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Assessment of Student Achievement in Introductory Physical Geology: A three-year study on delivery method and term length

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Assessment of Student Achievement in Introductory Physical Geology: A three-year study on delivery method and term length

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Geoscience education, online course, concept inventory, term length
I would like to especially thank my major professor Dr. Ping Wang for his guidance and patience throughout the long process of earning my Ph.D. including changing dissertation research topics. Dr. Wang continued to encourage me through the years and without his support it would not have been possible for me to complete my dissertation.

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Abstract

Physical Geology is a popular general education course at Hillsborough Community College (HCC) as at many other colleges and universities. Unlike many science courses, most students taking Physical Geology are not majoring in a STEM (Science, Technology, Engineering, and Mathematics) discipline. Typically most students enrolled in Physical Geology are majoring in business, education, or pursuing a general A.A degree for transfer to a four-year university. The class is likely to be one of the few, if not the only, physical science classes that many of these students will take in their academic career. Therefore, this class takes on increased importance, as it will provide students with the foundation for scientific knowledge to be applied throughout their working careers.

Student performance in an online general education physical geology course was examined and compared in this three and a half-year study involving over 700 students. Student performance was compared on the basis of term length (sixteen week semester versus nine week summer term) and delivery method (online versus face-to-face). Four identical tests were given each term; the average score of four tests was used to evaluate overall student performance. Neither term length or delivery method has a significant influence on student test scores as demonstrated by similar average score per term, similar standard deviation, and similar distribution pattern. Student score
distribution follows a normal distribution reasonably well. The commonly used ANOVA tests were conducted to confirm that there is no statistically significant difference in student performance.

A concept inventory of the geosciences can be valuable in providing a means to test if students are indeed learning geological concepts and to identify which misconceptions students are likely to enter class with so they can be addressed. Based on a set of 16 Geoscience Concept Inventory questions selected by the instructor, no difference in student performance was found between pre-test and post-test in terms of average score and score distribution. Some misconceptions were identified by the GCI, however little to no improvement was noted in the post-test. In contrast to the GCI, remarkable improvement in student learning is illustrated by the instructor-specific test. Possible reasons for this result are as follows, students may have adapted more to the individual instructor’s test writing style and teaching style throughout the semester. The pre-test and post-test for the instructor given tests were assigned as a grade, perhaps prompting the student to take the test more seriously and consider the answers more carefully. The questions written are instructor-specific and course-specific, meaning that the students likely were introduced to the concept more thoroughly and multiple times.
Chapter 1: Introduction

Community colleges are an important component of the higher education system in Florida because they are given the mission of providing education tailored for the local community. Education for the community can take a variety of forms, and commonly quite a diverse range of classes and programs are offered: non-credit continuing education courses or leisure topics such as yoga and art; vocational courses such as auto mechanics; training in public service fields such as fire-fighting and law enforcement; and specialized degrees such as nursing, sonography, and radiography providing medical training to students. As well, community colleges offer general education courses for degree-seeking students that provide the opportunity to complete more than sixty hours of college credit in preparation for a transfer to a university.

Students choose community colleges for their general education for various reasons. Community colleges offer opportunities for those who could not gain admission to a university the chance to pursue a degree. Public community colleges offer lower-cost tuition than universities and private colleges, opening up the opportunity for more students to be able to afford to go to college. Since there are no admission requirements, and transfers of course credit are fairly easy (in the Florida higher education system), it is relatively straightforward for a
university student to choose to take one or more courses at a local community college instead of at their university. Because the mission of community colleges is focused on teaching (unlike universities, where faculty must split their time between research and teaching), students experience a different and potentially more supportive environment in general education than they would encounter at a university. Class sizes are typically smaller (twenty to thirty students), giving students the opportunity for more individualized attention. Introductory level, general education courses are the main focus of teaching for most community college faculty.

Physical Geology is a popular general education course at Hillsborough Community College (HCC) as at many other colleges and universities. The course is usually taken to fulfill the general education requirement for physical science for an Associate of Arts degree (A.A.). Students earning A.A. degrees typically plan to continue their education further and pursue a Bachelor of Science (B.S.) or Bachelor of Arts (B.A.) degree as a transfer student at a four-year university. HCC has a large number of students, approximately 2000 per year (HCC Fact Book, 2011), transferring into four-year universities. Unlike many science courses, most students taking physical geology are not majoring in a STEM (Science, Technology, Engineering, and Mathematics) discipline, as students majoring in STEM disciplines are required to take chemistry and physics to fulfill the physical science requirements. Therefore, most students enrolled in Physical Geology are majoring in non-STEM fields, such as, business, education, or pursuing a general A.A degree for transferring to a four-year university. One
important exception is those students planning to major in geology or environmental science, because the Physical Geology course is listed in the Florida Uniform Prerequisites for the Geology Bachelors Degree, and it is commonly the “gateway” course to Geology Bachelors programs at universities. Because the course has a large population of non-science majors, the class is likely to be one of the few, if not the only, physical science classes that many of these students will take in their academic career. Therefore, this class takes on increased importance, as it will provide students with the foundation for scientific knowledge to be applied throughout their working careers. For example, future business leaders in Florida should be aware of the implications of building on sinkhole-prone land and also the potential risk of development in low-lying coastal areas. Typically a large number of education students take the Physical Geology course. In many cases this may be their only coursework preparing them for teaching geology and earth science concepts to K-12 students in their future teaching career. Therefore, it is vital that the students in education majors have a clear understanding of geological concepts. A community college Physical Geology course is thus in a quite unique position in providing a large population of non-STEM students, and especially education majors, essential knowledge in not only physical geology, but also physical science in general.

Of the students enrolled in Florida higher education institutions, 886,619 students or 62,362 FTE (Full Time Equivalent) students enrolled in community year colleges (two-year and four-year) during the 2009-10 academic year, the most recent year available for enrollment numbers. This number represents 67%
of the total students in Florida’s colleges
(http://www.fldoe.org/cc/pdf/annualreport2011.pdf). Recently some of Florida’s community colleges have begun to offer four-year degrees. These colleges are now called “state colleges” to distinguish them from universities but retain the multifaceted functions of community colleges. All two-year and four-year state colleges will be referred to as community colleges in this study.

The Associate of Arts (AA), the traditional two-year degree earned prior to entering a university, is the degree program with the highest number of degrees awarded at Florida community colleges. HCC, where this study is conducted, had an enrollment of over 42,216 (unduplicated headcount; 18,660 FTE) students during the 2009-2010 academic year (HCC Fact Book, 2010), representing 21% of students in Florida community colleges. This makes HCC one of the largest community colleges in the state.

Increasingly, students are beginning their college career at community colleges instead of at universities in Florida. The current economic climate makes the community colleges more attractive as the cost of attendance is much lower when compared to a university. Higher admission standards at four-year universities have also contributed to many students pursuing alternatives for their higher education. From this reality arise some real challenges in teaching advanced science in a community college setting, where many students may not be fully prepared from their K-12 schooling for higher education.
As well, in the past ten years there has been a significant increase in the number of students who are electing to take classes partially or completely online. This increase has been fueled by the advances in computer-based teaching technologies and the widespread use of personal computers by students. Students are now able to access learning activities, tests, quizzes, and assignments on a schedule of their choice, during the day or in the evening. The advent of these new information technologies has presented the option of new ways of learning for students, in a virtual classroom setting. This virtual classroom is very different than the conventional face-to-face classes. In the face-to-face classroom students follow a rigid schedule of lectures whereas in the virtual classroom students can access the lectures at any time. Face-to-face students have the opportunity to work collaboratively in small groups for the in-class assignments. The online students work independently on all assignments. Additionally students in the face-to-face classroom typically ask questions during or after class in person while students taking the online class use classroom email to get questions answered. Comparisons of student achievement between online and face-to-face courses need to be able to discern those differences that arise from their different delivery methods.

Scope and Objectives of the Study

This study endeavored to investigate student performance in a set of Physical Geology course offerings taught at HCC. Sections of the course were
taught in all three semesters, Fall, Spring, and Summer, in both face-to-face and online delivery formats. The results are based on data collected over a three-and-a-half-year period and a total student enrollment of over 700.

Several aspects of teaching and student learning are investigated in this study:

• Instructional Delivery Methods: Both face-to-face and online delivery methods were used and evaluated. In general, face-to-face teaching is largely instructor-guided learning with rigid time scheduling in a classroom. In contrast, online teaching is self-motivated learning with considerable flexible scheduling and individualized instructor guidance via, e.g., email-based questions and answers to individual student.

• The influence of term length on student learning: Summer terms are roughly half of the length of the Fall and Spring semesters. The shorter summer term gives students less time to absorb the information. However, the short time interval between presentation of class materials and testing may provide an advantage in that students may retain the class materials more effectively.

Two assessment methods were used in the present study, a recently developed standardized test of geologic concepts (the Geoscience Concept Inventory) and an instructor-specific cumulative assessment. Both a pre-test and post-test was given to students based on these two instruments. The pre-test was administered shortly after the drop-add period for the course to test students’
preexisting knowledge entering the class. The post-test was administered at the very end of the course during the last week.

In terms of assessing student learning, the objectives are to examine, using several assessment methods, several different factors that may be influencing student learning and achievement in Physical Geology. Specifically, the tasks of the study include:

- Assessing student achievement using the standardized Geoscience Concept Inventory (GCI) test. The GCI is largely instructor independent and potentially may provide an objective assessment of student learning. The results are compared with GCI study results from other institutions.

