post-test scores. Students' increase in average mean pre-test scores (6.48) to post-test scores (7.5) was significant ($p<0.001$). This significant change was reflected in the distribution of GLE scores, where the number of students scored higher on the post-test than on the pre-test (Figure 1).

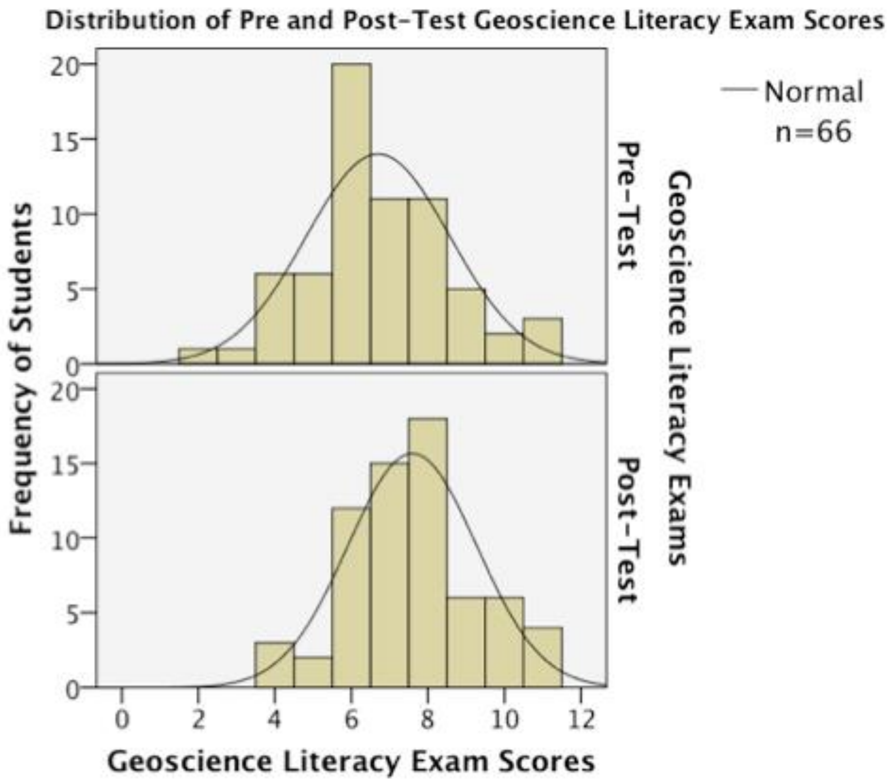


Figure 1. Distribution of Pre and Post GLE scores from MEA 101 section 1 and 2

Changes in Attitude about the Relevance of Science (CARS) across Sections

Statistical analyses showed that there were no differences in students' average Changes in Attitude about the Relevance of Science (CARS) scores across the three sections of MEA 101 (Table 5 and Figure 2). This result indicated that there were similarities among the students' attitudes in all three sections of MEA 101 and justified combining the three sections into one sample group for further analyses.

Table 5. Average CARS Scores across MEA 101 Sections

		Iteration 1			Iteration 2			Iteration 3		
Section	n	Mean	Std. Dev.	Sig.	Mean	Std. Dev.	Sig.	Mean	Std. Dev.	Sig.
1	59	3.52	0.402		3.61	0.496		3.55	0.614	
2	15	3.63	0.126	p=0.469	3.65	0.294	p=0.550	3.76	0.211	p=0.124
3	70	3.5	0.367		3.69	0.492		3.73	0.522	

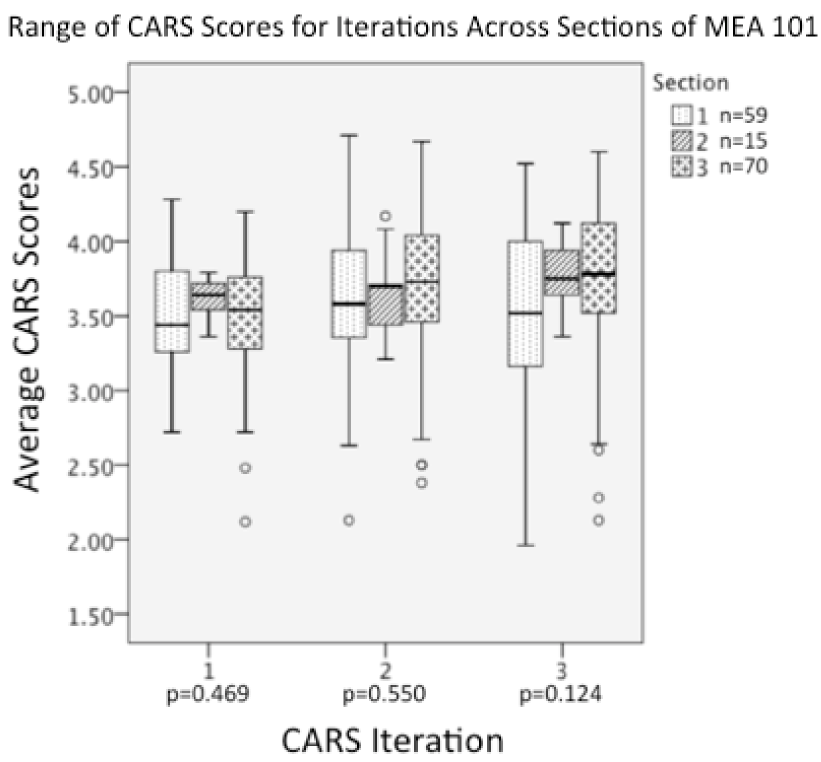


Figure 2. Box-plot of Average CARS Scores for Iterations across MEA 101 Sections

CARS over the Course of the Semester

Students' (n=144) average CARS scores significantly increased (p=0.018) over the course of the semester (Table 6). A Bonferroni analysis showed that the overall significance, derived from the difference in average CARS scores from Iterations 1 and 2 (p=0.046), and Iterations 1 and 3 (p=0.039). There was no significant difference among overall average CARS scores between Iterations 2 and 3 (p=1.000). While the mean CARS scores progressively increased, their variance around the mean also increased throughout the semester. The CARS scores shifted from a tighter normal distribution at the beginning of the semester to a wider normal distribution at the end of the semester (Figure 3). The majority (68%) of students' average CARS scores increased over the course of the semester. A lesser degree (29%) of students' average CARS scores decreased and the smallest portion (3%) of student scores did not change. Therefore overall attitudes improved, but inconsistency between these attitudes became more pronounced.

Table 6. Average CARS Scores for Iterations 1, 2, and 3

	CARS Scores		
Iteration	Mean	Std. Dev.	Sig.
1	3.52	0.366	
2	3.65	0.476	0.018
3	3.66	0.546	

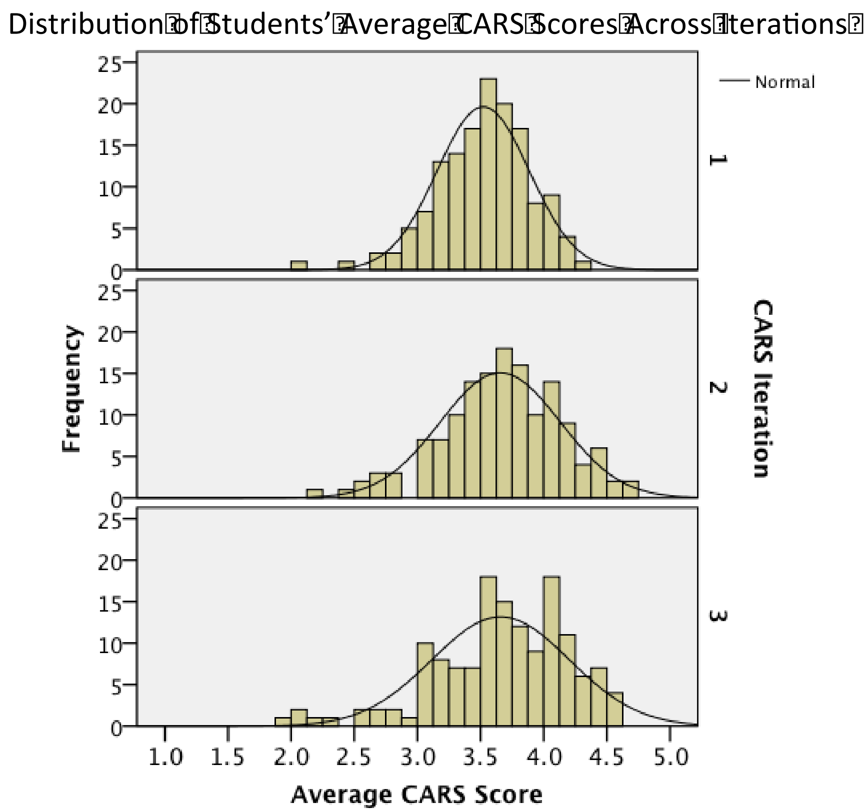


Figure 3. Distribution of Average CARS Scores for Iterations 1, 2, and 3

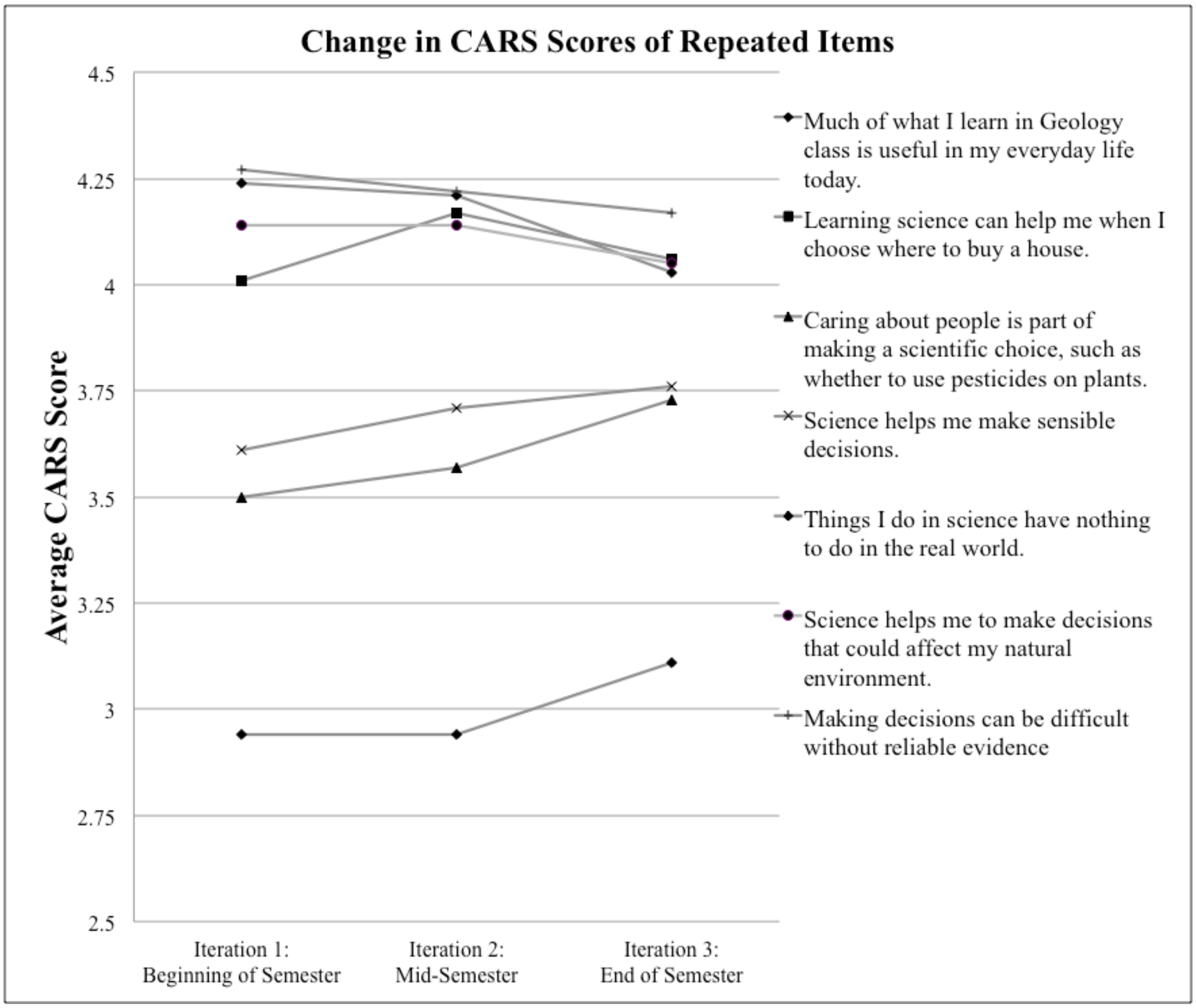
<u>Repeated CARS Statements</u>

Analysis of the seven repeated CARS items provided a higher resolution of the changes in attitudes for specific statements about the relevance of science throughout the semester. Students' average CARS scores increased on four of the seven repeated items (Table 7 and Figure 4). The three items that initially had the highest CARS scores decreased over the course of the semester (Table 7). These results showed that students' attitudes about some of the specific CARS items were higher at the beginning of the semester than at the end of the semester.

Table 7. Average CARS scores from Repeated Statements across Iterations 1, 2, and 3

Repeated CARS Items	Direction of Change in CARS Score	Iteration 1		Iteration 2		Iteration 3	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1. Much of what I learn in Geology class is useful in my everyday life today.	Increase	2.94	0.076	2.94	0.073	3.11	0.073
2. Learning science can help me when I choose where to buy a house.	Increase	4.01	0.738	4.17	0.662	4.06	0.795
3. Caring about people is part of making a scientific choice, such as whether to use pesticides on plants.	Increase	3.5	0.939	3.57	0.936	3.73	0.075
4. Science helps me make sensible decisions.	Increase	3.61	0.785	3.71	0.792	3.76	0.813
5. Things I do in science have nothing to do in the real world.	Decrease	4.24	0.748	4.21	0.801	4.03	0.919
6. Science helps me to make decisions that could affect my natural environment.	Decrease	4.14	0.654	4.14	0.644	4.05	0.672
7. Making decisions can be difficult without reliable evidence	Decrease	4.27	0.671	4.22	0.761	4.17	0.637

Figure 4. Average CARS Scores from Seven Repeated Statements across Iterations 1, 2, and 3


Change in CARS Scores of Repeated Items
Average CARS Score
4.5
4.25
4
3.75
3.5
3.25
3
2.75
2.5
Iteration 1: Beginning of Semester
Iteration 2: Mid-Semester
Iteration 3: End of Semester
Much of what I learn in Geology class is useful in my everyday life today.
Learning science can help me when I choose where to buy a house.
Caring about people is part of making a scientific choice, such as whether to use pesticides on plants.
Science helps me make sensible decisions.
Things I do in science have nothing to do in the real world.
Science helps me to make decisions that could affect my natural environment.
Making decisions can be difficult without reliable evidence

CARS and Performance

The measures of performance included: GLE pre and post scores, final course grade, and final exam short answer score. These measures were used as dependent variables in regression analysis of CARS data. A separate analysis was conducted using students' overall CARS score from the three iterations and their change in average CARS score from iteration 1 and 3.