- Assessing student achievement using instructor-generated tests. The instructor-specific tests provide direct, although somewhat subjective, assessment of the specific class, since they are instructor-generated.

- Measuring and comparing student performance in face-to-face classes and online courses using instructor-generated class tests.

- Measuring and comparing student achievement on two different time frames, a traditional 16-week semester and a shorter 9-week summer term based on instructor-generated class tests.

- Comparing student performance between the instructor-generated test and Geoscience Concept Inventory test. Although not a direct comparison,
measures of student achievement should be similar between the two instruments.

- Identifying student misconceptions based on their answers to the Geoscience Concept Inventory questions.

- Characterizing the demographic makeup of the students involved in the study including their self-motivation using a standardized self-efficacy survey.

This dissertation compiles a three-year study, involving over 700 students, on the teaching of Physical Geology course in a large urban community college. The dissertation is organized into the following seven chapters in addition to a list of references and appendices:

1) The Introduction provides a general overview of this study and gives study objectives and tasks.

2) The Literature Review compiles the findings of existing studies on delivery methods, length of term, concept inventories, and assessment methods of similar courses.

3) The Research Methods section documents the approaches and methods of data collection and analyses.

4) The Course Description provides information on class objectives and content, scheduling, and assessment methods.
5) The Student Population section describes the demographics of the students and summarizes results of the student efficacy survey.

6) The Results and Discussion sections describe and analyze in detail the data collected during the study.

7) The Conclusions highlight the findings of the study.

References list the existing research that is cited in this study. Appendices provide a copy of the course syllabus and schedule and Geoscience Concept Inventory questions.
Chapter 2: Literature Review

As the importance of college teaching has been increasingly recognized, there has been a movement to ensure that in addition to being subject matter experts, college-level educators are also proficient teachers. The result has been extensive research into the theory of teaching and higher education. Fry et al., (2008) outlined a range of theories of teaching and learning and presented case studies as a guide to good practices. Knight (2007) described best practices for planning, instruction, learning activities, and assessment. Ramsden (2003) emphasized that college instructors need to understand student’s previous experiences in learning, an important point when students may enter science classes with previous negative experiences. Additionally there are a number of subject-specific journals dedicated to teaching in college (Murray, 2008). In the field of geology and earth science this includes the Journal of Geoscience Education. Pertaining directly to the scope of this study, follows a review of the existing literature on delivery methods, length of term, and assessment approaches and methods.
**Research on Delivery Methods**

Online courses, by definition, are those whose course material is delivered over the Internet with limited (less than 20%) or no face-to-face contact (Allen and Seaman, 2010). Seok (2007) claims that “elearning” is the pedagogy for new learning in the 21st century. Taking advantage of the rapid increase in Internet access, the growth of online college courses has been very fast and is continuing. During the 2009 fall term, over five million students took at least one online course. This represents an increase of about one million students from the previous year, and an increase of four million students since 2002 (Allen and Seaman 2010).

The advantages of online courses over earlier distance learning methods include the availability of interactive learning exercises, the flexibility to interactively hear and see lectures, and the opportunities for more individualized instructor feedback. Online science courses have sometimes been viewed with suspicion by science faculty, but even the most biased faculty recognize that online courses have the advantage of providing students with animations and other learning activities at their fingertips, or one click of a mouse. Online learning may also provide students with more flexible time to think and absorb the course content without the limitation of a fixed lecture duration. In other words, students may be able to learn at their own pace, as opposed to working at the pace of the lecturer. It can therefore be argued that online teaching is more student-centered than face-to-face instructional approaches.
Recent research into online science learning indicates that online students can do as well as face-to-face students on assignments (Reuter, 2009). In a review of seventy-six studies comparing online, hybrid, and face-to-face instruction in a number of fields, Runnells et al (2006) found that learning in an online environment can be as effective as in a traditional classroom. Werhner (2009), in a direct comparison of online and face-to-face earth science classes, reported no difference in student achievement on tests. One distinctive advantage to the online environment is the easy access to information available from a variety of sources, including large databases, which can afford additional learning opportunities not easily available to face-to-face classes (Dong, et al, 2009).

Research on Length of Term

The influences of differences in term length on student learning have been a debate in the past (Daniel, 2000). A number of studies have been conducted on classes of differing lengths, but these studies have largely focused on face-to-face traditional format courses (Ferguson & DeFelice, 2010). From those studies exclusively focused on face-to-face courses, findings have been mixed. Some studies indicate no difference in student grade performance in terms of semester duration (Messina, 1996; Reardon et al., 2008). Some authors have found intensive courses to be more effective for student learning (Seamon, 2008; Anastasi, 2007), whereas others have found the traditional term courses are
more effective (Petrowsky, 1996). Daniel (2000) suggested that most courses, regardless of discipline, can be taught in a time-shortened format without sacrificing learning. Daniel (2000) further cited convenience as a major factor in choosing the shortened time frame and proposed that successful time-shortened courses require good planning, organization, and structure. However, these attributes of good planning, organization and structure can be applied to any successful class no matter the term length or format. Stein (2004) had similar findings in a study of over 200 students from three universities on both traditional face-to-face courses and online courses in a shorter term. In addition, Stein (2004) found that students considered the structure of a class the most important factor in student satisfaction. Furthermore, Daniel (2000) noted that students who are more likely to succeed, regardless of time length, tend to take time-shortened classes.

Despite the above-mentioned favorable findings, the perception of some faculty and administrators remains that summer and other shortened courses are less effective than traditional semester-long classes, simply because of the lesser amount of time available for learning (Kretovics et al., 2005). Faculty members have questioned whether the compressed format gives students sufficient time to process materials adequately. Faculty members have also expressed concerns about the amount of time students devoted to learning activities outside the classroom during a time-shortened semester (Daniel 2000).
Although a large number of studies have been conducted in several disciplines comparing face-to-face courses on various time schedules, little research has been conducted comparing time schedules for online courses. Typically, online courses offer more flexibility in scheduling and student time management than face-to-face courses, and therefore may yield different results than a traditional face-to-face class. To the best of my knowledge, the only published study on online course time scheduling was conducted by Ferguson and DeFelice (2010), a study of academic performance and student attitudes comparing an online course taught in both a shortened summer format (five weeks) and the traditional semester-long format for a graduate-level educational measurement and statistics course. Ferguson and DeFelice (2010) found that the overall mean final grade for students in the shorter summer course to be significantly higher than the mean final grade for students in the longer full-semester courses. The authors explained this difference as resulting from the intense nature of the shorter course, thereby requiring students to be focused and working continuously. Another factor cited was the short time frame giving students an advantage of having the materials fresh in their mind for testing. The students in the full 16-week semester class had an overall higher score of “perceived learning” but not high enough to be a statistically significant difference. It is worth noting that Ferguson and DeFelice (2010) study was based on a highly specialized graduate course, while the online course studied here represents a more typical general education course.
Research on Concept Inventories

Driven in part by national initiatives over the past fifteen years to document learning and the effectiveness of educational strategies and institutions (Bailey, 2006; Conner and Robovsky, 2011), there has been an increasing recognition that we need uniform ways to assess geoscience learning that allow comparisons among different instructors, student populations, and institutions (Libarkin and Anderson, 2005; Cervato et al., 2007; Libarkin, 2008; McConnell, et al., 2009, Libarkin and Ward, 2011). In order to make meaningful improvements in educational practice, it is necessary that geoscience educators at all levels be able to identify if students are learning what we think they are learning, and to be able to measure if they are leaving a geology course with an improved understanding of geoscience content than when they entered.

It is also important to understand and document students’ scientific and geoscience-specific misconceptions. Most college instructors recognize that students come to class with pre-existing notions about geologic topics. These pre-existing notions may be shaped by both previous coursework and popular culture including movies, television, and websites. Several authors have explored student’s misconceptions or “alternate conceptions” about geologic processes. Dove (1997) provided a review of college and high school students’ misconceptions in earth science concerning weathering and erosion. Students were not able to adequately distinguish between weathering and erosion processes and were likely to attribute the underlying cause of weathering to incorrect mechanisms. Marques and Thompson (1997) examined
misconceptions of plate tectonics by high school students. The students in their study cited ocean currents as a mechanism for plate movement. Students further believed that plates are stacked on each other with the oldest on the bottom. They also found student misconceptions concerning the link between paleomagnetic processes and geological processes. Students are likely to interpret plots of the magnetic pole positions through geological time on a diagram as an indication of some magnetic force that moves plates. Barnett et al (2006) found in a study on middle school students’ concepts of the earth’s interior that they were strongly influenced by science fiction movies. Similarly, Parham et al (2011) studied college student misconceptions on volcanoes and found that students often relied on movies as a source of information about volcanoes. Students were found to have the incorrect idea that volcanic eruptions were caused by changes in atmospheric conditions such as an increase in temperature. Additionally some students in the study did not understand that plate tectonics was the main cause of volcanism.

Together these studies indicate that students may enter college with a range of misconceptions about geology and earth science. Because it is likely that Physical Geology may be the only geoscience (and possibly the only physical science) course students take in their college careers, it is essential that students leave these courses with a good understanding of geological concepts. This is especially important for the education majors that may be ultimately teaching geosciences to K-12 students. It is important to identify pre-existing
misconceptions that students may enter the geosciences courses with and address these topics in detail to clarify student understanding.