Analysis of the three performance measures showed mixed results. The changes in pre and post GLE scores (n=66) did not show a relationship with students' overall CARS score (R^2=0.001, p=0.857) or with students' change in CARS scores (R^2=0.035, p=0.127). Students (n=144) final course grade showed a significant positive relationship with overall average CARS score (R^2=0.024, p=0.021). However, there was a stronger relationship (R^2=0.065, p=0.002) between students' change in average CARS scores and final course grade (Figure 5). Students' change in CARS scores explained 6.5% of the variance in the distribution of final course grades, in contrast to the 2.4% accounted for by students' average overall CARS scores.

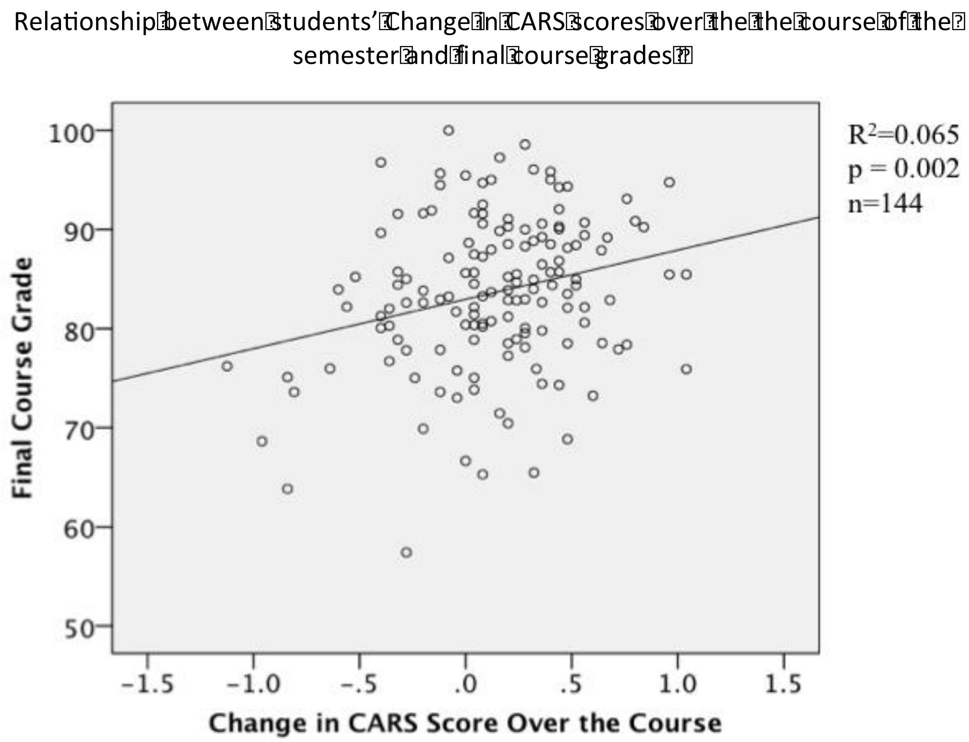


Figure 5. Relationship between Change in CARS Score and Final Grade

There was no significant relationship between students' exam short answer scores and overall CARS score (R^2=0.004, p=0.599). However, there was significant positive relationship between students' final exam short answer scores and change in CARS score (R^2=0.16, p<0.001). Figure 6 illustrates that students' change in CARS scores accounted for 16% of the variance of performance on the final exam short answer question, which was specifically designed to assess students on their ability to describe geoscience content that can be applied by citizens.

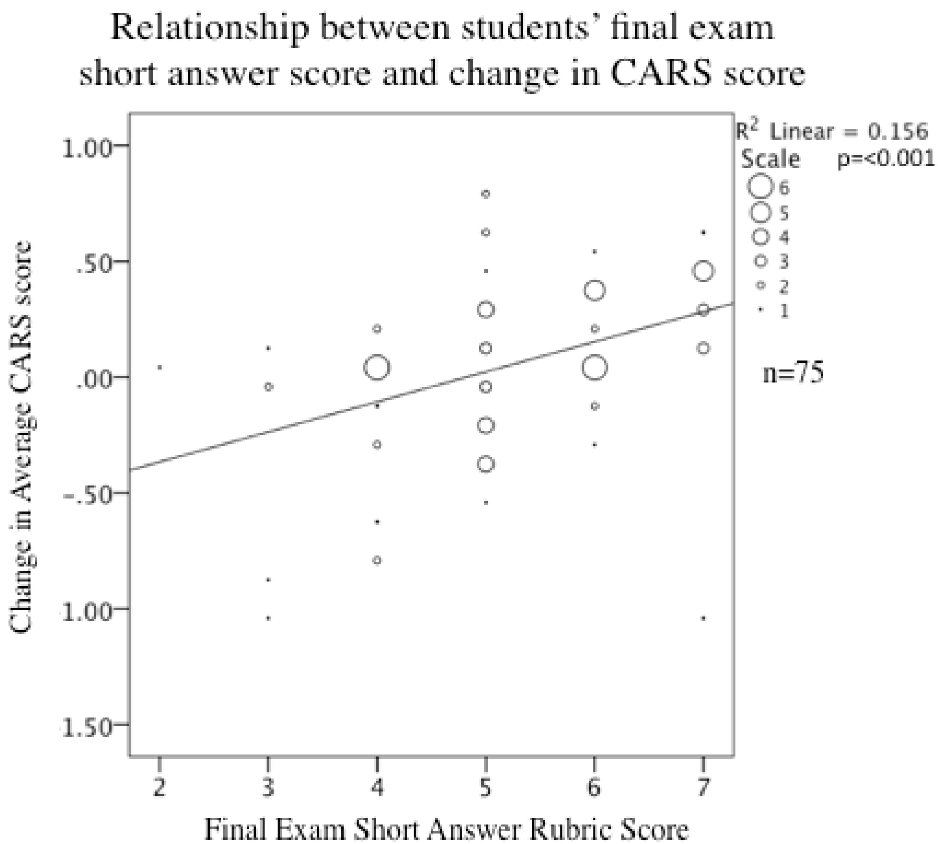


Figure 6. Relationship between students' Change in CARS Score and Short Answer Question Score. The size of the plotted circles corresponds to the number of students with that combination of change in CARS score and final exam short answer score.

Open-ended Responses

End-of-Module Responses

A total of 238 responses were analyzed using the characterization sheet (Appendix H). Analysis focused on three dimensions: 1) Who the content was relevant for; 2) Why the content was relevant; and 3) What content students identified as being relevant.

The majority of students (94%) addressed whom the content was relevant to differently from module to module. Of the 34 students who completed all end-of-module questions, only two students consistently responded in the same manner; one included ‘self’ and the other student always referred to “all individuals and communities around the world”. Figure 7 shows the proportions of who students identified in their responses across modules. Student responses most commonly cited that the information in the module was relevant to all communities or individuals (54%). For example, the following responses referred to communities or individuals around the world in general:

> I think this module is very important to the communities around the world. Being able to chronologically date different landmasses based on the layers of rock and other clues such as unconformities can play a vital part in determining how the land changed over the years. Knowing this can help reconstruct how the environment has changed throughout time and seeing the effects that environment had on an area. Being able to date rocks in different countries to a similar time period helps show how the continents split apart and how they have changed.

And

> It's completely relevant to everyone and communities around the world. People need to understand how climate cycles of Earth works so they can figure out have to thrive in certain situations. That's the only reason why we are still here today, because our ancestors figured out how our climate functions (seasons).

The second most common way (28%) students responded was by including themselves as part of the community or individuals to who the content was relevant (Figure 7). This was especially the case for responses from the Earths’ Climate Past and Energy Resources modules. In the response below, students included themselves as being part of the communities or individuals:

> I believe that the information is very relevant due to the fact that a lot of what is being presented in this Module [Earths’ Climate Past] is happening in the world today. In order to prevent climate change, we must first understand why it occurs and how it

> affects Earth. We live in a world that is constantly undergoing changes, so it would be beneficial to us both as individuals and communities to understand that change.

And

> It is very important to know where oil and coal comes from because we use so much of it and right now we cannot live without it. We need to make sure we keep peace with these countries so that they will not cut off our sources. It is also important to learn about other types of energy because eventually we will run out of fossil fuels and the more alternate energy we use now the longer fossil fuel will remain.

Students identified specific communities or individuals in 14% of the total responses. Students most commonly described that geoscience content was relevant to specific communities when referring to natural hazards. This was more prevalent in responses from Module 2: Plate Tectonics and Module 4: Earthquakes and Volcanoes. An example response that identified specific communities or individuals:

> I believe the information discussed in the [Plate Tectonics] Module is extremely relevant to individuals around the world that live close to plate boundaries, such as on the coasts of North America and South America. At these plate boundaries, individuals can experience earthquakes and also volcanic eruptions, which could harm them and the communities they live in. Knowing the information from this module could help them be better prepared for any natural hazards that come with living at a plate boundary.

In addition, students would state that the information was “only relevant to a geologist” or a scientist “who needed to know the information”.

It was rare (3%) for a response not to address for whom the module content was relevant. The statement below, in response to Module 5: Geologic Time, is an example:

> It is important to realize that everything that happens on Earth, by Earth itself, the atmosphere, or the living organisms that inhabit it, affects the future of the Earth and the life on Earth. It is also critical to understand the concept of geologic time in order to gain an understanding of Earth's past and where living organisms are derived from. Both of these points together help predict what will happen later on in time.

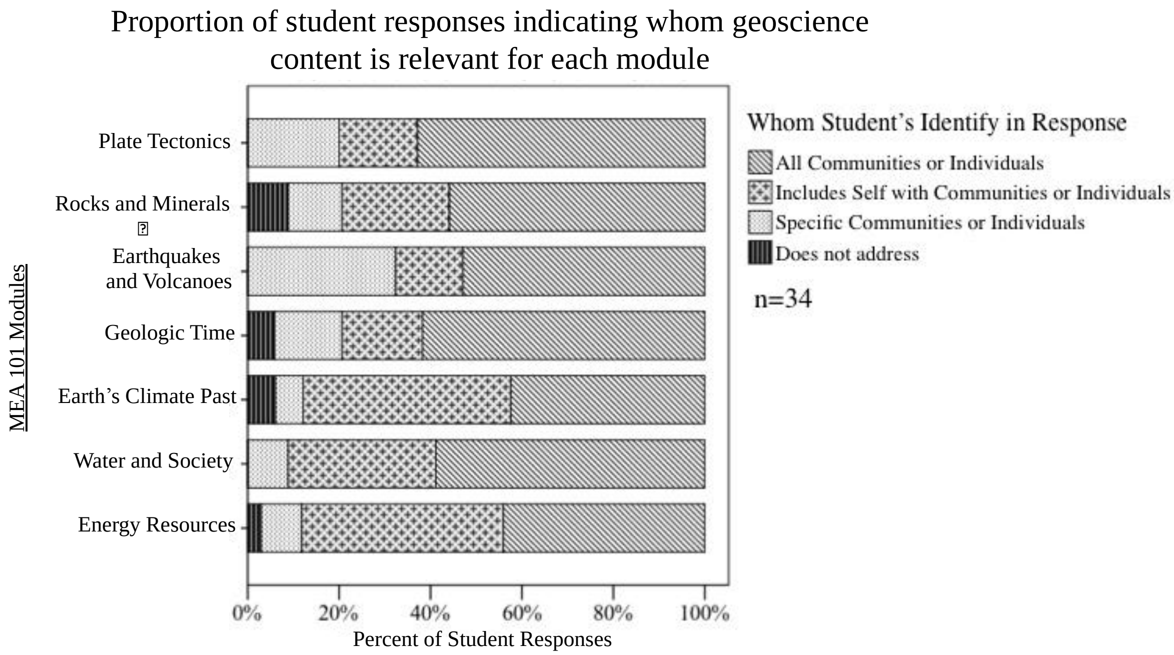


Figure 7. Proportion of Student Responses Identifying "who" geoscience is relevant for each of the seven end-of-module responses

Figure 8 shows results from the characterization of "why" the content in each module was relevant. The majority (92%) of students' wrote responses that were categorized as either application or knowledge responses. For example, the two responses that follow were from the same student:

> I believe that the information [in Rocks and Minerals Module] is very important to the lives of individuals and communities around the world. It gives people a better understanding of the different types of rocks located where they live and it also helps them learn about other major types of rocks around the world. This information is good for common knowledge.

And

> It [Water Recourse Module] is very relevant to individuals and society because water can be used to help our communities in many ways. Knowing how water can travel not on land but also underground helps us know where to build infrastructure and where crops can be placed. Without the help of this knowledge about water a lot of things we do easily today would become difficult tasks.

In the first response the student only discussed the information as relevant for understanding and was categorized as knowledge whereas the later response provided examples of how to use the information and was categorized as application. It was common for students to write several application responses and several knowledge responses over the course of the semester. The remaining 8% of students consistently illustrated how humans could apply the information acquired during the module and were therefore categorized as application responses. No students wrote knowledge responses for all modules.

The proportions of students writing application or knowledge responses varied across modules (Figure 8). In five of the seven modules analyzed, the majority of responses were categorized as application. This was especially the case for Module 3: Rocks and Minerals (63%), Module 7: Water and Society (68%) and, Module 8: Energy Resources (71%) of students explained how an individual or a community could use the information presented in the course.

Student Example for Rocks and Minerals Module:

> The information we have learned in this module is relevant because it allows scientists to determine where rocks came from and how they were formed. In our communities we use different types of rocks in our everyday lives whether it be for decoration or are necessary for building communities. For example by knowing how granite and marble are created (which many people have in their homes as counter tops for example) scientists who work with companies can determine where it is located and can be mined, how long it takes to be created and how abundant. Using this information will determine how much it is worth.

Student Example from Water Resource Module:

> I think the information in the Water Module is very important to individuals and communities around the world because water is a necessary part of our everyday lives, from drinking water to irrigating crops. With individuals knowing the information from this module, they can make better decisions on how to use water in their communities and also be safe from the dangers of water. This module would be extremely relevant to anyone who lives near a river or stream that can flood because the information from this module described the hazards of flooding. By knowing what these hazards are, the individuals close to rivers and streams could be better prepared in the event of a flood.