As early as the 1960's, the American Geological Institute recognized the importance of standardized testing for Earth Science students (Cervato, et al., 2007). The Earth Science Curriculum Project was instituted to provide a comprehensive Earth Science course in middle and high schools. A group of forty-one geoscientists and science teachers developed a curriculum including a text, laboratory manual, and teacher's guide. Recognizing the importance of assessing the impact of this curriculum, the students were given both pre-course and post-course tests along with five unit tests (Heller, 1964). The motivation for development of the curriculum was recognition that earth science teachers needed better preparation in subject competency and materials for teaching. The pre-course and post-course evaluations were used as guides in the three revisions of the curriculum. Presently, this standardized curriculum is no longer used and there is no standardized national exam on middle school or high school geosciences knowledge.

In an attempt to create a standardized instrument for various instructors and institutions, the Geoscience Concept Inventory was developed to allow comparable assessment of learning in entry-level college geosciences courses among various instructors and institutions (Libarkin and Anderson, 2005). The idea grew from the recognition that students may enter the geosciences classroom with misconceptions which may interfere with their learning (Kurdziel
and Libarkin, 2001). As noted earlier, these misconceptions may result from both the student’s previous experience and instruction.

Concept Inventories are multiple-choice test instruments designed to measure student learning and conceptual understanding (Libarkin and Ward, 2011; McConnell et al., 2006). The assessments tend to focus on and test subject-specific content, e.g., geology (Reed-Rhodes and Imbire, 2008). Concept inventories can also be learning opportunities for both students and faculty (Reed-Rhodes and Imbire, 2008). Students can use the concept inventory to identify preexisting notions that are not correct. Faculty may use the data to make instructional decisions to identify common student misconceptions and modify instruction to reinforce correct concepts.

A number of concept inventories have been developed in the sciences (Libarkin, 2008). For example, in physics there are at least five concept inventories focusing on different sub-disciplines, such as graphing-measurement, force-mechanics, energy, thermodynamics, and electricity-magnetism (Lindell et al., 2007). Similarly, astronomy, chemistry, and biology have developed concept inventories on multiple topics (Mulford and Robinson, 2002; Klymkowsky and Garvin-Doxas, 2008; [http://astronomy101.jpl.nasa.gov/teachingstrategies/teachingdetails/?StrategyID=4](http://astronomy101.jpl.nasa.gov/teachingstrategies/teachingdetails/?StrategyID=4)).

The interest in concept inventories in science began after the development of the Force Concept Inventory (FCI) in 1992 and the FCI has proven instrumental in recognizing that what instructors think students understand and what the students actually do understand are not the same (Lasry et al, 2011). The
success of FCI in identifying student misconceptions has helped to spread its applications by many physics teachers with thousands of students worldwide. The FCI can be used in a number of different ways, but in most cases, the FCI test is administered twice to the same group of students; once before instruction and then after it. Both results can be compared using the normalized gain between them; this parameter is an indicator of the effectiveness of the instruction process. Although still widely used, recent research (Lasry et al, 2011) has questioned the reliability of individual questions but notes that the test as a whole gives reliable results.

The Geoscience Concept Inventory (GCI) was methodically developed beginning with research into the use of concept inventories and recognition that validity must include construct, content, communication, and culture (Libarkin, 2008). The description of the GCI question is called a stem. The response options for the students include the correct answers and several distracters (i.e., wrong answers). Unlike most concept inventories, the GCI is unique in that users have the opportunity to choose sixteen questions from a validated test bank in the Webcenter rather than a predetermined set of questions (http://gci.lite.msu.edu/adm/login). Other science concept inventories typically have more questions, ranging in number from twenty to forty-seven (Libarkin, 2008). The argument for a smaller set of questions is that students are more likely to spend more time on each question, stay focused on the questions, and complete the test. Also different from most other science concept inventories, the present version of GCI attempts to be inclusive of many geosciences topics,
aiming at testing multiple sub-disciplines. In this aspect, the small number of questions may limit that ability of identifying systematic misconceptions. Since geoscience covers a wide range of diverse topics, a limited number of questions may be a disadvantage in evaluating student learning on a particular topic. As part of its continued development and refinement, the authors have asked for input from the geosciences community in composing questions (Libarkin and Ward, 2011). A similar effort to develop a concept inventory encompassing several sub-disciplines is underway in biological sciences (Klymkowsky, et al, 2010).
Chapter 3: Research Methods

Course Sections, Numbers of Students, Instructional Modalities

Data were collected in ten semesters (three and a half years) of Physical Geology course sections offered between 2008 and 2011. In each of the Fall and Spring terms, one face-to-face section and three online sections of the Physical Geology class were taught, whereas in the summer terms only online delivery sections of the class were taught. A total of thirty-five sections of Physical Geology were examined in this study (Table I). Enrollment in each section began with twenty-eight students, but not all students completed the course. All of these course sections were taught at the Dale Mabry campus of Hillsborough Community College in Tampa, Florida, using the same course materials, including the textbook, a supplemental study guide, and additional learning activities including both graded and non-graded work. The online courses were delivered completely online using the WebCT learning management system (now Blackboard). Students in the face-to-face courses had access to the same online content, but its use was optional as their subject material was delivered completely in the classroom.
Table I. Number of Physical Geology sections in study.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Number of Online Sections</th>
<th>Number of Face-to-Face Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2008</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Spring 2009</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Summer 2009</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Summer 2010</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Fall 2010</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Summer 2011</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

A total of thirty-five sections of Physical Geology with beginning enrollment of twenty-eight students was included in the study.

Two specific quantitative measures of student performance were used: instructor-specific class examinations, and a subtest from the Geoscience Concept Inventory test. The instructor-specific instruments comprised four tests, each scaled to 100%. The Geoscience Concept Inventory tests consisted of sixteen questions, with detailed analyses of student answers. The following data
were available for download from the GCI Webcenter after the concept inventory closed: mean score (including all questions), standard deviation of the mean score, maximum score, minimum score, percent of students selecting the wrong answer, degree of difficulty for each question, and KR-21 reliability statistic. For this study, statistical analyses were conducted using the individual student answers in order to study each question individually.

**Analysis of Student Performance in Differing Delivery Methods and Term Lengths**

Online classes have experienced rapid growth the past several years in all areas of higher education (Allen and Seaman, 2010). The Physical Geology classes in this study are an example of this growth as the class initially was taught only in the face-to-face delivery method but expanded to include one section online in 2007. Gradually the number of online sections increased, and the number of online sections has now exceeded face-to-face sections by three to one. This increase in number of online sections came in response to student demand. At Hillsborough Community College, many students choose online classes because of the flexibility they offer. Working HCC students and those with families prefer taking class on their own schedule. Some HCC students do not have access to reliable transportation, or the cost of commuting is a financial hardship. Also, students with mobility issues or other physical disabilities may find it easier to take the class online. Students recovering from surgery or illness
are able to continue working on their degree when they normally could not. In addition, students taking online classes can obtain individualized questions and answers from the instructor through email communications.

In this study the face-to-face classes are offered only during the Fall and Spring semesters, with fewer sections and smaller numbers of students. In order to examine student performance as a function of these different delivery methods, the student population over the entire three-year period is divided into face-to-face and online student subsets. As face-to-face courses are not offered in the summer, for analysis of student performance relative to the length of term only the online delivery course sections were used. Similar methods for evaluating student performance are used to examine the influences of delivery methods and term durations.

**Data Collection and Examined Subsets**

The main data gathered were scores from instructor-generated tests. For the term-length study, the individual online sections offered in Fall, Spring, and Summer were bundled by term yielding three populations for comparisons. For the delivery method study, given the comparatively limited number of face-to-face students each term, all of the data from the live versus online offerings were compiled into two groups to try and obtain more reliable results statistically. No differences were expected among the multiple online sections offered each term, as students self-selected the section they enrolled in when they registered for the course. Results were included only from those students who completed all four of
the lecture tests, to try and maintain data consistency and compatibility. In other words, students who did not complete all the tests, or who missed a test for whatever reason, were not included in this study.

**Statistical Analysis Methods**

Various statistical approaches were used to identify potential differences in student performance on the tests. An average of the four test scores was used as a main indicator of student performance. The mean, variance, standard deviation, skewness, and maximum and minimum student scores for each term were compiled and compared to identify potential differences in performance among the studied terms. Student scores were assumed to be normally distributed, so the actual score distribution was compared to a normal distribution curve to verify this assumption. A normal distribution curve for each term was constructed based on the mean and standard deviation of student score, using the following equation:

\[
f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{(x-m)^2}{2\sigma^2}}
\]

where \( f(x) \) is the probability density, \( m \) is the mean student score, and \( \sigma \) is the standard deviation.

The data for the comparison of the online and face-to-face classes were further analyzed using a t-test. The t-test is a statistical test conducted when comparisons are made between two groups to determine if there is any difference in means between the two groups. These assumptions include: 1) the
samples are independent, 2) the population is normally distributed, and 3) population variances are roughly equal (Stevens, 2007). For this study, the samples are independent as the test scores are discrete and not related to any previous score. The populations are roughly normally distributed and variances are approximately equal (discussed in the following sections). An alpha (α) of .05 is the generally accepted cut-off. The t-test is calculated as follows:

\[ t = \frac{X_1 - X_2}{\sqrt{\frac{s_p^2}{n_1} + \frac{s_p^2}{n_2}}} \]  

(Eq. 2)

Where \( s_p^2 \) is the pooled estimate of the assumed common population variance for the groups. Both the t-test and ANOVA statistical test (discussed below) results were obtained using EXCEL.

The data for the term-length study were analyzed using an ANOVA statistical test since there were three groups – Fall, Spring, and Summer. ANOVA (analysis of variance) is a statistical test commonly used to compare more than two groups simultaneously on a dependent variable (Stevens, 2007). Assumptions of ANOVA, similar to t-test assumptions are met by the data used in this study and discussed in the following sections. These assumptions are the same as the t-test: 1) the samples are independent, 2) the population is normally distributed, and 3) population variances are roughly equal. Similarly for this study, the samples are independent as the test scores are discrete and not related to any previous score. The populations are roughly normally distributed and variances are approximately equal (discussed in the following sections). The
main output of ANOVA includes a $F$-statistic and a $p$-value. The $F$-statistic is calculated as:

$$F = \frac{V_{\text{between}}}{V_{\text{within}}}$$  \hspace{1cm} (Eq. 3)

where $V_{\text{between}}$ is the between-group variation and $V_{\text{within}}$ is the within-group variation. Therefore, a large $F$ value indicates that there is more difference between the groups than that within the groups, while a small $F$ value suggests that the difference between the groups is not significant in comparison with the variations within the group. The $p$ value represents the probability that the $F$ value is at least as extreme as the one observed. An alpha ($\alpha$) level of .05 is normally accepted as the cut-off, meaning that values less than .05 are considered statistically significant (Stevens, 2007). The ANOVA was conducted to facilitate general comparison with findings from other similar studies.

**Analysis of the Geoscience Concept Inventory**

For this study the Geoscience Concept Inventory was administered over five terms (Spring 2010, Summer 2010, Fall 2010, Spring 2011, and Summer 2011). Testing was done through the GCI Webcenter (http://gci.lite.msu.edu/adm/login) with all students taking the test online, including those students taking a traditional face-to-face lecture course. A list of the GCI questions used in the study can be found in Appendix A and student
scores in Appendix B. A pre-test was given during the first two weeks of the term, and a post-test with the same questions as the pre-test was given the last week of the term. Since taking the GCI was not part of the class grade, but was instead offered as extra credit, somewhat predictably more students took the post-test than the pre-test, likely because of a greater interest in extra credit at the end of the term.

The student answers were extracted directly from the Webcenter for analysis. Percentage correct answers were used for an assessment of student performance as that appeared to be the most straightforward comparison. Student score on the test was taken as the number of correct answers. For example, a score of five means the student answered five out of the sixteen questions correctly. Student answers to each question were examined to identify any potential trend of misconception. The statistical analyses provided by the Webcenter, although quite comparable with the results obtained here, are not directly used.

The students’ answers to each GCI question on pre-tests and post-tests were examined in order to obtain the following information.

1) An overall score on the pre-test and post-test was downloaded from the GCI Webcenter and the difference between pre-test and post-test scores was calculated. The overall score is simply defined as number answered correctly out of total number of questions (sixteen). The statistical method used by Libarkin and Anderson (2005) to scale the raw GCI test results to
a 100 point scale using an IRT (item-response theory) approach was not used in this study.

2) The overall average pre-test and post-test scores and standard deviation were obtained by averaging the raw score as described in the procedure above.

3) The student score distribution was plotted and compared with a normal distribution pattern using Equation 1.

4) The overall percentage of correct answers to questions was calculated and analyzed to identify students’ understanding of individual questions and discern changes between pre-test and post-test.

5) Student answers to individual questions were examined to see if there are misconceptions in students’ choices of answers.

6) The student performances on multiple-response questions and single-response questions were examined to see if the test scheme had any influence on student performance.

In the last semester of the study (Fall 2011) an instructor-designed comprehensive final exam, that includes the many sub-disciplines that are covered by the course, was given as both a pre-test and post-test format to provide an alternative analysis. This exam was composed solely of single-response questions and the post-test functioned as the final exam. The motivation of the instructor-designed test was to determine if the instructor had a strong influence on the student performance and the associated assessment in
terms of test content and approach, and to provide a comparison with the Geoscience Concept Inventory pre-test and post-test results.
Chapter 4: Course Description

Physical Geology (GLY 1010) is an introductory physical science class covering general topics in geology. HCC’s course description of Physical Geology provided to the students is as follows:

“This course covers basic geology and concepts and principles. Topics include origin and structure of the earth, processes involved in shaping the earth’s crust, the nature and classification of earth materials, and the dynamic interactions of the lithosphere with the hydrosphere and the atmosphere that produce characteristic landforms.” (HCC 2011-2012 Catalog, 2011)

Course objectives and specific learning goals of Physical Geology, as approved by the HCC science cluster committee, are:

- Describe the scientific method and discriminate between scientific and non-scientific information.
- State the age of the Earth as determined by scientific means and divide geologic time into the established Eras, Periods, and Epochs of the Geologic Time Scale.
• Describe the structure of an atom and discuss how atoms bond, relating this to the structure and properties of minerals.

• Define what a mineral is and describe the relationship of minerals to rocks.

• Describe the Rock Cycle, listing and relating its products and processes.

• Describe how igneous rocks may be characterized by their texture, composition, and provenance.

• Describe the origin of magma and the nature of intrusive and extrusive igneous processes and landforms.

• Describe the Earth’s differentiated structure and list the names and properties of the Earth’s internal layers.

• Describe and discuss the basic tenants of the theory of Plate Tectonics, including the origin of the theory, the types of plates, and the nature and consequences of their interactions.

• Relate the theory of Plate Tectonics to the locations and occurrence of geologic hazards including earthquakes, tsunamis, and volcanic activity.

• Describe the Hydrologic Cycle, both in general terms, and how it specifically relates to geologic processes.

• Describe the formation, properties and classification of sedimentary rocks.

• Describe the processes involved in metamorphism and discuss the textural and mineralogical changes that occur in metamorphic rocks.
• List and describe the major types of crustal deformation and associated geologic structures.

• Define and describe the processes of weathering, erosion, and mass movement (mass wasting).

• Describe fluvial processes and landforms.

• Describe the processes effecting shorelines and the resultant shoreline features.

• Describe the distribution and movement of water in the earth’s crust, relating this to karst topography and other hydrogeological features such as springs, hot springs and geysers.

• Describe the origin and nature of glacial landforms and the circumstances that have been hypothesized to explain the Pleistocene glaciations.

• Describe the role of wind as a geomorphic agent, listing the major types of aeolian erosional and depositional features, and the location of their occurrence.

Student grades are based on their scores on four tests (which we are considering in this study), and on additional learning activities, including a final exam, writing exercises, homework questions, review quizzes, field trip reports (both virtual and face-to-face), and a PowerPoint presentation on the geology of a National Park. Upon completion of the course, students are expected to
1) understand fundamental geology concepts and principles,

2) recognize geologic processes and resulting major landforms,

3) be able to classify basic earth materials and geologic time, and

4) recognize key geologic hazards.

Additionally students are expected to learn to differentiate between science and pseudo-science and follow the scientific method of investigation. During tests students are expected to think critically and to answer questions that require reasoning in addition to demonstrating a basic knowledge of geology and scientific terminology.

Typically three sections of online Physical Geology were taught in each Fall, Spring, and Summer Term, respectively and one section of face-to-face class was taught in each of the Fall and Spring terms. For the online offering, the instructor provided recorded PowerPoint lectures, similar to classroom lectures, but available online on demand in the virtual classroom. All the learning activities were available from the first day of class, but subsequently closed after each test on the subject material. A co-requisite, Physical Geology Lab, is required so students receive opportunities for additional learning activities in the lab which provide reinforcement for concepts taught in the lecture class. The co-requisite lab is also delivered both online and face-to-face. Students enrolled in online lecture courses must register for an online lab course whereas students in the face-to-face lecture course must register for a face-to-face lab course so no students should be enrolled in both delivery formats.
The Physical Geology face-to-face class meets on a traditional college class schedule of twice a week for one hour and fifteen minutes. One day each week immediately after the lecture class, the co-requisite Physical Geology lab class meets for one hour and fifteen minutes (seventy-five minutes). In a typical class meeting the students view a lecture using Powerpoint slides for forty-five to fifty minutes. The remaining class time is devoted to completing learning activities related to the preceding lecture. Students in the face-to-face class take all tests, including the final exam, using the traditional pencil and scantron method. Students take all tests at the same time in the classroom with one class period, seventy-five minutes, allowed for completion.

The face-to-face class is classified as “web-enhanced”, meaning that a virtual classroom is set up for student use; students may complete all parts of the course without going online. In the virtual classroom, copies of the Powerpoint lectures, additional non-graded learning activities, extra credit opportunities, and the digital gradebook are available. Since use of the virtual classroom is optional, some students in the face-to-face class never log in to the virtual classroom or take advantage of the resources.