Student Example from Energy Resource Module:

> The information from this module is important to individuals and communities around the world in that it discussed climate change and the effects it could have on

Earth. This information is very important because there are many negative effects associated with climate change and by knowing these effects people can be prepared for them. Also, by knowing information on climate change, individuals could begin taking measures now to try and prevent climate change from getting any worse.

Two modules where the majority of students wrote knowledge responses included Module 2: Plate Tectonics (62%) and Module 5: Geologic Time (74%). In these responses students either did not provide an explanation of how humans could apply geoscience content or stated the information was not relevant. An exemplary response below, illustrates that when a student stated the information was not relevant they often explain why.

> Not much of what I read seemed to have all that much to do with life. The subject of geologic dating is a useful development for the furthering of human knowledge, but it has little affect on many communities. Some individuals will take an interest, and the general quality of the understanding of the earth would increase in communities, but it, again, is just additional knowledge without much seeming impact on the lives of those who know it (excluding geologists). The study of natural threats, or resource gathering seem to me to be the only "necessary" focuses, but to expand the human mindset, exploring the other applicable fields are a boon.

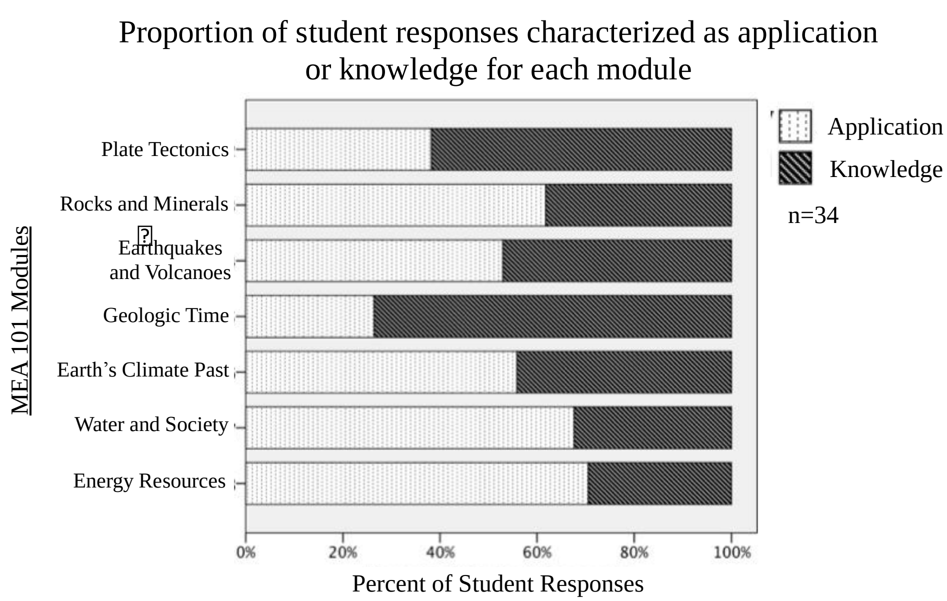


Figure 8. Proportion of Application and Knowledge Responses for each Module

Figure 9 shows the results from the characterization of what content or concepts students described in the end-of-module responses. The proportion of responses that did or did not align with particular human-Earth Big Ideas: Big Idea 7 (Humans depend on Earth for resources), Big Idea 8 (Natural hazards pose risks to humans), or Big Idea 9 (Humans significantly alter the Earth), varied between modules. Responses describing relevant content in Modules 3, 5, and 6 included all six response types, which in addition to the three human-Earth Big Ideas, included: “Vague”, “Not Relevant” or “Other” responses. Module 6: Earths’ Climate Past had the largest portion (18%) of students who wrote responses that were too vague to categorize. Module 5: Geologic Time had the largest portion of students who stated the content was not relevant (21%) or described other geoscience concepts (41%) in the response. Module 7: Water and Society, was the only module where every student response clearly described one of the three Big Ideas and no responses were too vague or stated that the content was not relevant.

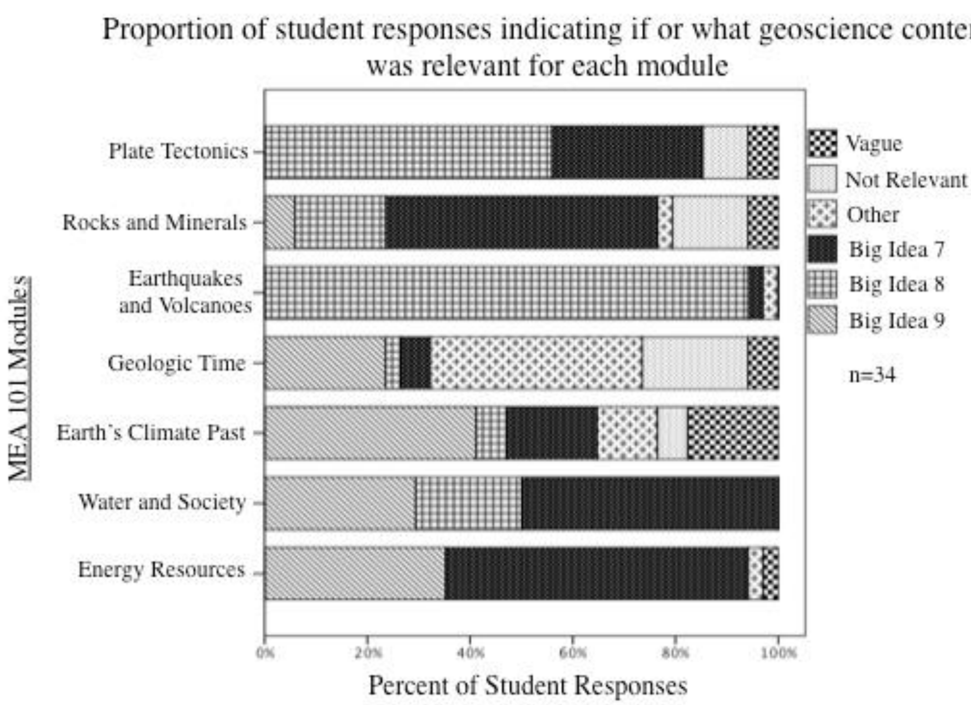


Figure 9. Proportion of Characterization Content Mentioned in Student Responses

Responses that included concepts aligning with Big Idea 7 were the most common for Module 3: Rocks and Minerals; (53%), Module 7: Water and Society; (50%), and Module 8: Energy Resources; (58%). The topics covered in Big Idea 8 were most prominent in student descriptions in Module 2: Plate Tectonics (56%) and Module 4:Earthquakes and Volcanoes (94%). Topics covered in Big Idea 9 were present in 5 of the 7 modules assessed but did not represent a majority in any one module.

Table 8 shows the total counts of the specific human-Earth Big Idea supporting concepts that aligned with topics or examples that students mentioned in their responses across all modules throughout the semester. Responses that described two different supporting concepts were counted separately. No responses included two supporting concepts from different Big Ideas. Responses that did not present a concept or an example that aligned with one of the three human-Earth related Big Ideas were eliminated from this analysis.

There were 25 of the 27 Big Idea supporting concepts described at least one time in a student response from one of the seven modules analyzed (Table 8). Of all the student responses, from all of the modules, there were an equal percentage (39%) of responses that aligned with supporting concepts from Big Idea 7 and 8 and the remaining 22% of responses aligned with Big Idea 9 supporting concepts. See Table 8 for the Big Idea supporting concepts, number of times the concepts appeared in a response, and examples of student responses that aligned with each Big Idea supporting concept.

Table 8. Student Examples and Counts for Big Idea Supporting Concepts Mentioned in Students Responses

		Big Idea Supporting Concept Description	Number of times concept appeared	Examples of Student responses
Big Idea 7 Humans depend on Earth for resources	7.1	Earth is our home; its resources mold civilizations, drive human exploration, and inspire human endeavors.	5	It's this geologic history that shapes our cultures, our identities, and even opprotunities. The landscapes formed by tectonics dictate what kind of lifestyle can be supported. Mountains are harder to support agriculture or isolated islands arcs can support small populations. These geologic and geographic occurances shape the people who interact with them. Nomads, farmers, urban populations are all products of the earth's tectonic past.
	7.2	Geology effects the distribution and development of human populations.	21	I belive that the knowlege of knowing what has happened to the ground underneath you in the past and how stable the ground is, is important information. It should dictate where new towns are made and how safe and prodcutive it is to use the land.
	7.3	Natural resources are limited.	6	Water is important to everyone in the world because we need water in order to survive. By learning more about water people can understand that even though water is recycled, our Earth is still very limited to the amount of water we can use for day-to-day tasks that are necessary. When people understand this concept, people around the world can make the change to conserve water more carefully and efficiently.
	7.4	Resources are distributed unevenly around the planet.	6	The information from this module is relevant is industrial minerals are a 41.6 million dollar industry, which produces more than the metal industry and coal industry. Knowing information from this module can help this industry continue to do well and also help educate individuals in this industry on where to find certain rocks and minerals.
	7.5	Water resources are essential for agriculture, manufacturing, energy production, and life.	14	Using this module allows people to understand the flow and movement of groundwater, allowing them to harness it for their own specific purposes. Knowing how to locate groundwater can also be useful in deciding where to build new cities, farms, and other things that need a ample supply of water to function efficiently.
	7.6	Soil, rocks, and minerals provide essential metals and other materials for agriculture, manufacturing and building.	14	This module is very relevant to people around the world, since it is useful for people to know what rock types are in their area so you can utilize them properly. For example, since there are mostly sedimentary rocks in this area, which include mudstone, sandstone, and clay gives us an understanding that the clay from these rocks can be utilized to make bricks.
	7.7	Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction.	4	I think it is very important for people to understand what's hapening with global warming and what could happen in the up in coming years if certain precautions aren't taken and if people don't realize how harmful some things really are to the environment. I think that things such as energy sources are important to those that work within industries using them, they need to know what is the best energy sources to use and what sources are more harmful than others. It is kind of interesting though to learn about fossil fuel exploration and where its going.
	7.8	Oil and natural gas are unique resources that are central to modern life in many ways.	2	It is very important to know where oil and coal comes from because we use so much of it and right now we can not live without it. Fossil fuels do not form overnight and therefore we need to be careful not to use them all up.
	7.9	Fossil fuels provide most of our energy resources.	4	I feel that the information that is presented within this module is increasingly relavent to people around the world. Sedimentary rock is where we get most of our resources from such as oil and coal.
	7.10	[Knowing geoscience content can] help society move toward greater sustainability.	13	Having the awareness of the earth's climate in the future may help us make decisions on determining what lifestyle to have to help prevent destroying the environment for our next generation. An example would be gradually become more dependent on solar-system. Knowing more information about the energy resources may also help us further develop innovation for the best of the next generation. For example, gradually developing more technology like solar-based systems.

Table 8. Continued

Big Idea 8 Natural Hazards pose risks to humans	8.1	Natural hazards result from natural Earth processes.	17	The informationin the [Plate Tectonic] module is fairly relevent to the lives of individuals and communities around the world because this module explains a lot about the tectonic plates, plate boundaries, and the result of theri movements. This infromation is important to ohers because it can show people what dangerous hazards (ex volcanoes, earthquakes, etc) that happen in certain regions, how different land masses are formed, and why are world has changed so much from millions of years ago.
	8.2	Natural hazards shape the history of human society.	5	I believe that the information in the Volcanoes vs. Earthquakes is much more relevant to the lives of individuals around the world than the rocks and minerals section was. I feel this way because this section provided descriptions on events that can cause damage to lives and living areas. That relates much more to people's lives than the types of rocks that are around them or what makes up the rocks around them. The relevency is just much more.
	8.3	Human activities can contribute to the frequency and intensity of some natural hazards.	0	No student responses addressed this supporting concept.
	8.4	Hazardous events can be suddden or gradual.	1	I think it will be more relevant in the future when changes that are taking place now become aparant to everyone around. While things are slowly changing now, at one point they will build up to a major change. As the Earth changes in major ways communities will have to adapt by moving, changing what and when they grow crops, their mode of transport etc. But while these changes happen gradually individuals don't have much to worry about.
	8.5	Natural hazards can be local or global in origin.	5	If people don't have any knowledge of these natural disasters and if there is any chance of one happening in or around their geographical region then they could potentially get hurt. It is also important to know how far the effects of such disasters could go, such as volcanic eruptions. The cloud of ash could travel much farther than just cities surrounding the volcanoe itself. It's important to know if you live in an area that could potentially be affected so you can be prepared and ready incase of such disasters.
	8.6	Earth scientists are continually improving estimates of when and where natural hazards occur.	10	We can not stop natural disasters but if we are able to predict when they may happen we are able to prepare for them and make the damage less. We are not able to predict the specific time at which these disasters will occure however we are able to to know if a natural disaster might happen so we can plan for them and make evacuation plans and tell people to leave before a volcano like Mount St Helen errupts.
	8.7	Humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts.	33	I believe the information is highly relevant because people need to know if the community is in an earthquake zone, so they can properly build buildings that can withstand vigorous earthquakes. Also, places that have previous knowledge of the area they live in can properly prepare for emergency action plans in the case of dealing with unstoppable natural disasters.
	8.8	An Earth-science-literate public is essential for reducing risks from natural hazards.	17	I think the information in the Water and Society Module is extremely relevant to the lives of individuals and communites around the world. Floods are common as well as dangerous and need to be taken seriously. Local and global communities need to respect, as well as provide sustainable, safe management practices for water as it is crucial to our survival.

Table 8. Continued

Big Idea 9 Humans significantly alter the Earth	9.1	Human activities significantly change the rates of many of Earth's surface processes.	2	The information in the energy resources and earth's climate is extremely relevant to everyone on our planet because it covers issues we are facing currently and will continue to face throughout our lifetimes. Energy needs are continuing to increase as our planet's population continues to grow. There are many problems we face and will need to solve in order to meet these needs without destroying our planet in the process. Climate change needs to be understood because it will cause global changes that people need to be aware of and prepared for.
	9.2	Earth scientists use the geologic record to distiguish between natural and human influences on Earth's systems.	9	I think this module is one of the most important modules yet. Because of all the controversy about global climate change, it is useful to know about how ice ages, greenhouse gases, and wind patterns and how they contribute to the climate. Also, knowledge of these things enable us to predict the future climate and see how much humans are affecting the climate.
	9.3	Humans cause global climate change through fossil fuel combustion, land-use changes, agricultural practices, and industrial processes.	12	Its relevant to individuals and communities around the world because global warming is happening. Global warming is effecting the world by putting our economy in danger but it also has some positives to it. Cutting down on our fuel resources can help out our green house gases effects which helps our atmosphere.
	9.4	Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater.	12	Understanding the Hydrologic Cycle and the global water budget has a great effect people's lives. By understanding how they contaminate the hydrologic cycle, they can then adapt and change how they live so that they won't contaminate the hydrologic cycle. They also could learn how they could save more water and use it smarter through learning the information in this module. They would also be able to decide where good places to put groundwater wells are by studying the surroundings of the area for springs, lakes, and geysers.
	9.5	Human activities alter the natural land surface.	2	I think understanding the different types of minerals that make up rocks and different kinds of rocks are important to indiviuals around the world. Rocks create jobs too for certain individuals. Some peopel need to extract the rocks and mineral from the Earth. If you think about it, mining, agriculture, architecture, and construction, all require the basic knowledge of rocks and their characteristics so that you know how to use them.
	9.6	Human activities accelerate land erosion.	0	No student responses addressed this supporting concept.
	9.7	Human activities significantly alter the biosphere.	3	It is extremely relevant to individuals and communities because to understand our effects on the environment. For example fracking can lead to ground water contamination, oil transportation can lead to oil spills that kill numerous ocean organisms, and emissions are eroding our protective atmosphere that is a valuable part of life. Without Earth's special atmosphere we would not exist and be able to sustain diverse life on Earth.
	9.8	Earth scientists document and seek to understand the impacts of humans on global change over short and long time spans.	3	It is important for people to know how they are affecting the atmosphere, and how they can help preserve it. If people knew how their behavior effected the atmosphere, then they could help preserve it by reducing their activities which damage the atmosphere. The atmosphere is slowly being destroyed, and if we don't do anything to stop this, Earth will one day be uninhabitable. If people understand how much the atmosphere has changed from the past, they might realize that something needs to be done in order to allow life to be able to inhabit Earth.
	9.9	An Earth-science-literate public, informed by current and accurate scientific understanding of Earth, is critical to the promotion of good stewardship, sound policy, and international cooperation.	9	It is important that people are made aware of the consequences of industrial trends. With a heavy enough shift in popular opinion, those most capable of enacting wide change will be pressured into implementing new policies. Honest facts need to be spread, so that a proper understanding of the situation can be reached. Extremes in both directions will do the communities no good.
Total	27		229	

Figure 10 shows the same data from Table 8, representing total counts for the 25 Big Idea supporting concepts students described over the course of the semester. The most commonly cited Big Idea supporting concept was 8.7: Humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts, which was mentioned 33 times throughout the semester. The second most common supporting concept mentioned was 7.3: Natural resources are limited, which was described 21 times. The supporting concepts that appeared the least in student responses were: 8.4: Hazardous events can be sudden or gradual (1 mention), 7.9: Fossil fuels provide most of our energy resources and 9.5: Human activities significantly alter the natural land surface, both with 2 mentions. Two supporting concepts 8.3: Human activities can contribute to the frequency and intensity of some natural hazards and 9.6: Human activities accelerate land erosion never appeared in student responses and are therefore not represented in Figure 10.

Figure 10. Total Count of Big Idea Supporting Concepts in Students' End-of-Module Responses over the Course of the Semester

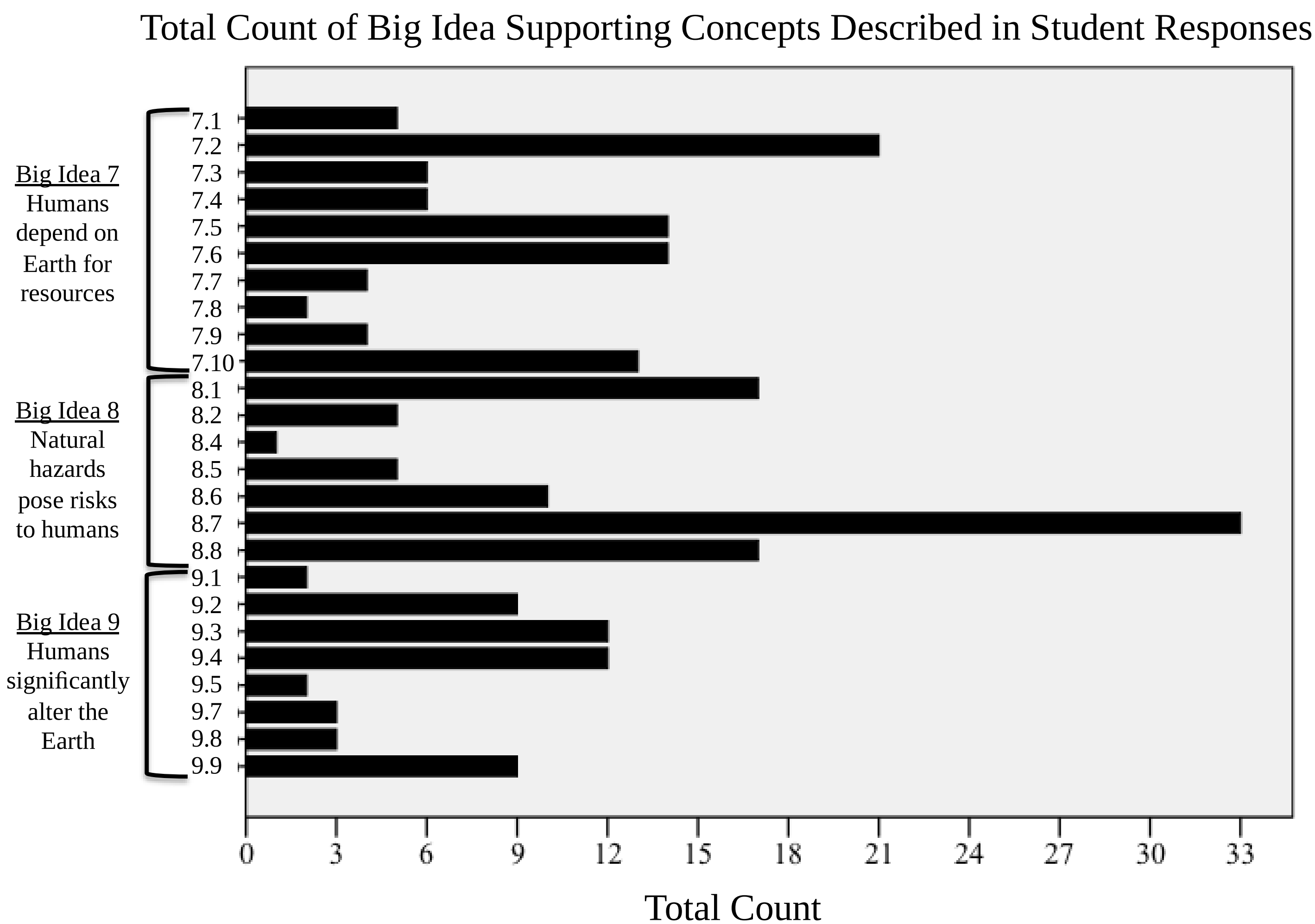

Total Count of Big Idea Supporting Concepts Described in Student Responses
Big Idea 7
Humans depend on Earth for resources
Big Idea 8
Natural hazards pose risks to humans
Big Idea 9
Humans significantly alter the Earth
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9
7.10
8.1
8.2
8.4
8.5
8.6
8.7
8.8
9.1
9.2
9.3
9.4
9.5
9.7
9.8
9.9
0
3
6
9
12
15
18
21
24
27
30
33
Total Count

Figure 11 shows the same data from Figure 10 but separates the number of times each supporting concept was mentioned in each of the seven modules. The number of supporting concepts ranged from seven specific supporting concepts from two Big Ideas mentioned in Module 4 to sixteen supporting concepts from all three Big Ideas in Module 8. Results indicated that some Big Idea supporting concepts clustered in certain modules and were not mentioned at all in other modules. The following provides a more detailed analysis of the results from each of the seven modules characterized.

Responses from Module 2: Plate Tectonics showed that the majority of students (66%) focused on topics that aligned with Big Idea 8: Natural hazards. Seven of eight supporting concepts were accounted for in responses. Concept 8.1 (Figure 11) was most commonly (28%) described in student responses. Thirty-four percent of student responses also included content that aligned with Big Idea 7: Humans depend on Earth for resources. Four of the ten Big Idea 7 supporting concepts were accounted for in responses, most commonly 7.3. No student responses included topics that aligned with Big Idea 9.

Responses from Module 3: Rocks and Minerals showed that 66% of students focus on Big Idea 7: Humans depend on Earth for resources. Six of the ten supporting concepts were accounted for in the responses with most common being 7.7: Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction, representing 41% of total responses for the module. Concepts that aligned with Big Idea 8 appeared in 28% of student responses and 3 of 8 indicators were accounted for in responses. Two students mentioned a topic in Big Idea 9.

Responses from Module 4: Earthquakes and Volcanoes showed that 97% of students focused on topics that aligned with Big Idea 8: Natural hazards. Six of eight indicators were accounted for, with 43% of the responses mentioning 8.7: humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts (Figure 11). Only one student mentioned a topic from Big Idea 7 and no students mentioned topics from Big Idea 9.

Results from Module 5: Geologic Time showed that there were a total of eight students who described content that aligned with one of the human-Earth related Big Ideas.

This module had the fewest supporting concepts discussed in responses. The majority (56%) of responses that did discuss supporting concepts, aligned with Big Idea 9 (Figure 11).

Responses from students concerning Module 6: Earth's Climate Past showed that 63% of students focus on Big Idea 9: Humans significantly alter the Earth. Five of nine Big Idea 9 supporting concepts were represented in student responses. Considering all three Big Ideas, the most common Big Idea supporting concepts were 7.2 and 9.2 (Figure 11), each representing 21% of the total responses in Module 6.

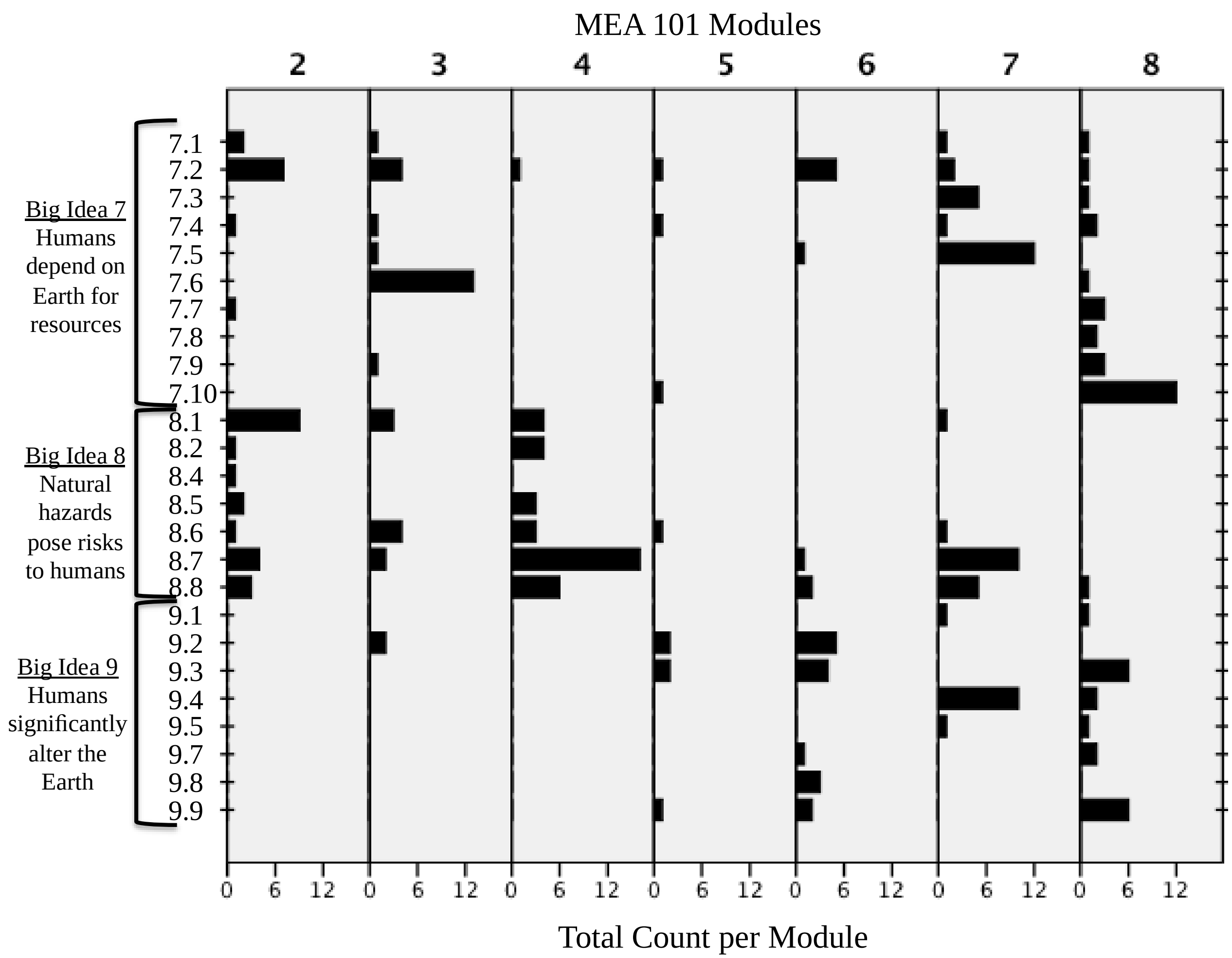
The proportion of Big Ideas covered in Module 7: Water and Society were more evenly distributed than other modules; Big Idea 7: 42%, Big Idea 8: 34%, and Big Idea 9: 24%. Sixteen students mentioned two indicators, which was more than any of the other modules. The most common themes aligned with Big Idea indicators; 7.6: 24%, 8.7: 20% and 9.4:20% (Figure 11) of the total responses.

Results from the characterization of student responses for Module 8: Energy Resources showed that 58% of responses focused on Big Idea 7: Humans depend on Earth for resources. The most common supporting concept was 7.10 (Figure 11) with 27% of total responses mentioning concepts that aligned with either knowledge of geoscience or Earth scientists help society move toward greater sustainability. The second largest portion of responses (40%) aligned with Big Idea 9: Humans significantly alter the Earth.

The results from the characterization of students' end-of-module responses indicated that students identified a portion of similar concepts perceived as relevant to society as the ones stated in the human-Earth related Big Ideas. In addition, these results signified that some of the human-Earth Big Idea supporting concepts appeared more frequently in student responses whereas others were rarely mentioned or did not appear at all.