The online course is delivered through the WebCT Learning Management System (now Blackboard). The class was designed in a systematic fashion so that the students can easily navigate the links. There are three main sections: a general information folder, a chapter resources folder, and a folder with links to assessments and assignments. In the general information folder students are provided a copy of the syllabus, an orientation to the website, and class policies
detailed in a “frequently asked questions” document. In the chapter resources folder students are provided the bulk of the content of the course, including narrated Powerpoint lectures for each chapter and non-graded learning activities. These non-graded activities include virtual matching games and virtual flashcards. The virtual flashcards are boxes with a geological term which you can “flip-over” with a click of the mouse to reveal its definition. An assessments and assignments folder is the location where students find links to take tests, review quizzes, and post assignments.

Students in the online course have a more flexible course schedule than students in the face-to-face course. Assignments have deadlines, and tests must be completed within a two-day period, but the specific schedule of work is left up to the student. All assignments are submitted online, using individual links to each specific assignment. By contrast, in the face-to-face class, in-class writing assignments can be completed only on the day assigned.

Tests are taken online on one of two scheduled days. Students have the option to choose which day they will take the exam. The exams have a time limit that is the same as the face-to-face class, seventy-five minutes. Limiting the time students have to answer questions helps ensure that they actually have retained and understand the material and do not merely look up answers using the Internet or another resource. For further testing security, questions are delivered one at a time and must be saved prior to advancing. Students are not allowed to go back and change their answer to a previous question once it has been answered and saved. This feature prevents students from using one question to
assist them with answering a different question. Students in the face-to-face class have the option to view all questions at once, since their tests are traditional paper tests. Students taking the online class are required to be computer-proficient in multiple tasks, including generating, saving, and uploading files and taking test online.

No substantial changes to the course content were made during the three-and-a-half-year study period. Basically, similar content was delivered using different methods, i.e., face-to-face and online, with different term lengths, i.e., sixteen-week Fall and Spring semesters and nine-week summer terms. Similar assignments, tests, and test formats were applied, and a similar grading scheme was used for all classes over the study period.
Chapter 5: Student Population

The beginning of community college education was in the 1800’s with the founding of two private colleges: Monticello College, established in 1835 and Susquhenna College, established in 1858. Both were among the first post-secondary institutions to offer two-year degrees (Blocker et al, 1965). Similar to the four-year universities, two-year colleges grew as a result of the 1862 Morrill Act which allowed federal lands to be sold to establish universities (Witt et al, 1994).

Although there were less than ten two-year colleges in 1900, there was explosive growth after the return of soldiers from World War I. By 1921, over 200 two-year colleges had been established in the United States (Cohen and Brawer, 1996). The same effect of an increased enrollment occurred after World War II and the number of community colleges continued to grow. The Truman Commission in 1947 provided further support to community colleges and eventually our current system expanded to over 1,600 colleges.

Enrollment in community college is influenced by various factors. During post-war periods, such as after World War I and World War II, enrollment increased because of returning soldiers. During periods of booming economy,
the enrollment at community colleges decreased. This occurred throughout the history of community colleges, including the Great Depression of the 1930’s and even more recently from 1991-97 (Geller, 2001). The community colleges in Florida exhibited a similar inverse-enrollment-employment trend between 1996 and 2009 (http://www.fldoe.org/cc/pdf/FCS_BusinessPlan.pdf).

![Graph showing trends of unemployment and unduplicated headcount in Florida community colleges](image)

**Figure 1.** Trends of unemployment and unduplicated headcount in Florida community colleges. This includes both full-time and part-time students. Notice the strong inverse trend where enrollment falls during times of low unemployment and rises during time of high unemployment. The most recent year in the study (2009-10) shows a gain of about 130,000 students since 2005.
Hillsborough Community College (HCC) is a two-year multi-campus community college located in Tampa, Florida. HCC mainly serves the greater Tampa Bay area with approximately 45,000 students. Demographically, HCC is approximately 55% female and 45% male with a median age of 22.5 years (HCC Fact Book, 2010). By ethnicity, students were classified as 21.5% African American, 0.4% American Indian, 3.9% Asian, 23.7 Hispanic, and 50.6% White.

The majority of students enrolled in Physical Geology are in the A.A. degree program (Associate of Arts) at HCC. A smaller number of students are considered transient students as they attend a university and chose to classes at HCC. Located in Hillsborough County Florida, HCC has five campuses spread throughout the county. The face-to-face classes examined in this study were all held at the largest campus, the Dale Mabry campus, which is located in an urban setting in Tampa. Students from any of the other campuses were eligible to register and take the online course sections, so the population of students came from across Hillsborough County. Each semester all sections filled initially with 28 students, but attrition resulted in a typical ending enrollment of 25-26 students per section (Table 2).

**Student Self-Efficacy Survey**

In addition to the external physical learning environment (textbooks, assignments, study materials), student achievement may also be influenced by
Table 2. Summary of research conducted per term.

<table>
<thead>
<tr>
<th>Term</th>
<th>Number Sections</th>
<th>Number Students</th>
<th>Research Questions Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2008</td>
<td>3</td>
<td>60</td>
<td>Delivery method, length of term</td>
</tr>
<tr>
<td>Spring 2009</td>
<td>4</td>
<td>83</td>
<td>Delivery method, length of term</td>
</tr>
<tr>
<td>Summer 2009</td>
<td>3</td>
<td>67</td>
<td>Length of term</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>4</td>
<td>72</td>
<td>Delivery method, length of term</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>4</td>
<td>91</td>
<td>Delivery method, length of term, Geoscience Concept Inventory</td>
</tr>
<tr>
<td>Summer 2010</td>
<td>3</td>
<td>61</td>
<td>Length of term, Geoscience Concept Inventory</td>
</tr>
<tr>
<td>Fall 2010</td>
<td>4</td>
<td>75</td>
<td>Delivery method, length of term, Geoscience Concept Inventory</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>4</td>
<td>68</td>
<td>Delivery method, length of term, Geoscience Concept Inventory</td>
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<tr>
<td>Summer 2011</td>
<td>2</td>
<td>46</td>
<td>Length of term</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>4</td>
<td>81</td>
<td>Self-efficacy survey, instructor-generated pre-test and post-test</td>
</tr>
</tbody>
</table>

Total students N=704

The total number of students participating in the study varies from term to term depending on enrollment and number of sections taught. All classes began with twenty-eight students enrolled but student withdrawals during the term altered the number of participants.

their internal personality traits and self-esteem. These internal traits are commonly referred to as self-efficacy. Self-efficacy is the belief that one can
perform a difficult task or cope with adversity (Schwarzer et al, 1995). Self-esteem is defined as the way we value ourselves (Huit, 2004). Previous educational research has noted a significant correlation between self-efficacy, self-esteem, and academic performance (Vidacek-Hains, 2010). Therefore to fully describe a student population it is helpful to examine student’s internal characteristics and motivation.

A self-efficacy survey (Pintrich, et al, 1990) was administered to the Fall 2011 classes in order to generally characterize the motivation and study habits of students. This test was administered to classes in the semester following the completion of the our data collection activities, but can nonetheless be considered representative of students attending HCC. A total of eighty-one students, or 72.3% of the total enrollment, took the self-efficacy test. Students were also asked to provide basic demographic data including gender and age. The survey used a seven-point Likert Scale, with the number 1 representing “not at all true of me” and 7 representing “very true of me”. The data were analyzed for all students, and then comparisons were made between male and female students, and between online and face-to-face students.

Overall, based on their answers to the efficacy test, the students demonstrated solid self-confidence on their drive to study irrespective of their interest in the subject or their study skills. Students rank themselves as diligent workers, interested in earning good grades. They emphasized that they had good study skills and were willing to stick with a subject they did not find interesting, and most stated that they did not give up when the subject material
was difficult. They also expressed high expectations of themselves in term of
class achievement. For all the students tested, the following statements had high
average scores (out of 7), reflecting the above-mentioned solid self-confidence:

“When I study for a test, I try to put together the information from class and
from the book.” (6.2)

“When I am studying a topic I try to make everything fit together.” (6.2)

“I work hard to get a good grade even when I don’t like a class.” (6.3)

“It is important for me to learn what is being taught in this class.” (5.8)

“Even when study materials are dull and uninteresting, I keep working
until I finish.” (5.9)

“I am sure I can do an excellent job on the problems and tasks assigned
for this class.” (5.3)

When the questions are asked from an opposite approach, answers
indicating high self-confidence and excellent study skills are also demonstrated.
The lowest scores were given to the following statement:

“When work is hard I either give up or study only the easy parts.” (3.3)

Student answers to some of the questions, or the questions themselves,
are puzzling. For example,

“Compared with other students in this class I think I know a great deal
about the subject.” (3.8)
“My study skills are excellent compared with others in this class.” (5.4)

“Compared with other students in this class I expect to do well.” (4.7)

“Compared with others in this class, I think I am a good student.” (4.9)

It is not clear how the students are able to make the comparison with other students, especially for online classes during which they do not likely meet and interact with each other. The responses are probably based on experience in other classes. Therefore, the answers to these questions for online students may not be relevant to other students in the specific class. However, for the face-to-face class with a lab session, a high level of interaction among the students is part of the lab exercise. Therefore, the answers to the above questions for face-to-face class should be relevant, and will be compared to the answers from the online student in the following. It is worth noting that only fourteen face-to-face students took the self-efficacy test, versus sixty-seven online students.