Figure 11. Distribution of Big Idea Supporting Concepts in Student Responses per Module

Count of Big Idea Supporting Concepts Described in Student Responses



Final Exam Responses

Figure 12 shows the results from students' (n=75) final exam short answer question: "From the information presented in MEA 101, what do you think are the two most important concepts citizens need to comprehend in order be considered an Earth-science literate person who can make sound decisions for a sustainable future?" They were then instructed: "In a minimum of 3 complete sentences, describe two concepts and how citizens can apply the knowledge." Five of the 75 students did not clearly identify two concepts in their responses, resulting in 145 concepts identified. The concepts identified were grouped into the following themes and are reported with their overall percentage of responses; Water Resources, 20%; Natural Hazards, 23%; Energy Resources, 24%; and Climate Change, 26%.

A miscellaneous category that included concepts outside of the student established themes accounted for 7% of the total concepts identified. Five students highlighted the overarching concept that Earth is a changing system. For instance, "Earth is constantly undergoing changes. These changes are both naturally occurring and caused by anthropogenic means. Humans constantly affect Earth's processes in both positive and negative ways and, depending on the effect, can later affect humans in the future. As a result, citizens have to understand that the choices they make now can affect others in the future."

The concepts that made up the theme of Water Resources included: Water systems, Freshwater is an important and finite resource, and Water pollution (Figure 12). Students tended to state that water was a vital resource before further discussion of a specific aspect of water resources. The most common concept described focused on sources of water pollution. For example, "…improving the handling of water, the most valuable resource on the planet. Analyzing things such as permeability and direction of groundwater flow will prevent widespread problems such as stream and river contamination, which are extremely hard problems to fix." Seven students described the importance of water systems:

> "All citizens should be knowledgeable of water in general, especially dealing with the hydrologic cycle and the concepts of groundwater. It is essential to understand where it comes from and where it is located, and how it can be obtained. By understanding how ground water flows and knowing about the water table for instance, humans can

> work toward sustainability by not only using the water they need, but also know how to protect the water they have."

Concepts related to water as a finite resource included descriptions of citizens, knowing where their water "comes from", examples of conserving freshwater resources, and not "taking water for granted".

The most common concepts discussed under the Natural Hazards theme was earthquake hazards (Figure 12). Students focused on how knowledge of earthquakes and monitoring earthquakes contributed to better building decisions. One student stated: "By knowing more about earthquakes, society can take more precautions to invest in safer building plans so people are not as harmed." Other students described more general concepts related to the "need for public awareness of hazards" or "understanding that plate tectonics is the source of natural disasters". Students that focused on flooding cited "knowledge of monitoring discharge", "being aware of the hazards" for the purpose of "community planning and zoning" as relevant for making decisions for a sustainable future.

The most common concepts discussed under the theme of Energy Resources were energy consumption and waste of non-renewable resources:

> One concept every citizen should understand is how we consume our energy and the effects energy production and consumption have. Fossil fuels are currently the most common source of energy and are very bad for the environment. Citizens can make decision for a sound future by using less energy and buy more efficient appliances.

Five students were more specific by focusing on the formation of fossil fuels. For example, "A science literature person should know is where our energy comes from. Coal and petroleum can't be made overnight. It takes millions of years to make these resources." Another student described:

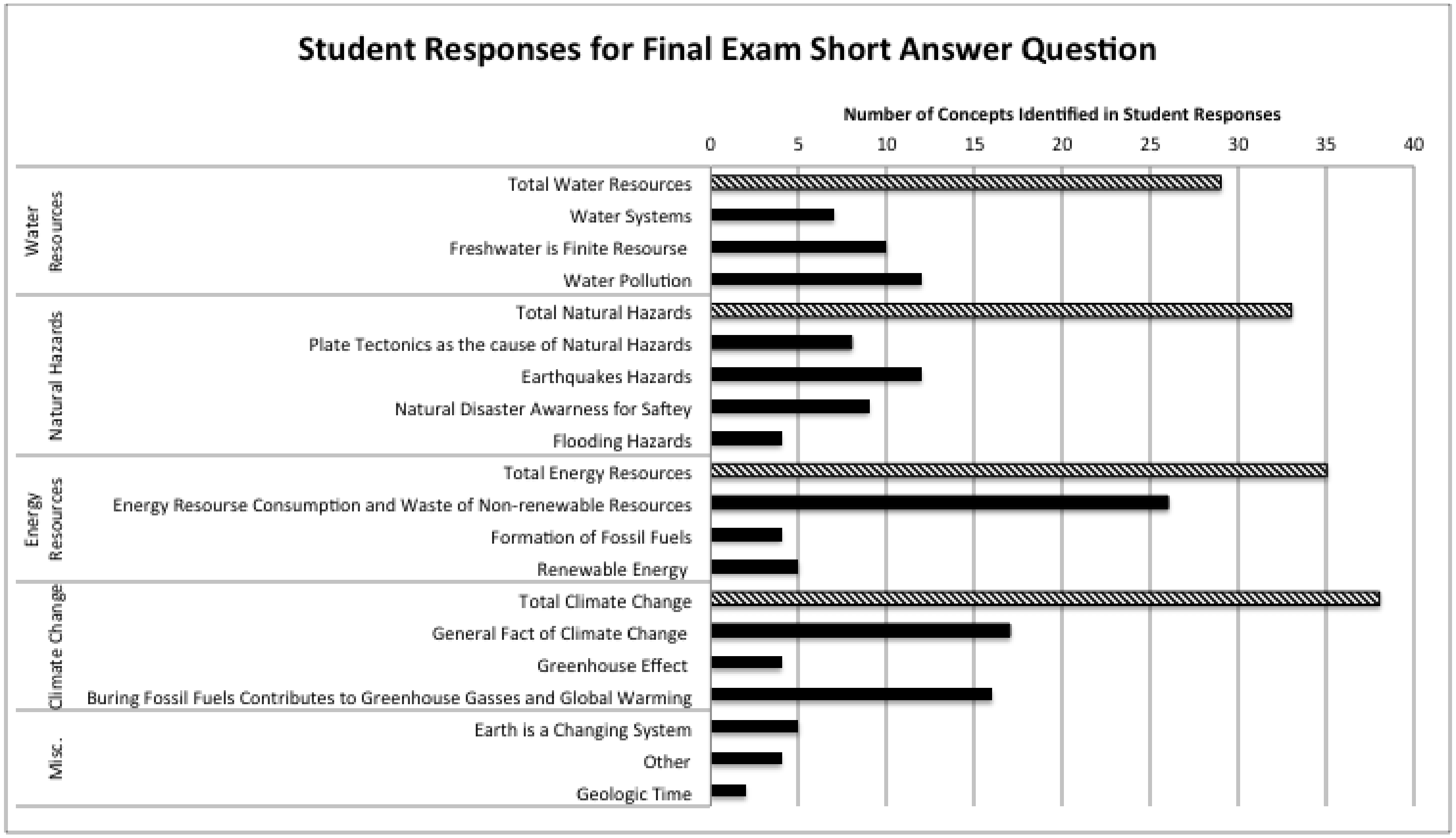
> Citizens should understand where it comes from but also understanding the process in which it takes for coal and oil to be made. People could apply this knowledge to change how they use their electricity to make sure they are conserving, which is the key to a sustainable future.

Four students specifically described the importance of renewable energy resources. For example, "Utilizing cleaner energy sources that don't come from fossil fuels and aren't extremely dangerous such as nuclear reactors will help prevent future environmental disasters in the creation of electricity. Solar, wind, and hydro-power energy sources are the cleanest and smartest solutions for future sources of power."

The most common concept under the theme of Climate Change was the general concept that climate change exists. This was often characterized by statements such as: "climate change is real", "climate change is a debatable topic; not everyone believes in it, let alone takes it serious, but this does not mean that it is not happening" or "I think each person needs to understand that the climate crisis is a global problem that each individual has an obligation and a responsibility to take action." Students also mentioned the concept that "we are increasing the amount of greenhouse gasses in the atmosphere, thus contributing to a gradual warming of the climate." Students further described that "global temperature has risen over the past century and it is predicted to rise even more in the future. There are multitudes of ways that citizens could apply their knowledge of this trend…but the biggest obstacle in the way of getting them to actually act." Four students focused on how "the greenhouse effect is not the same as climate change" and how it is a "naturally occurring phenomena" but does play a role in understanding climate change.

These qualitative results from the final exam short answer responses provided insight into students' perceptions of the relevance of geoscience content in society and for decision-making for a sustainable future. In addition, responses also provided evidence that students continued to describe similar topics on their final exam as they did during the end-of-module responses.

Figure 12. Themes and Concepts Described in Students' Final Exam Short Answer Question Responses


Student Responses for Final Exam Short Answer Question
Number of Concepts Identified in Student Responses
0
5
10
15
20
25
30
35
40
Water Resources
Total Water Resources
Water Systems
Freshwater is Finite Resourse
Water Pollution
Natural Hazards
Total Natural Hazards
Plate Tectonics as the cause of Natural Hazards
Earthquakes Hazards
Natural Disaster Awarness for Saftey
Flooding Hazards
Energy Resources
Total Energy Resources
Energy Resourse Consumption and Waste of Non-renewable Resources
Formation of Fossil Fuels
Renewable Energy
Climate Change
Total Climate Change
General Fact of Climate Change
Greenhouse Effect
Buring Fossil Fuels Contributes to Greenhouse Gasses and Global Warming
Misc.
Earth is a Changing System
Other
Geologic Time

DISCUSSION

The observed changes in students' attitudes about the relevance of science and perceptions of geoscience established a baseline characterization of undergraduates in MEA 101. We presumed that with growing public concern of environmental challenges (accompanied with increased popular conversations about sustainability) some students had prior knowledge that Earth systems were related to issues of sustainability. Nevertheless, as students progressed through the semester they were exposed to lessons that discussed Earth system concepts that were likely unfamiliar. Some topics emphasized the connection between humans and geoscience and 20% of the course learning objectives aligned with the human-Earth related Big Ideas from the Earth Science Literacy Principles (ESLPs). However, the course modules were not specifically designed to teach the relevance of geoscience in the context of society or for decision-making in everyday life. Therefore, for much of the course students were independently assimilating the relevance of geoscience. It is important to note that the qualitative data is situated within this particular study and cannot inform generalizations for other populations.

Students' Perceptions of the Relevance of Geoscience in the Context of Society

Students' responses from the question: "How relevant do you think the information in the [module title] module is to individuals and communities around the world?" provided insight into how undergraduates perceive the relevance of specific themes presented in a semester long introductory geology course. Responses from the final exam question: "From the information presented in MEA 101, what do you think are the two most important concepts citizens need to comprehend in order be considered an Earth-science literate person who can make sound decisions for a sustainable future?" captured students' perceptions of the most relevant content from the entire MEA 101 course. The latter question's emphasis on decision-making for a sustainable future builds on student's descriptions of the application of geoscience contented presented throughout the course. Both open-ended questions addressed the Research Question: How do undergraduates' perceptions of the relevance of geoscience emerge from student writings on geoscience content in the context of society?

Mapping students' responses throughout the course gave a comprehensive picture of students' perceptions about the relevance of geoscience in society. At the beginning of the course, students' responses were fairly positive, which was demonstrated by the majority of students' (85%) discussing the relevance of basic geoscience principles in society. Students also mentioned that "the geologic processes that shape our world do not only affect one group of people or one region, they affect everyone." Furthermore there was an undertone in student responses that "we should understand how the Earth changes since we are living on it." Conversely, some students cited that geoscience is not relevant because they "have a hard time believing scientists." This skepticism was not widespread but sporadically appeared in student responses throughout the semester.

While the first two modules did not explicitly discuss the connection between plate tectonics and natural disasters, students comprehended that there is a relationship between the two phenomena. Within the first two weeks students pointed out that "by understanding basic geologic processes and concepts, we can better prepare ourselves against natural disasters such as earthquakes and volcanoes." However, not all students shared the perspective that broader foundational geoscience concepts are relevant. Some express that learning about the forces that drive the changing Earth are not relevant because of the vast timescales and unlikeliness of experiencing "the occasional earthquake and volcano that might destroy something." In these cases, some students added a caveat that it might be relevant for those who live near a volcano or on a fault line but that it does not pertain to them individually and is therefore "not really relevant".

Students distinguished content presented in the courses as either relevant to geology or relevant for personal applications. Applying Newton's (1988) terminology, students discern between internal and external relevance by stating whether information presented was limited to geology (internally relevant) or could be applied outside of the field of geoscience (externally relevant). The sentiment that knowledge of geoscience content that is not useful in students' everyday lives, and thus internally relevant, echoes throughout students' responses. This was most apparent in students describing how content presented in the geologic time module is relevant to geologists but not to individuals or communities around the world. During this module some students contrasted other content presented in the courses as types of information that they perceived as relevant to communities such as "natural threats" or "resource gathering". Other responses throughout the semester commonly identified content as externally relevant if it could be used to either "keeping people safe" or "provide essential resources." The pattern of students identifying content as relevant when they could explain a use for the knowledge suggests that students connect relevance with application and hence view geoscience content as being externally relevant.

When students wrote about the information being externally relevant they often referred to the ability to use knowledge to help make choices about the use of resources (concepts related to Big Idea 7) or for preparation of potential natural hazards (concepts related to Big Idea 8). This was most evident in the end-of-module responses from the Rock and Mineral, Water and Society, and Energy Resources modules. During these modules students cited multiple examples where geoscience content has applications outside of the classroom in local, regional, or global contexts. This ability to identify applications of content in a real-world setting is significant because it indicates perception of content having relevance to an individual's life, which is closely tied with motivation to learn material (Keller, 1987; Frymier and Shulman, 1995) and increasing students attitudes about the importance of attaining knowledge for future decision-making (Newton, 1988).

The vital connection between geoscience and individuals or communities was most clearly reflected in responses for Modules 7 (Water) and 8 (Energy) where every student response (n=34) indicated that the information was relevant. In addition, more students discussed at least two separate (Big Idea) supporting concepts in their responses for these two modules than for any other: 16 students in the Water Module: and 11 responses in the Energy Resources Module. Some students stated that these modules were the most relevant geoscience content of the semester. For instance, one student said that the information in the Water Module "is far more relevant than much of what has been covered. Water is an essential for our continued existence, and understanding how our fresh water supply functions is of severe importance." Another student vied for Module 8 as being "the most relevant of the whole semester because it relates to the most important global issues facing the world in the 21st century." These responses exemplify students' perceptions that geoscience content that is directly related to their daily lives and hence its external relevance is perceived to be of greater importance.

Because water and energy resources are related to students' everyday lives, it is not surprising that students expressed the relevance of these topics more clearly than more novel geoscience topics. However, it cannot be ruled out that the increasing number of learning objectives that highlight the connection between geoscience content and society play a role in students responses. Regardless of the source of communication or personal experience with water and energy resources, students' positive perceptions of the relevance of science increase when content is affirmed as applicable to every day life (Liu et al., 2011).

The concepts most commonly discussed in the end-of-module responses are congruent with the overall themes and concepts students identified as most important for an Earth-science literate person to make sustainable decisions. Students' focused on describing information that could be used for decision-making related to the potential risks from natural hazards, water and energy resources, and aspects related to climate change. Because the final exam question asked students to consider all the information from the MEA 101 course, it increases confidence that the way students' described the relevance of geoscience content to society in the end-of-module responses represented students' overall perception of the relevance of geoscience in society.

The consistency of concepts described in both of the open-ended questions provides further evidence for the connection between application of science and perception of the external relevance of science. Students often mentioned that geoscience content "needs to be able to be used" in order for it to be relevant. Even though the end-of-module question does not mention decision-making or sustainability, students discerned relevant from irrelevant content on the basis of its applicability in decision-making. Likewise, the end-of-module question did not mention sustainability, yet students used similar phrases, such as "well-being of communities" when describing why geoscience content was relevant. Students' tendencies to associate relevance with application may explain why students selected similar concepts for both open-ended questions related to the relevance of geoscience in society.

The implication for students finding some geoscience content relevant is that students will more likely assimilate the content into their daily and future decision-making process (Newton, 1988). These students will arguably make better decisions related to human-Earth interactions at the conclusion of the course than at the onset of MEA 101. For example, externally relevant concepts mentioned in student responses that were most likely comprehended before enrolling in introductory geology included: “humans need freshwater to drink” or “there is a limited amount of freshwater in the world”. New information likely included the concept of the water table, and the impact of permeability, porosity, and terrain on groundwater flow. By the end of the course students were citing such concepts as vital for citizens to know and illustrated ways in which to apply this knowledge. Portions of students’ responses included geoscience concepts presented in class: “Analyzing things such as permeability and direction of groundwater flow will prevent widespread problems such as stream and well water contamination” and “citizens should learn about the water table so they understand if it is being impacted by a factory taking too much water or if there is enough groundwater during a drought. The level of the water table is important to know so that people can make decision about how much water to use”. These geoscience concepts provide students with a deeper understanding of their freshwater resources and provide them with the vocabulary and conceptual knowledge to better comprehend local groundwater contamination, media coverage about impending regional drought, or a global environmental report. Students that demonstrated an ability to describe the application of this knowledge are better equipped to make human-Earth related decisions for a sustainable future.

Aside from the geoscience concepts identified, a common theme in students’ final exam responses was the need for “more than an awareness” of knowledge, there was the need for action. Students discussed ways in which they or others could take action to make better decisions about the use of resources on a daily basis. For example, “Citizens can know everything there is to know about global warming, but if nothing gets done, their knowledge is essentially meaningless.” Students’ emphasis on the need for behavioral change was an unexpected, but notable, outcome of the study. The implications of this observation are discussed in the future work section of this study.

Students' Attitudes about the Relevance of Science among Sections of MEA 101

Research findings do not support the rejection of Null Hypothesis One: There is no difference in undergraduates' attitudes about the relevance of science among sections of MEA 101. Results suggest no significant difference in students Changes in Attitude about the Relevance of Science (CARS) scores in iterations 1, 2, or 3, among the three sections of MEA 101. The explanation as to why students' attitudes were initially similar at the beginning of the semester is beyond the scope of this study but is presumably related to similar life experiences prior to enrolling in the course. It is reasonable to attribute similar changes in CARS scores to similar course structure and content exposure and a similar degree of student-centered lectures. It is assumed that no two instructors are exactly alike nor are student dynamics consistent among classes. However, the consistency of shared curriculum and average RTOP scores increases confidence that students received a comparable introductory geology course experience.

Changes in Students' Attitudes about the Relevance of Science over the Semester

The average Changes in Attitudes about the Relevance of Science (CARS) scores provide evidence that supports Hypothesis Two: Exposure to geoscience content changes students' attitudes about the relevance of science. The overall shift in the distribution and average CARS scores indicates that students' attitudes changed in a positive direction over the course of the semester, which means undergraduates were more likely to perceive that science as relevant to their daily lives and decision-making at the end than at the beginning of the semester. Students' initial average CARS score was 3.52. According to the Likert response words provided in the survey, students' attitudes were between neutral and agreeing that science was relevant in their daily lives and decision making at the onset of MEA 101. Data from the CARS survey iteration 2 shows that students' average CARS score significantly increased to 3.65 ($p=0.046$), indicating a shift toward being more agreeable to statements about the relevance of science in everyday situations. Another shift toward a more positive attitude about the relevance of science was observed at the end of the semester where average CARS scores increased to 3.66 ($p=0.039$). While these shifts were small, they were quantitatively significant and in a positive direction.

The findings in the current study are consistent with the findings from the original research using the CARS instrument. The developers of CARS observed students' average CARS scores slightly but significantly increased over the course of the semester. Other research suggests that students' attitudes about different facets of science can be difficult to change and thus positive change would most likely be minimal (Osborne et al., 2003; Himschoot, 2012).

While the CARS is a single scale instrument, examination of the seven repeated items on the CARS survey provides a higher resolution of the changes on some of the statements. The timing and direction of change in attitudes about the relevance of science varies. Some of these variations may be explained by assessing the sequence of the geoscience content covered in the course and the nature of the CARS statements. An appraisal of the end-of-module responses provides insight into the connection between students' perceptions of the relevance of science and their change in CARS scores. The five items that changed the most over the course of the semester are discussed.

The second CARS iteration was administered during the earthquakes and volcanoes module that focuses on natural hazards and includes 4 learning objectives that align with Big Idea 8: Natural Hazards pose risks to humans. After this module, average CARS scores for the statement "Learning science can help me when I choose where to buy a house" increased from 4.01 to 4.17, meaning students more strongly agreed with the statement. The concepts of natural hazards posing threats to humans and governing decisions about where to live were common themes in students' end-of-module responses. Students typically explained how "understanding the information can help determine whether individuals are putting themselves in harms way or not when choosing where to live." In addition to "knowing the closer you are to a convergent boundary, the more likely you are to experience earthquakes and tsunamis", students discuss the dangers associated with choosing "to live in an area that has buildings that are old and not well equipped for earthquakes." Some students provided more comprehensive responses that included details about the type of information an individual should acquire if living near a natural hazard, such as "records of any small earthquakes or any signs of activity in last few years" or "building codes". These open-ended responses explain how the information in the module provided relevant information that would help in the decision-making process of choosing where to live, which can be extended to a CARS statement that includes "where to buy a house".

Students' attitudes about the CARS statement "Much of what I learn in Geology class is useful in my everyday life" changed in the second half of the semester, where there was an increase in students' discussing multiple supporting concepts and an increase of number of the learning objectives aligned with the Big Ideas. These learning objectives alluded to the connection between geoscience and society by including concepts such as; anthropogenic factors of climate change, the value of discharge data to communities, and use of energy in the US. Because learning objectives were communicated to the students and incorporated into lessons plans, reading assignments, and assessments, this communication may account for some of increase in students' CARS scores.

In addition to the content students discussed, whom students mention in their responses about the relevance of geoscience shifted in the latter part of the course. During Module 6: Earth's Climate, a greater number of students began including themselves as part of the community of people for whom the geoscience content is relevant. Students increase in using phrases such as, "we line in a world", "it would be beneficial to us", "so we can keep ourselves safe", and "I believe this information is relevant to my life" indicate that students are assimilating the relevance of geoscience into their own lives. The trend of students moving from identifying information as being relevant to others, to characterizing the information also being personally relevant continued in responses for Module 7 and 8. Since this CARS statement specifically addressed the individual student using the information from geology class, a greater number of students including themselves in the later modules provides context for the timing of the positive changes in CARS score.

The CARS statement “Caring about people is part of making a scientific choice, such as whether to use pesticides on plants” showed an increase between CARS iteration 2 (3.57) and 3 (3.73). The timing of this increase in CARS scores may be in part due to the nature of the topics covered in these later modules (Climate change, Water and Society, Energy resources). While the end-of-module responses did not include the term “scientific choices” per se, students’ discussions in the second half of the semester frequently referred to the consideration of others by expressing a concern for their own future and future generations. This was most clearly expressed in responses that discussed climate change. Representative of several responses, one student stated how “having the awareness of the earth's climate in the future may help us make decisions on determining what lifestyle to have to help prevent destroying the environment for our next generation. Knowing more information about the energy resources may also help us further develop innovation for the best of the next generation.” This response provides context for the increase in CARS scores on the statement that incorporated the consideration of others during a decision-making process.

Limitations with using the end-of-module responses to provide context for changes in CARS scores are evident in repeated CARS statements that include the general term “science”. As a result of this vagueness, two repeated CARS items that changed over the course of the semester cannot be tied to specific modules that might inform the reason for change. The statement “Things I do in science have nothing to do in the real world” decreased from 4.24 during iteration 1 to 4.03 at iteration 3. This question was a reverse scored question, which means that students more strongly disagreed with this statement at the beginning of the semester than at the end of the semester. The statement “Science helps me make sensible decisions” increased from 3.61 at iteration 1 to 3.76 at iteration 3. While students often referred to the “real-world” and “decisions” in their in end-of-module responses, it would be incongruous to extend student perceptions of the relevance of geoscience to the broader concept of “science”.

This study provides evidence that the MEA 101 course had positive impacts on students’ attitudes about the relevance of science in daily decision-making. The implication of this finding is that undergraduates who completed the introductory geology course were more positive about incorporating science into their decision-making, which is a shared science goal amongst those who advocate for a scientifically literate citizenry (Gogolin and Swartz, 1992 Klotz, 1992; Bralower, 2008; Holbrook and Rannikmae, 2009).

Relationship between student attitude about the relevance of science and performance

Research findings provide evidence that partially support Hypothesis Three: There is a relationship between students' change in attitudes about the relevance of science and performance. The strength of the relationship among change in CARS scores and performance differed dependent upon the nature of the performance measure. The Geoscience Literacy Exam (GLE) is composed of lower-order thinking questions that measured students' knowledge of geoscience content. Change in GLE score showed no significant relationship ($R^2<0.001$, $p=0.884$) with change in CARS score. Students' final course grades were a compilation of different types of assessments; some of which are lower-order and others that are higher-order assessments. This measure showed a significant positive relationship ($R^2=0.065$, $p=0.002$) with change in CARS score. The final exam short answer question required students to engage in higher-order thinking by critically assessing the information from the course, select the concepts people would need to know to be considered Earth science literate, and then communicate their reasoning for their selection. This performance measure showed the strongest positive relationship ($R^2=0.16$, $p<0.001$) with change in CARS score. In order to earn full credit, students had to illustrate how geoscience content was relevant to other facets of life and sustainability. The more the performance measures incorporated geoscience content related to society the stronger the relationship with student's change in average CARS score.

Students' change in average CARS scores showed a stronger relationship with performance measures than overall CARS scores. Data from this research suggests that students who are more likely to change their attitude toward agreeing that science was relevant to daily decision-making explains more of the variance in performance assessments than students with a more positive attitude about the relevance of science. This finding is consistent with other research showing that an individual's willingness to change their perspective about the Nature of Science was a stronger predictor of performance than initial positive perspective, especially if the performance measure required higher-order and critical thinking (Schommer-Aikins and Hutter, 2002). The implication of this finding supports the implementation of curricula that integrates the relevance of geoscience to society in order to cultivate students who can engage in critical thinking about the application of geoscience for a sustainable future.

Future Work

While this study suggests that students' demographic characteristics did not play a role in students' change in attitude about the relevance of science, future studies should take the demographics of the sample into account. As demonstrated in other studies, demographics have played a role in students' attitudes and perception about science (Gogolin and Swartz, 1992; Weinburgh, 1995). Research using similar methods as described in this study with students of various backgrounds and geographic locations would provide a more comprehensive landscape of the impact an introductory geology course has on undergraduates change in CARS scores.

Research using the Changes in Attitudes about the Relevance of Science (CARS) instrument in other geoscience courses would help determine the impact pedagogical practices and/or course structure has on students' attitudes about the use of science in everyday decision-making. We recommend that the RTOP tool be used to measure the degree of student-centered lectures. It would be beneficial to determine if more traditional (lower RTOP score) or more student-centered (higher RTOP scores) introductory geology course would produce similar results in change in CARS scores. It would also be valuable to evaluate the course structure to determine if the order of content impacts students CARS scores over the course of the semester.

Future research on the impact of curricula that teaches geoscience within the societal context might benefit from the utilization of the Elaboration Likelihood Model (ELM) of persuasion model. The ELM was developed to explain how or if an individual would change their attitude (Petty and Cacioppo, 1986). The premise of ELM was that the presentation of the relevance of content influences how motivated an individual is to put forth cognitive effort and engage with the content. The posited outcome of the higher engagement was greater assimilation of the identified relevant content that would then lead to behavioral changes. In recent educational research, the ELM framework has been used to evaluate the effectiveness of certain methods for changing attitudes and behavior of students (Wanzer et al., 2010; Lee, 2012; Johnson and Aboud, 2012).

According to ELM, there are two basic methods to communicate information: peripheral and central. A peripheral method is described as being indirect communication that does not clearly make an intended connection or provide a cognitive structure for an individual to assimilate information. In the current study the way in which the relevance of geoscience was communicated over the course of the semester would be considered peripheral. Conversely, a central method directly states the relevance of information and promotes reflection of ways content is relevant to an individual. In MEA 101, the learning objectives in the Water and Society Module that aligned with the Big Ideas that highlighted the relevance of geoscience could be considered central. These methods of communication are linked to the types of individual attitudinal changes: peripheral attitude change and central attitude change. According to the ELM, central attitude change was more enduring and predictive of behavior than peripheral attitude change (Petty et al., 1997).

In future studies, ELM could help explain any changes in attitude that may occur as a result of the InTeGrate curricula, which would be considered central communication. In addition, ELM could contribute to the understanding of the impact geoscience education has on undergraduates' behavioral changes. After all, behavior will ultimately determine if students, as citizens and of the planet, will make decision for a sustainable future.

CONCLUSIONS

This study provided quantitative and qualitative results that addressed students' attitudes and perceptions about the relevance of geoscience in society over the course of the semester in an introductory geology course. Findings suggest that undergraduates' overall attitudes about the relevance of science for decision-making in everyday life became more positive throughout the semester. No significant differences in student change in CARS scores were dependent upon demographic characteristics or MEA 101 course section. Students' change in attitude about the relevance of science showed a positive relationship with students final course grades and a short-answer questions score that assessed a students' ability to describe the applicability of geoscience concepts for a sustainable future.