Comparing the males to females on the self-efficacy test, several observations were evident. The greatest difference in statements between males and females was concerning the anxiety associated with testing. For the statement “I have an uneasy, upset feeling when I take a test”, females answers ranked the statement as 5.0 whereas males ranked it as 2.9, a difference of 2.1. A similar ranking was given to the statement “I worry a great deal about tests”. Females ranked it as 5.8 whereas males ranked it as 3.8, a 2.1 difference. Along the same lines females also ranked the statement “I am so nervous during a test
that I cannot remember facts I have learned”. That statement had a 1.6 difference, with 4.8 for females and 3.3 for males.

Males and females also appeared to differ in their interest in the class and opinion of future usefulness of the class. For the statement “I think that what we are learning in this class is interesting” males selected 6.9, the highest score on the survey overall, whereas females selected 5.3, a 1.6 difference. For the statement, “I like what I am learning in this class” males selected 6.8 whereas females selected 5.7, a 1.1 difference. Males also answered higher on “I think that what I am learning in this class is useful for me to know” (6.3 males, 5.3 females) and “I think I will be able to use what I learn in this class in other classes” (males 5.4, females 4.3). The opinions of the females about their interest in the class may contribute to their less-than-confident answers concerning test anxiety noted above. It is worth noting that the self-efficacy survey was conducted during the first 10 days of the class, after an introduction of the class was given. At this point of the class, the students’ knowledge about the details of contents may be very limited.

In comparing the face-to-face student results with the overall surveys, several differences are identified. The online students are more likely to agree with the statement “I like what I am learning in this class” (6.1 for the overall survey versus 4.1 for the face-to-face students only. Additionally the face-to-face students are less likely to answer that “I expect to do very well in this class” with a ranking of 4.6 as compared to the online students’ ranking of 6.1. The response to the statement “When I study for a test I try to remember as many
facts as I can” the online students ranked this statement as their highest overall (6.4) but looking at the face-to-face students, the survey response was 2.6, indicating that remembering facts was not as important to them. These are interesting results considering that one of the main concerns of online testing is students having ready access to information. Apparently the online students are concerned in remembering the facts during tests instead of simply looking them up. Other differences were noted in the statement “When work is hard I either give up or study only the easy parts.” Online students ranked this statement very low (2.3), meaning that it does not describe them whereas face-to-face students ranked this statement very high (6.1). Similarly, the statement “When I take a test I think about how poorly I am doing” was ranked low by online students (3.7) but was the highest ranked item by face-to-face students (6.4).

These findings, although preliminary, provide a snapshot view of students’ self-motivation and self-confidence. Students indicated they had the necessary study skills for college-level work. There appear to be differences in self-efficacy between genders and differences between students in the two delivery methods. Overall it painted a picture of students willing to work hard and confident that they could be successful in the class. Unfortunately for some students this confidence did not always translate into success in the classroom.
Chapter 6: Results and Discussion

Measuring student achievement in classes can be done by a variety of means including writing assignments, homework questions, and projects. This study uses the straightforward measure of the average of student scores on instructor-generated class tests, and student scores on the standardized Geoscience Concept Inventory Test. Although these do not represent all graded assignments in these classes, they provide a uniform basis for quantitative comparisons of student achievement. Remarkably during the entire length of the study, mean grades on the instructor-generated tests showed only minor differences between the fall, spring, and summer terms. Similar small differences were noted between the online and face-to-face class performances. The average of the four tests has a wide range, from a high of 94.8 to a low of 40. (Table 3).

The Geoscience Concept Inventory was given as an extra credit option and administered as both a pre-test and post-test. Results of the GCI remained consistent throughout the course with students scoring low on the assessment. The grades (out of 16) on the GCI ranged from 1 to 11.
Influence of Delivery Methods on Student Performance

With the previously mentioned growth of online education, valid concerns have been raised about the security and fairness of online testing. Some of the more creative security ideas for remote online testing include retinal scans of the person taking the exam to ensure the correct person is taking the test and online video monitoring of the test-taker to ensure that no one is assisting them with the test (Mulkey et al, 2006). Other more conventional approaches include changing the grading scheme to put less weight on online tests and more on assignments and structuring the test so that the student is not easily able to look up answers. The online Physical Geology course here has adopted one of the more fundamental and cost efficient approaches - to include in exams questions that require higher-level reasoning that are not easily looked up in a book. The tests also include content specific to the Gulf of Mexico area and Florida geology that cannot not be easily located in an Internet search. Nevertheless, there are still basic knowledge-based questions included on the test since the course is introductory and students are not required to bring any pre-existing knowledge to the class. Clearly testing conditions cannot be exactly duplicated between online and face-to-face students, but the class test average provides a reasonably comparable measure.

In examining the influence of delivery methods on student achievement, the following statistical measures were calculated based on test score data:
Table 3. Summary of student scores for each term and composite terms.

<table>
<thead>
<tr>
<th>Term</th>
<th>Mean</th>
<th>STD</th>
<th>%STD/Mean</th>
<th>Skewness</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2008</td>
<td>76.61</td>
<td>12.6</td>
<td>16.45</td>
<td>-0.15</td>
<td>55.88</td>
<td>94.75</td>
</tr>
<tr>
<td>Spr 2009</td>
<td>69.85</td>
<td>12.59</td>
<td>18.02</td>
<td>-0.18</td>
<td>41.63</td>
<td>92.63</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>71.48</td>
<td>11.56</td>
<td>16.17</td>
<td>-0.88</td>
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<td>92.5</td>
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<tr>
<td>Spr 2010</td>
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<td>12.54</td>
<td>17.42</td>
<td>-0.76</td>
<td>65.75</td>
<td>88.3</td>
</tr>
<tr>
<td>Fall 2010</td>
<td>75.82</td>
<td>6.98</td>
<td>9.21</td>
<td>0.29</td>
<td>65.75</td>
<td>91.13</td>
</tr>
<tr>
<td>Spr 2011</td>
<td>74.18</td>
<td>6.79</td>
<td>9.15</td>
<td>0.61</td>
<td>63.94</td>
<td>88.3</td>
</tr>
<tr>
<td>Composite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>74.49</td>
<td>10.64</td>
<td>14.28</td>
<td></td>
<td>40</td>
<td>94.75</td>
</tr>
<tr>
<td>Spring</td>
<td>71.85</td>
<td>11.09</td>
<td>15.43</td>
<td></td>
<td>41.63</td>
<td>92.63</td>
</tr>
<tr>
<td>Face-to-Face</td>
<td>73.07</td>
<td>10.93</td>
<td>15.96</td>
<td></td>
<td>40</td>
<td>94.75</td>
</tr>
<tr>
<td>Online</td>
<td>71.62</td>
<td>11.95</td>
<td>16.79</td>
<td></td>
<td>41.4</td>
<td>93.15</td>
</tr>
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<td>Deviation</td>
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<td>about</td>
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<tr>
<td>Mean</td>
<td>2.14</td>
<td>2.16</td>
<td>3.18</td>
<td>11.43</td>
<td>2.41</td>
<td></td>
</tr>
</tbody>
</table>

N Online = 491  N Face-to-face = 132

Appendix B lists data used for calculations.

mean, standard deviation, percent standard deviation divided by mean, skewness, and maximum and minimum scores. These results were parsed based on differences in term length (semester versus the shorter summer term)
and differences in delivery method. Overall, the average face-to-face score on instructor-generated exams is slightly higher than online scores, 73.07 versus 71.62 on a scale of 100 (Table 3). This should be considered only a slight difference as the numbers are close and the standard deviation about the composite mean is only 2.14. The summer classes were not included in these calculations, since only online courses were taught during that time, and the shorter length of term during the summer could impact the results.

Looking at the fall term first, the highest average fall term score was in Fall 2008 with a mean of 76.61. The mean for Fall 2010, 75.82, was very similar to Fall 2008. The lowest fall term mean (71.48) occurred in Fall 2009. The standard deviations of the mean scores varied from 12.80 in Fall 2008 to 6.98 in Fall 2010. This relatively high standard deviation is not unexpected considering the wide range of grades expected in an introductory course. The greater spread on the left side of the diagram is also not unexpected as students at the lower end have a wider range of scores than those at the upper end (Figure 2). Most of the scores represent true performance on class tests, although it is possible that some of this variance represents students that gave up on the tests, but finished the course. Students have the option to replace their lowest test grade with the final exam, so low scores may also reflect students taking the test to maintain their enrollment while intending to replace it with the final exam.

Although the means for the fall term are similar, it is also necessary to examine the distribution pattern, as it is possible for data with different distribution patterns to have similar means and standard deviations. Figure 2 is a
normal grade distribution graph, using a five point interval for ease of visual display based on Equation 1 (Figure 2). The distribution suggests that the population is indeed random, and that there is no apparent bias in the data. The distribution also exhibits a tail on the left side, representing the “stretch” in grades at the lower end of the grading scale.

![Normal Population Distribution Graph](image)

**Figure 2.** Overall student performance on tests during three fall terms of study. The shape of the distribution indicates a random population. Note the wide spread of grades on the lower end of the distribution.

For the spring term courses, the highest overall mean score was 74.18 in Spring, 2011. The lowest overall mean score of 69.85 was recorded during Spring 2009. Spring 2010’s mean grade on the four tests was 71.97. All numbers are reasonably close and represent similar means during spring terms. Standard deviation varied from 6.79 in Spring 2011 to 12.59 in Spring 2009. As in the Fall, a similar long tail of low grades is found in the spring scores. Figure 3
presents a normal grade distribution curve for Spring, constructed based on mean and standard deviation of grade distribution. The distribution of the spring semesters (Figure 3) also suggests that a random population and no bias in the data. The normal distribution for the Spring similarly has a left-side tail indicating the spread of grades at the lower end of the scale.