Analysis of open-ended responses about the relevance of geoscience in society revealed a pattern of students identifying information as most (externally) relevant when they could also identify how to use the information for decision-making related to safety or use of resources. The geoscience concepts students described as relevant were similar to the human-Earth related concepts stated in the recently published Earth Science Literacy Principles. This indicates that undergraduates are cognizant of the connection of geoscience in society. Furthermore, students reiterated the similar concepts discussed as relevant in their responses throughout the semester as those deemed important for an Earth science literate citizen to know in order to make sustainable decisions for the future.

If the community of geoscience educators wants to establish geology as an important field of study for students to learn so that they are able to make better decisions for a sustainable future, this research suggests that it is advantageous to communicate (through learning objectives, course materials, and active-learning lectures) that geoscience is relevant to society. This study provides evidence that advocates for the development and implementation of curricula that integrates geoscience content within the context of societal issues.

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APPENDICES

Appendix A.1. ESLP Big Idea 7: Humans depend on Earth for resources

BIG IDEA 7. Humans depend on Earth for resources.

Humans rely on petroleum for the manufacturing of plastics, fertilizers, and other goods in addition to being a major source of energy. The thoughtful use of this resource is necessary to ensure its availability.

7.1 Earth is our home; its resources mold civilizations, drive human exploration, and inspire human endeavors that include art, literature, and science. We depend upon Earth for sustenance, comfort, places to live and play, and spiritual inspiration.

7.2 Geology affects the distribution and development of human populations. Human populations have historically concentrated at sites that are geologically advantageous to commerce, food production, and other aspects of civilization.

7.3 Natural resources are limited. Earth's natural resources provide the foundation for all of human society's physical needs. Most are nonrenewable on human time scales, and many will run critically low in the near future.

7.4 Resources are distributed unevenly around the planet. Resource distribution is a result of how and where geologic processes have occurred in the past, and has extremely important social, economic, and political implications.

7.5 Water resources are essential for agriculture, manufacturing, energy production, and life. Earth scientists and engineers find and manage our fresh water resources, which are limited in supply. In many places, humans withdraw both surface water and groundwater faster than they are replenished. Once fresh water is contaminated, its quality is difficult to restore.

7.6 Soil, rocks, and minerals provide essential metals and other materials for agriculture, manufacturing, and building. Soil develops slowly from weathered rock, and the erosion of soil threatens agriculture. Minerals and metals are often concentrated in very specific ore deposits. Locating and mining these ore deposits provide the raw materials for much of our industry. Many electronic and mechanical devices have specific requirements for particular rare metals and minerals that are in short supply.

7.7 Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction. For example, land reclamation can partially restore surface environments following surface mining.

7.8 Oil and natural gas are unique resources that are central to modern life in many different ways. They are the precursors to chemicals used to make numerous products, such as plastics, textiles, medications, and fertilizers. Petroleum sources are needed to manufacture most industrial products.

7.9 Fossil fuels and uranium currently provide most of our energy resources. Fossil fuels, such as coal, oil, and natural gas, take tens to hundreds of millions of years to form. Their abundance will make them the dominant source of energy for the near future. New sources, such as methane hydrates, are being explored.

7.10 Earth scientists help society move toward greater sustainability. Renewable energy sources, such as solar, wind, hydroelectric, and geothermal, are being developed. They will replace fossil fuels as those become scarcer, more expensive to retrieve from Earth, and undesirable due to environmental damage. Earth scientists foster global cooperation and science-informed stewardship that can help to ensure the availability of resources for future generations.

Appendix A.2. ESLP Big Idea 8: Natural hazards post risks to humans

BIG IDEA 8. Natural hazards pose risks to humans.

8.1 Natural hazards result from natural Earth processes. These hazards include earthquakes, tsunamis, hurricanes, floods, droughts, landslides, volcanic eruptions, extreme weather, lightning-induced fires, sinkholes, coastal erosion, and comet and asteroid impacts.

8.2 Natural hazards shape the history of human societies. Hazardous events can significantly alter the size of human populations and drive human migrations. Risks from natural hazards increase as populations expand into vulnerable areas or concentrate in already-inhabited areas.

8.3 Human activities can contribute to the frequency and intensity of some natural hazards. These hazards include floods, landslides, droughts, forest fires, and erosion.

8.4 Hazardous events can be sudden or gradual. They range from sudden events such as earthquakes and explosive volcanic eruptions, to more gradual phenomena such as droughts, which may last decades or longer. Changes caused by continual processes such as erosion and land subsidence can also result in risks to human populations, as with the increased risk of flooding in New Orleans.

8.5 Natural hazards can be local or global in origin. Local events can have distant impacts because of the interconnectedness of both human societies and Earth's systems. For example, a volcanic eruption in the Pacific Ocean can impact climate around the globe.

8.6 Earth scientists are continually improving estimates of when and where natural hazards occur. This analysis is done through continuously monitoring Earth, increasing our understanding of the physical processes that underlie its changes, and developing scientific models that can explain hazard-related scientific observations.

8.7 Humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts. Loss of life, property damage, and economic costs can be reduced by identifying high-risk locations and minimizing human habitation and societal activities in them, improving construction methods, developing warning systems, and recognizing how human behavior influences preparedness and response.

8.8 An Earth-science-literate public is essential for reducing risks from natural hazards. This literacy leads to the promotion of community awareness about natural hazards and to the development of scientifically informed policies that reduce risk.

A lava flow devours a road in Hawaii. This natural hazard creates an inconvenience; however, many natural hazards can be life threatening. The impact of natural hazards can be greatly reduced through the education of citizens about the risks in their region.

Appendix A.3. Big Idea 9: Humans significantly alther the Earth

BIG IDEA 9. Humans significantly alter the Earth.

9.1 **Human activities significantly change the rates of many of Earth's surface processes.** Humankind has become a geological agent that must be taken into account equally with natural processes in any attempt to understand the workings of Earth's systems. As human populations and per capita consumption of natural resources increase, so do our impacts on Earth's systems.

9.2 **Earth scientists use the geologic record to distinguish between natural and human influences on Earth's systems.** Evidence for natural and human influences on Earth processes is found in ice cores and soils, and in lake, estuary, and ocean sediments.

9.3 **Humans cause global climate change through fossil fuel combustion, land-use changes, agricultural practices, and industrial processes.** Consequences of global climate change include melting glaciers and permafrost, rising sea levels, shifting precipitation patterns, increased forest fires, more extreme weather, and the disruption of global ecosystems.

Humans have significantly altered Earth's surface. The Bingham Copper Mine in Utah demonstrates that humans have moved entire mountains in a quest for resources. (Courtesy of Michael Collier)

9.4 **Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater.** Engineered structures such as canals, dams, and levees significantly alter water and sediment distribution. Pollution from sewage runoff, agricultural practices, and industrial processes reduce water quality. Overuse of water for electric power generation and agriculture reduces water availability for drinking.

9.5 **Human activities alter the natural land surface.** Humans use more than one-third of the land's surface not covered with ice to raise or grow their food. Large areas of land, including delicate ecosystems such as wetlands, are transformed by human land development. These land surface changes impact many Earth processes such as groundwater replenishment and weather patterns.

9.6 **Human activities accelerate land erosion.** At present, the rate of global land erosion caused by human activities exceeds all natural processes by a factor of ten. These activities include urban paving, removal of vegetation, surface mining, stream diversions, and increased rain acidity.

9.7 **Human activities significantly alter the biosphere.** Earth is experiencing a worldwide decline in biodiversity—a modern mass extinction—due to loss of habitat area and high rates of environmental change caused by human activities. The rates of extinctions are now comparable to the rates of mass extinctions in the geologic past.

9.8 **Earth scientists document and seek to understand the impacts of humans on global change over short and long time spans.** Many of these human impacts on Earth's systems are not reversible over human lifetimes, but through human cooperation their impacts on future generations can be lessened and even reversed.

9.9 **An Earth-science-literate public, informed by current and accurate scientific understanding of Earth, is critical to the promotion of good stewardship, sound policy, and international cooperation.** Earth science education is important for individuals of all ages, backgrounds, and nationalities.

Appendix B. Informed Consent Form for Research

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

Title of Study: Undergraduate Understanding of the Role of Geoscience in Humanity

Principal Investigator Hayley Joyell Smith (MEAS)

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above. You should not participate in this study if you are under 18 years of age.

What is the purpose of this study?

This study will investigate student understanding of geoscience content related to human-earth interactions.

What will happen if you take part in the study?

If you agree to participate in this study, you are giving permission for your pre and post-test, selected learning journal questions, responses to a relevance survey, and selected exam questions to be analyzed. You are also giving permission for your demographic profile to be included in full class data analysis. Individual student demographic information will not be used in this study. All students will complete the same class assignments, regardless of whether they agree to be participate in the study or not.

Risks

There are no risks associated with this study. Participation or lack of participation will have no impact on your course grade.

Benefits

There is no direct benefit associated with this study. Participation or lack of participation will have no impact on your course grade.

Confidentiality

The information in the study records will be kept strictly confidential. Data will be stored securely in a database where a random code number will identify each student. No reference will be made in oral or written reports that could link you to the study.

Compensation

You will receive no compensation whether you agree or not to be part of the research study.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Hayley Joyell Smith 765-425-2062 or hjsmith7@ncsu.edu.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature ____ Date ______________

Investigator's signature __________________________________ Date ______________

Appendix C. Demographic Profile Survey

Demographic Profile

Student Name (First, Last): ____

Intended major: ____

Age: _____________

Gender: _______________________________

For the following, please circle one option per question.

What is your current class standing?

Freshman Sophomore Junior Senior

Which description best fits the environment in which you lived during childhood through high school?

Rural Suburb Urban Other (please specify)

How often do you talk to your friends and family about ways that you affect the environment?

A lot

A fair amount

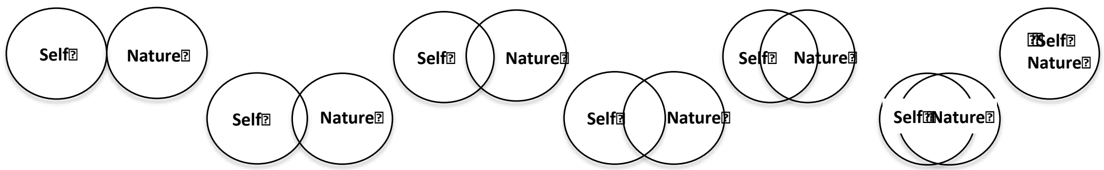
Only a little bit

I may have mentioned something once or twice

Not at all

Please circle the picture below which best describes *your relationship* with the *natural environment*.

How interconnected are you with nature?



What were your reasons for taking the class? Circle all that apply.

It is a major requirement

It was one of my options to fulfill the University science requirement

It sounded interesting

Friends recommended the course

Something else (please specify) ________________________________

Ethnicity:

African American/Black

Asian

Caucasian/White

Hispanic/Latin American

Native American

Multi-racial/ethnic

Other (please specify)_____________________________

Appendix D.1. Changes in Attitude about the Relevance of Science Survey (CARS)

STUDENT NAME (FIRST, LAST) ________________________________

ITERATION 1

Relevance of Science Questionnaire

Please read the below statements and indicate the degree to which you agree or disagree by circling 0-4.

0 = Strongly Disagree (SD) **1** = Disagree (D) **2** = Neutral(N) **3** = Agree (A) **4** = Strongly Agree (SA)

	SD	D	N	A	SA
1. My parents encourage me to continue with science.	0	1	2	3	4
2. I plan to take more science classes in college.	0	1	2	3	4
3. Science helps me to work with others to find answers.	0	1	2	3	4
4. Science class helps me to evaluate my own work.	0	1	2	3	4
5. Learning science helps me understand about the environment.	0	1	2	3	4
6. Emotion has no place in science.	0	1	2	3	4
7. Science class helps me to judge other people's points of view.	0	1	2	3	4
8. Science will help me understand more about worldwide problems.	0	1	2	3	4
9. Science has nothing to do with my life outside of school.	0	1	2	3	4
10. Experiments in science help me to learn with a group.	0	1	2	3	4
11. Science teaches me to help others make decisions.	0	1	2	3	4
12. Knowing science will not help me in sports.	0	1	2	3	4
13. Science has nothing to do with buying things, such as computers and cars.	0	1	2	3	4
14. Knowledge of science could make it easier to fix a bicycle.	0	1	2	3	4
15. Science teaches me to think less clearly than I already do.	0	1	2	3	4
16. Making a good decision is a scientific process.	0	1	2	3	4
17. Geology class will help prepare me for a career.	0	1	2	3	4
18. Much of what I learn in Geology class is useful in my everyday life today.	0	1	2	3	4
19. Learning science can help me when I choose where to buy a house.	0	1	2	3	4
20. Caring about people is part of making a scientific choice, such as whether to use pesticides on plants.	0	1	2	3	4
21. Science helps me to make sensible decisions.	0	1	2	3	4
22. The things I do in science have nothing to do with the real world.	0	1	2	3	4
23. Science helps me to make decisions that could affect my natural environment.	0	1	2	3	4
24. Learning science will have an effect on the way I vote in elections.	0	1	2	3	4
25. Making decisions can be difficult without reliable evidence.	0	1	2	3	4

Appendix D.2 Changes in Attitude about the Relevance of Science Survey (CARS)

STUDENT NAME (FIRST, LAST) ________________________________

ITERATION 2
Relevance of Science Questionnaire
Please read the below statements and indicate the degree to which you agree or disagree by circling 0-4.

0 = Strongly Disagree (SD) **1** = Disagree (D) **2** = Neutral(N) **3** = Agree (A) **4** = Strongly Agree (SA)

	SD	D	N	A	SA
1. Science has nothing to do with local issues, such as waste from nearby factories.	0	1	2	3	4
2. Science can help me make better decisions about what I buy.	0	1	2	3	4
3. Science experiments can help me to better understand the world.	0	1	2	3	4
4. Much of what I learn in Geology class is useful in my everyday life today.	0	1	2	3	4
5. Learning science can help me when I choose where to buy a house.	0	1	2	3	4
6. Caring about people is part of making a scientific choice, such as whether to use pesticides on plants.	0	1	2	3	4
7. Science helps me to make sensible decisions.	0	1	2	3	4
8. The things I do in science have nothing to do with the real world.	0	1	2	3	4
9. Science helps me to make decisions that could affect my natural environment.	0	1	2	3	4
10. Learning science will have an effect on the way I vote in elections.	0	1	2	3	4
11. Making decisions can be difficult without reliable evidence.	0	1	2	3	4
12. Science class helps me to work with others to make decisions.	0	1	2	3	4
13. I am interested in learning more about computer technology.	0	1	2	3	4
14. I would like to learn more about strategies for thinking in my science class.	0	1	2	3	4
15. Knowledge of science helps me to avoid natural hazards.	0	1	2	3	4
16. Using scientific methods helps me make environmental decisions.	0	1	2	3	4
17. Learning science is not important for my future success.	0	1	2	3	4
18. I only take science because it is a required course.	0	1	2	3	4
19. In most cases, personal feelings are important for making choices in science.	0	1	2	3	4
20. Knowing science can help me to make better choices about energy issues.	0	1	2	3	4
21. Collecting evidence is an important part of making a decision.	0	1	2	3	4
22. Geology class will help prepare me for major decisions in my future.	0	1	2	3	4
23. I will only take math classes for as long as I have to.	0	1	2	3	4
24. Learning science enables me to explain my thoughts better to others.	0	1	2	3	4
25. Knowledge of science will help me protect the environment.	0	1	2	3	4

Appendix D.3 Changes in Attitude about the Relevance of Science Survey (CARS)

STUDENT NAME (FIRST, LAST) ______________________________

ITERATION 3

Relevance of Science Questionnaire

Please read the below statements and indicate the degree to which you agree or disagree by circling 0-4.

0 = Strongly Disagree (SD) **1** = Disagree (D) **2** = Neutral(N) **3** = Agree (A) **4** = Strongly Agree (SA)

	SD	D	N	A	SA
1. Much of what I learn in Geology class is useful in my everyday life today.	0	1	2	3	4
2. Learning science can help me when I choose where to buy a house.	0	1	2	3	4
3. Caring about people is part of making a scientific choice, such as whether to use pesticides on plants.	0	1	2	3	4
4. Science helps me to make sensible decisions.	0	1	2	3	4
5. The things I do in science have nothing to do with the real world.	0	1	2	3	4
6. Science helps me to make decisions that could affect my natural environment.	0	1	2	3	4
7. Learning science will have an effect on the way I vote in elections.	0	1	2	3	4
8. Making decisions can be difficult without reliable evidence.	0	1	2	3	4
9. I do not expect to use science much when I get out of school.	0	1	2	3	4
10. I value careers in science, such as a hydrologist or engineer.	0	1	2	3	4
11. Making decisions can be difficult when I don't understand the choices.	0	1	2	3	4
12. My intuition helps me make decisions in science.	0	1	2	3	4
13. Science will help me to understand the effect I have on the environment.	0	1	2	3	4
14. Science helps me to ask others for help with my work.	0	1	2	3	4
15. Using scientific methods helps me think things through.	0	1	2	3	4
16. Science can help me decide how to treat my cold or illness.	0	1	2	3	4
17. Science impacts my feelings about global issues I am considering.	0	1	2	3	4
18. Science should be required in college.	0	1	2	3	4
19. Science could help me figure out how to spin / shoot / throw / hit a ball.	0	1	2	3	4
20. Science class helps me to evaluate my own work.	0	1	2	3	4
21. I have support from others to excel at science.	0	1	2	3	4
22. Using scientific methods helps me decide what to buy in the store.	0	1	2	3	4
23. Science will help me understand the importance of recycling.	0	1	2	3	4
24. Learning science can help me understand about things that affect people's health.	0	1	2	3	4
25. Science can help me to make better choices about various things in my life.	0	1	2	3	4

Appendix E. Modifications for CARS instrument.

CARS Iteration	Original	Modification
Repeated in all iterations	Much of what I learn in **science classes** is useful in my everyday life today	Much of what I learn in **geology class** is useful in my everyday life today
Repeated in all iterations	Learning science can help me when I **pick food to buy**	Learning science can help me when I pick **where to buy a house.**
Repeated in all iterations	Science helps me to make decisions that could affect **my body.**	Science helps me to make decisions that coule affect my **natural environment**.
Iteration 1	I plan to take more science classes in **school**.	I plan to take more science classes in **college.**
Iteration 1	**Science** class will help prepare me for a career.	**Geology** class will help prepare me for a career.
Iteration 1	Science has nothing to do with buying things, such as **food** and cars.	Science has nothing to do with buying things, such as **computers** and cars.
Iteration 2	Knowledge of **science** helps me to prevent **the spread of colds/diseases.**	Knowledge of **geoscience** helps me to avoid **natural disasters.**
Iteration 2	Knowing science can help prepare me to make better choices about **medical issues.**	Knowing science can help prepare me to make better choices about **energy issues.**
Iteration 2	**Science class** will help me prepare for major decisions in my future.	**Geology class** will help me prepare for major decisions in my future.
Iteration 3	I value careers in science, such as a **hyrologist** or engineer.	I value careers in science, such as a **hyrologist** or engineer.
Iteration 3	Science should be required in **school**.	Science should be required in **college.**

Appendix F. Geoscience Literacy Exam

Student Identification number ______________________

Pre-test

1. Natural hazards can be put in two major categories. Some natural hazards can be made worse by humans; others are largely independent of human activities. Select the natural hazard least likely to be affected by human activity.

   a. Forest fires
   b. Tsunami
   c. Landslides
   d. Coastal erosion

2. Which of the following geologic processes are mostly likely caused by the interactions between tectonic plates at their boundaries? Select all that apply.

   a. Earthquakes
   b. Continental Glaciation
   c. Floods
   d. Volcanic eruptions
   e. Mountains

3. Which of the following statements about the distribution of life in the oceans is most correct?

   a. Life is more abundant and diverse in some parts of the ocean than in others.
   b. Life is abundant and diverse throughout the ocean.
   c. Life is less abundant and diverse in the oceans than it is on land.

4. Which of the following ways do humans affect oceans? Select all that apply.

   a. Humans alter ocean ecosystems through fishing.
   b. Humans alter shorelines through development
   c. Humans mine mid-ocean ridges.
   d. Humans change overall ocean composition by desalination.
   e. Humans alter tidal cycles.

5. Which of the following processes primarily involves the atmosphere and the biosphere?

   a. The formation of limestone
   b. The photosynthetic cycle
   c. The hydrological cycle

6. Which of the following processes are sources of carbon to the atmosphere? **Select all that apply.**

   a. Plant decay
   b. Limestone formation
   c. Cattle ranching
   d. Fossil fuel use

7. There are several climate models used to research future change. Which climate modeling statement about 21st Century temperature change projections is most accurate?

   a. Climate model projections do not agree on future likely outcomes.
   b. Climate model projections show similar trends for future outcomes.
   c. Climate model projections show the same results for future outcomes.

8. The first reasonably accurate mercury thermometers were invented in 1724, almost 300 years ago. What kinds of processes and/or data are used by scientists to determine temperatures **more than** 10,000 years in the past? Select all that apply.

   a. Written records
   b. Ice cores
   c. Tree rings
   d. Sedimentary layers
   e. Oxygen isotopes

Appendix G. Examples of Student Responses and Scores from Final Exam Short Answer Question

Examples of high scoring responses:

> The first most important concept is that not all resources are renewable. If you go around believing that oil and coal reserves will never run out, then you can not be considered and Earth-science literate person. Citizens need to understand that these resources take millions of years and specific conditions to form and as a result, are nonrenewable. A citizen could then take this knowledge and apply it to creating a new renewable energy source or improving on an existing one. This advancement would no only preserve natural environments, but would also provide well-being of earths' population. The second most important concept is that Earth is constantly undergoing changes. These changes are both naturally occurring and caused by anthropogenic means. Humans constantly affect Earth's processes in other positive and negative ways and, depending on the effect, later affect humans in the future. As a result, citizens have to understand that the choices they make now can affect others in the future. A citizen could apply this knowledge and begin to make smarter decisions that affect the Earth in less negative ways such as cleaner fuel, building in safer areas, etc. These smarter decisions would cause less harm to the Earth thus creating a safer future for citizens. (7 points)

And

> I think the most important concept citizens need to comprehend in order to be considered an earth –science literate person who can make sound decisions for a sustainable future is that greenhouse gasses absorb infrared radiation and warm the Earth. They need to understand that amount of greenhouse gasses in our atmosphere is increasing and that global temperatures will continue to rise unless they apply their knowledge, that greenhouse gases warm the Earth, and decide to reduce the amount of greenhouse gasses that are emitted. By applying what they know about greenhouses gases, citizens can make decisions to regulate greenhouse gas emissions and lead us towards a more sustainable future. A second concept that is essential for citizens to know about is the action of the tectonic plates and how they influence activities such as landforms and natural hazards. For example, if citizens know about convergent boundaries and the earthquakes that are associated with them, they can live safer lives. This is because they will know what to look for when a natural occurrence is coming and will be able to adjust accordingly. Citizens will also be able to make smarter decision on where to live and work as well. Knowing about plates and what they cause to happen is essential for people's well-being. (6 points)

Examples of a medium scoring response:

> People absolutely need to have an understanding of how our ground water works. It is vital to understand where it goes, and where contaminations can get into it. We will be better capable of pushing for sticker dumping regulations, and generally

monitoring our supply of water on a person-by-person basis. Despite all the hub-bub about global warming, people need to property understand it and its sources (including fossil fuels). They will be able to make smarter decisions about what to buy, thereby reducing their energy requirement, but also understand that it is not the end of the world. A level headed and adaptive approach will ease the population through future changes. (5 points)

And

Two of the most important concepts citizens need to comprehend in order to be considered Earth science literate are seismic activity and the use of natural resources. Seismic activity will determine where someone will live and build their home. If citizens don't understand how seismic activity happens, and how to determine what foundations can hold the most seismic activity, their safety could be in dangers. Natural resources are important for citizens to know about because that is what fuels the Earth and everything on it. If citizens know how energy is used through things such as burning coal, they can be more environmentally efficient when using things such as cars. (5 points)

Examples of low scoring responses:

The first way people can apply knowledge from earth science is by understanding groundwater movement. It is not as important in the city, because water and sewage are provided. In rural areas people can use this information in finding and to keep from contaminating their water supply. The second major way to apply knowledge from earth science is in choosing a location to live. Be sure to find a house a fair distance from any major fault line to avoid earthquakes. Understand that the density of the ground will affect your decision to, as well as the closeness to the ocean for tsunamis. (4 points)

And

Citizens can apply this knowledge in one way by using it to understand flooding. If they use the information about flooding they will know where to live if they want to avoid it. Another way that citizens can use this knowledge is to build houses or buildings. This knowledge can help determine what builds the strongest houses or buildings. This can also be for earthquake hazards. (3 points)

Appendix H. Characterization of end-of-module short answer question

Characterization Sheet for end-of-module short answer responses

The open-ended question asked at the end of each module was designed to provide insight into how students perceive each geoscience module to be relevant.

Prompt given to students in the last learning journal of each module:
In 3 complete sentences or more, respond to the question below. **Please include any concepts or examples that will provide a context for your reasoning.** There are multiple "right" answers. Your response will be graded on the quality of your explanation.

How relevant do you think the information in the ______________Module is to the lives of individuals and communities around the world?

Who the student identifies as finding the content relevant

1	All Individuals and/or Communities	Does not distinguish between communities and individuals. This is often expressed at the beginning of the response with a statement that the information is relevant to "individuals and communities..." or Identifies relevance for individual or communities as a general statement. Example of terms: "a person", "people", "everyone"
2	Specific Individuals or Communities	Identifies relevance for specific for some individual or communities but not others. Specifically cites relevance for individuals or communities in certain situations or specific locations. Examples: "someone living near the ocean" or "an engineer would find the information relevant..."
3	Includes Self in Communities Ind.	Identifies one's self as finding information relevant by including themselves in the response as part of a community or one of the individuals. Examples "I", "we", "us", "our"
4	Does not addressed	Response addresses relevance but does not mention who would find the information relevant.

Why the student identifies the content as relevant

Active/Application	1	Response mentions that the reason the content is relevant is because it can be actively applied. Includes action verbs such as: "to be able to make decisions", "use the information to prepare", "help make a smart choice".
Passive/Knowledge	2	Response points to the content being relevant for the purpose of attaining knowledge or being more aware but not taking any action. Statements such as: "allows us to recognize", "help better understand", "important to know".

Principle(s) – Reasons students' identify for content relevance predominately align with Big Ideas 7, 8, and 9. The reasons students cite are coded based on the indicators within each of the Big Ideas. See Earth Science Literacy Principles.

Appendix I. Rubric for Final Exam Short Answer Question

Final Exam Short Answer Grading Rubric

Question on Exam:
From the information presented in MEA 101, what do you think are the two most important concepts citizens need to comprehend in order be considered an Earth-science literate person who can make sound decisions for a sustainable future?

In a minimum of 3 complete sentences, describe two concepts and how citizens can apply the knowledge. There are multiple "right" answers. Your response will be graded on the quality of your explanation.

Rubric-7 total possible points

1 Point Response includes the minimum of 3 complete sentences that address the questions. Grammar is acceptable, and statements are logical.

0 Points Response does not meet the sentence requirement. The answer does not address the question. The response contains portions that are not logical.

Quality of response is address for each of the geoscience concept discussed
(3 points possible for each of the two concepts)

0 Points Concept is not from one of the eight introductory modules or is not accurately described.

1 Point Concept discussed is from one of the eight introductory modules. Content is accurately described.

2 Points Meets the above requirements. Concept is related to society and there is mention of using knowledge but only in a superficial and obvious manner.

3 Points Meets all the above requirements. Concepts are related to society in an insightful manner that acknowledges the need for sustainability and why it is crucial for people to understand them. There is a clear explanation of how citizens can apply the knowledge.

Appendix J. Demographic profile characteristics of end-of-module sample

Demographic Item and Item Options		**Sample used for qualitative analysis from MEA Section 1 n=34**	**Sample used for quntatative analysis MEA Sections 1,2,and 3 n=144**
Intended Major	STEM	44%	47%
	Non-STEM	56%	53%
Gender	Male	59%	49%
	Female	41%	51%
Class Standing	Freshman	73%	52%
	Shophmore	18%	30%
	Junior	3%	8%
	Senior	6%	10%
Childhood Environment	Rural	27%	30%
	Suburb	64%	57%
	Urban	6%	1%
	Other	3%	3%
Amount Students Talk about Affecting the Environment	Not at all	24%	16%
	Mentioned once or twice	30%	33%
	Only a little bit	35%	11%
	A fair amount	6%	11%
	A lot	6%	3%
ISN Venn Diagram	1	3%	3%
	2	35%	25%
	3	21%	24%
	4	26%	28%
	5	6%	11%
	6	6%	6%
	7	3%	3%