Figure 3. Overall student performance on tests during three spring terms of study. The shape of the curve indicates a normal distribution and a random population. A higher number of low grades is seen in the spring term.

When the distribution patterns of Fall and Spring terms are compared, they are quite similar, as expected from the data comparison in Table 3 (Figure 4). Although the Spring curve exhibits a sharper peak as compared to the Fall, it is apparent that the Fall has more students on the higher end of the grade scale.
Comparing the performances of face-to-face and online students, the means are close, with a composite face-to-face mean of 73.07 and a composite online mean of 71.62 (Table 3). Examining the shape of the curves for the student scores, the face-to-face students have a more restricted grade range under the curve with a higher percentage of students scoring around the mean (Figures 5 and 6). Both groups had a longer tail on the lower end of the grading scale.

Similar to the pattern observed in the student scores, a plot of the normal distribution of student scores for both face-to-face and online reveal a slightly tighter curve on the face-to-face scores than the online scores (Figure 6). The patterns are very similar with a peak between 70 and 75 with a normal distribution on both sides of the curve. The only deviation from a bell curve distribution is the longer tail on the lower score side, addressed previously.
Figure 5. Face-to-face student performance compared to online student performance. Face-to-face students have a more restricted grade range under the curve with a higher percentage of students scoring around the mean.

Figure 6. Normal population distribution of face-to-face and online student scores. The normal grade distribution curve shows the higher peak of the face-to-face students.
Since the means are so similar it is not surprising that a t-test of the online and face-to-face data yields $p=.42$, a value indicating there is no statistical distinction between the two groups.

This study provided a unique opportunity to compare the performance of face-to-face and online students as directly as possible since the same instructor, using the same materials, taught all sections of the class. Although the means varied slightly between terms and sections, there was no statistically significant difference in means between face-to-face and online students. Therefore, all students taking Physical Geology in the three-year study period performed the same on the classroom tests regardless of delivery method.

**Influence of Differing Term Lengths on Student Performance**

Increasingly colleges are attempting to accommodate student and faculty schedules by offering courses on term lengths shorter than the conventional sixteen-week semester timeframe. This is especially true of community colleges that have a large population of non-traditional students who may be seeking accelerated courses. Although most courses at HCC are offered in a sixteen-week term, there are multiple alternative schedules including five-week, six-week, eight-week and nine week terms. This portion of the study compares student achievement on instructor-generated class tests in Physical Geology between sixteen-week semesters and nine-week summer terms to determine if there are any differences between the longer versus shorter term.
The term-averaged student scores range from a low of 68.51 for the 2010 Summer term to a high average of 78.68 for the Summer of 2011 (Table 3), but generally, the means of each term during the three-year study are quite similar. The overall average score of the nine terms is 71.62 with a standard deviation of 3.06, or 4.28% of the mean. The standard deviation values about the mean for each term range from 11% to 22% of the means. This suggests that although there is considerable spread of student scores, as reflected in the standard deviation in each term, the overall term-averaged score is rather similar. This is further confirmed by ANOVA, as discussed below.

Although the term-averaged values during the nine terms are similar, as illustrated in Table 3, it is necessary to once again examine the distribution pattern as it is possible for different distribution patterns to have similar means and standard deviations. In order to more directly compare the overall Spring, Fall, and Summer terms and to examine the influence of academic term duration on student performance, the three terms are combined to create a composite group for all spring, fall, and summer term offerings, respectively. Figure 7 illustrates the student score distribution pattern for the composite spring, fall, and summer term offerings. As shown in Figure 7, the overall distribution patterns of the different terms are quite similar, with no apparent differences. Therefore, in addition to similar means and variances (Table 3), the similar distribution patterns confirm that the different time durations did not result in differences in student performance as measured by overall score.
A model normal distribution curve was constructed (following Eq. 1) based on the means and standard deviations of the composite term offerings. The actual student score distributions in each term follow a normal distribution pattern reasonably well. Figure 8 illustrates an example from the Spring 2010 term, which had the greatest number of students (Table 3). The remaining eight terms illustrate similar patterns. The distributions plotted suggest that the population is normally distributed. Most of the distributions illustrate a “tail” toward the low-score end, as seen earlier in our distribution plots (e.g., Figure 6). Also, as shown in Table 3, the lowest score varies substantially from term to term, with a 9-term mean of 41.40 and a standard deviation of 8.19, whereas the highest score is fairly consistent, with a mean of 93.15 and a standard deviation of 2.79. The very low scores likely arise not only by poor performance on the tests, but
also for reasons related to course rules, as discussed previously: Students may have begun a test and not completed it, opting instead to take the final exam as a substitute. In other situations, students may simply have given up on the course, but continue to take exams to maintain their enrollment in order to maintain their financial aid eligibility.

The normal distribution constructed using the mean and standard deviation provides an idealized tool to examine and compare the student score distribution. Composite curves combining all three spring, fall, and summer terms are shown in Figure 9. Similar to the actual distribution of the student score shown in Figure 8, the idealized distribution patterns are also similar for all
The overall student performance was also averaged for the three-year period for the fall, spring, and summer terms (Table 3). Although the differences are quite small, a pattern can be identified from the average values, distribution
pattern, as well as idealized distribution pattern. Overall, the fall term yields the lowest average score (70.30), followed by spring term (71.99), while the summer term yields the highest score (72.55) influenced somewhat by the high scores of 2011. The reason for this trend (although admittedly a rather weak trend) might be that the fall term tends to have the most first-semester-in-college students, while the summer term tends to have more transient students from universities and more upper-class students. The more-experienced upper level students likely perform better in tests than the first-semester-in-college students.
To statistically compare these means, a series of ANOVA tests were conducted to determine if there is a significant difference between the different terms. Based on the above discussion, the student scores are 1) independent, 2) roughly normally distributed, and 3) with approximately equal standard deviation. In other words, the assumptions required by ANOVA are met. Three ANOVA tests were conducted to evaluate the statistical differences. The first ANOVA test was conducted for the composite fall, spring, and summer terms. The ANOVA test yielded a $F$ value of 1.16 (2,488) and a corresponding $p$ value of .31, indicating that there is no statistically significant difference among the overall fall, spring, or summer terms.

A second ANOVA test was conducted to include all nine terms. The ANOVA yielded a $F$ value of 3.14 (8,482) and a corresponding $p$ value of .001, indicating that there is a statistically significant difference among the individual fall, spring, or summer terms. Recognizing that the summer of 2011 term represents a considerable anomaly (Figure 4), a third ANOVA test was conducted without the 2011 summer term. The ANOVA yielded a $F$ value of 0.99 (7,437) and a corresponding $p$ value of .44, indicating that there is not a statistically significant difference among the individual fall, spring, or summer terms excluding the summer of 2011 term. The reason for the anomalous 2011 Summer term is not clear. A large number of transient students from universities in the summer taking advantage of lower community college tuition due to difficult economic conditions might attribute to this anomaly. Overall, the ANOVA tests
further confirm, from a commonly used statistical approach, the earlier descriptive assessment of negligible differences in student performance.

Term length does not have an effect on student performance on class tests in the three-year study. Students enrolled in the shorter summer term had the same scores as students enrolled in fall or spring terms. Although there were slight differences between terms and a notably higher Summer 2011 term, there was no statistical significance between the means. Therefore, all students taking Physical Geology in the three-year study period performed the same on the classroom tests regardless of term length.

**Student Performance on Geoscience Concept Inventory**

The Geoscience Concept Inventory (GCI) offers a standardized test for comparisons of learning among students at different colleges taking differing geosciences courses. The motivation for using the GCI was to take advantage of a second, externally vetted, quantitative measure of student learning to compare with the instructor-generated tests. Also the GCI is designed to be used as a pre-test and post-test, giving the instructor the ability to measure changes in student learning that occur during a specific class term. The GCI was used for five different terms, including fall, spring, and summer terms, and these cohorts included students in both online and face-to-face classes. The GCI was administered as both a pre-test and post-test in each semester it was used.
One of the attractive features of the GCI’s design is that the instructor is able to select sixteen questions from the GCI test bank, which includes a large menu of validated questions. The questions selected for use in this study all focused on topics deemed important by the instructor that were scheduled to be covered in the curriculum. Most of the questions available in the GCI test bank at the onset of this study (Spring 2010) related to plate tectonics and structural geology topics. Few of the questions covered topics in sedimentary and coastal geology. As such, the GCI test bank of questions should not be considered a comprehensive assessment for course content in a typical introductory geology course.

Overall Student Performance on the Pre-Test and Post-Test

The overall student score distributions of pre-test and post-test are largely the same (Figure 11). In addition to the actual student score distributions, Figure 11 also illustrates the idealized normal distribution developed based on the average score and the associated standard deviation. The modeled normal distribution fits the actual distribution well for both pre-test and post-test, indicating that there is no bias in student scoring. The student score distribution is also similar between pre-test and post-test. Slight differences can be identified comparing the pre-test and post-test distributions. The post-test distribution is skewed moderately toward the higher score but also has a higher percentage of
low scores. In addition, the pre-test score distribution fits the normal distribution closer than that of the post-test scores.

Figure 11. Student score distribution for both pre-test and post-test. The idealized normal distribution is based on average score and standard deviation. The normal distribution exhibited suggests that there is no bias in the student performance. No apparent difference in student scores can be identified from the pre-test and post-tests.

The average score of the 222 students for the pre-test is 4.85 (out of a full score of 16) versus the 4.91 of 256 students for the post-test, a negligible difference of 1.2% of the pre-test average score. In other words, the overall student performance in the pre-test and post-test is largely the same, as also confirmed by the similar score distribution (Figure 11). This somewhat disappointing finding has also been reported by other researchers. Similar
negligible difference between pre-test and post-test on the GCI was also reported by Libarkin and Anderson (2005) based on a much larger and more diverse student population. It is important to note that the post-test standard deviation of the mean is 2.19, which is 16.5% higher than the pre-test standard deviation of 1.88, indicating a wider score distribution on the post-test.

The average score of both pre-tests and post-tests represent approximately 30% of the possible full score, i.e., on average only 30% of the questions were answered correctly during both pre-test and post-test. Similar low pre-test and post-test scores, although slightly higher than 30%, were also reported by Libarkin and Anderson (2005) and Petcovic and Ruhf (2008). These studies used Rasch analyses of the scores instead of raw test score as used here, so a direct comparison is not possible. The highest score for both the pre-test and post-test is 11, or 68.8% of the full score. For a typical scoring scheme, this is equivalent to a letter grade of C.

The Geoscience Concept Inventory has two different formats for answers, single-response and multiple-response questions. For the single-response question students choose only one answer as the correct one. For multiple-response questions students have the option of choosing as many answers as they wish. Overall, students scored better on the single-response questions than the multiple-response questions. For the single-response questions, on average students answered 39.6% of the questions correctly during the pre-test and 41.3% during the post-test. For the multiple-response questions, on average
students answered 16.8% of the questions correctly during the pre-test and 16.1% during the post-test.

The sixteen test questions are also grouped by how much difference there was between pre-test and post-test scores. Five questions clearly had an increase in students answering correctly on the post test (Figure 12). Five questions had an increase in students answering correctly on the post test compared to the pre-test. Five questions had no or very little difference between pre-test and post-test. Six questions had a higher percentage of students answering incorrectly in the post-test than the pre-test.

Figure 12. Overall student performance on both pre-test and post-test GCI questions. Of the sixteen questions five questions clearly had an increase from pre-test to post-test. Five questions had no or very little difference between pre-test and post-test. Six questions had a higher percentage of students answering incorrectly in the post-test than the pre-test. Six questions had essentially no difference (less than 3%) between the pre-test and post-test. Six questions had a higher percentage of students answering incorrectly in the post-test than in the pre-test a somewhat disheartening result.
In the following, student answers to selected questions are analyzed in detail to examine possible misconceptions and the validity of the example GCI questions.

As apparent in Figure 12, the percent correct answers varied greatly among the 16 questions, ranging from over 80% correct answers to Question 4 to less than 5% correct answers to Question 5. In the following section, student answers to each question are discussed. Single-response and multiple-response questions are discussed separately. Student answers to the sixteen questions are analyzed in detail to examine possible misconceptions and the validity of GCI questions.

Questions and Associated Student Answers to Single-Response Items

Question 3 (Figure 13) is designed to test both the concept of plate tectonics and students’ understanding of geologic time. The question was selected mainly to gauge students’ pre-existing knowledge of the concept of geologic time and to see if they adequately understood the scale of geologic time after the course. Question 3 reads as:

“Some people believe there was once a single continent on Earth. If this single continent did exist, how long did it take for the single continent to break apart and form the arrangements of continents we see today?

1. Hundreds of years
2. Thousands of years

3. Millions of years

4. Billions of years

5. It is impossible to tell how long the breakup would have taken.”

The correct answer is 3, millions of years. Examining the answers, most students selected either millions of years or billions of years, thus indicating that they recognize that the earth is very old (82% in the pre-test and 84% in the post-test). In the pre-test, 49% of the students correctly selected millions of years, with that number falling to 42% in the post-test as more students selected billions of years instead of millions, with a change from 33.6% to 44.7%. Perhaps students had not been introduced to the concept of billions of years before the course and felt that answer must be correct since it was the longest expanse of time. This suggests students recognize the earth is old entering the class but are still not clear on the scale of geologic time leaving the course. A smaller number of students selected that it is impossible to know how long the long the breakup would take in the pre-test than in the post-test (9.4% in the pre-test versus 6.2% in the post-test. When these options with answers worded as “do not know”, it is difficult to determine if the student has a misconception about geologic time or they possibly have a good understanding that timing of events that occurred long ago in earth history is difficult and contains significant possibility for error.
Figure 13. Student performance on GCI question 3. Students recognize that the earth is very old with 82% of students in the pre-test and 84% of students in the post-test selecting either millions of years or billions of years. However, the inability to distinguish the difference between the two indicates that they do not have a solid understanding of the concepts of geologic time.

The question with the highest percentage of correct answers was

Question 4 (Figure 14). This question, also covering the concept of plate tectonics, requires that students understand the concept of plate breakup and the mechanisms for plate movement. The question reads as:

“Some people believe that there was once a single continent on Earth. Which of the following statements best describes what happened to the continent?

1. Meteors hit the Earth, causing the continent to break into smaller pieces
2. The Earth lost heat over time, causing the continent to break into smaller pieces

3. Material beneath the continent moved, causing the continent to break into smaller pieces

4. The Earth gained heat over time, causing the continent to break into smaller pieces

5. The continents have always been in roughly the same place as they are today

Figure 14. Student performance on GCI question 4. Question 4 had the highest percentage of correct answers indicating that students understood the basic process of plate movement. The small number of students that answered “meteors” must have some misconceptions concerning meteors and overestimate their effect on earth.
The correct answer for Question 4 is 3. Although the question had a very positive with a high number of correct answers, the percentage correct actually decreased slightly (3.8%). The post-test yielded an increase in the students answering 4 incorrectly with an increase from 5.4% to 8.2% indicating a misconception related to the idea that the earth gains heat over time. Another increase in students answering 1 in the post-test was noted. This indicates that students answering 1 must have some misconception concerning what meteors are and overestimate how much meteors affect earth. One positive note is that very few students in the post-test selected 5, that the continents are in the same place. This question also indicates that most, but not all, students come to the class with some understanding of plate tectonic processes and retain that knowledge throughout the class.

Question 5 is another question on plate tectonics that has the distinction of having the lowest percentage of correct answers, with less than 5% of students answering correctly. The question even shows a slight decrease of 1.2% in students answering correctly between the pre-test and post-test (Figure 15). Question 5 reads as:

“What is the best definition of a tectonic plate?

1. All solid, rigid rock beneath the continents and above deeper, moving rock

2. All solid, rigid rock beneath the continents and oceans and above deeper, moving rock
3. All solid, rigid rock that lies beneath the layer of loose dirt at the Earth’s surface and above deeper, moving rock

4. All solid, rigid rock and loose dirt beneath the Earth’s surface and above deeper, moving rock

5. The rigid material of the outer core

The majority of the students answered 2 or 3 (over 70%) on both pre-test and post-test, reflecting their understanding of the concept that the lithosphere is solid and plates are moving. The correct answer was 4, requiring students to include loose dirt as part of the answer. The majority of the students (over 50%) during both the pre-test and post-test answered 2, which would be correct except for not including “loose dirt” as part of the answer. It is possible that when the students were reading the question, they did not read all possible answers but picked 2 as it was the first reasonable answer. Since the study of plate tectonics did not focus on soil the selection of 2 should possibly be considered correct. Most teaching of plate tectonics focuses on the lithosphere as a rigid solid layer, and it is reasonable that students would not think that it is necessary to include the rather ambiguous and non-scientific term “loose dirt”. Student performance on this question could be considered much better than the 5% score as they recognize the movement of the rigid plates.

Of note is that even after the class, approximately 10% of the students retain a misconception that the outer core is rigid. This answer showed a slight
increase from pre-test to post-test. Overall there was very little change in the pre-test than the post-test, indicating that students are entering the class with

![Figure 15. Student performance on GCI question 5. Most students selected 2 “All solid, rigid rock beneath the continents and oceans and above deeper, moving rock” which is correct except for the omission of the term “loose dirt” to signify the soil layer. The concept of soil included as part of the lithosphere was made but not emphasized.](image)

some knowledge of plate tectonic theory but about 10% of students do not have a good grasp on the process. Neither the instructor nor the textbook emphasized the concept of “loose dirt” as being an important aspect of a plate.

Question 8 sought to test student understanding of both global temperature change and volcanic eruptions. Although during the class this topic was covered, student performance on the question was low. Only a small
positive change occurred between pre-test and post-tests (Figure 16) with about
the same percentage of students selecting each answer

![Bar chart showing student performance on GCI question. More students believed that the earth would be hotter a year after a volcanic eruption with ash than cooler indicating that they did not understand the association of ash with global cooling of air temperature. The distribution of student answers point to students randomly guessing.](image)

**Figure 16.** Student performance on GCI question. More students believed that the earth would be hotter a year after a volcanic eruption with ash than cooler indicating that they did not understand the association of ash with global cooling of air temperature. The distribution of student answers point to students randomly guessing.

**Question 8 reads as follows:**

“A large, ashy volcanic eruption occurs in Europe. Which effect would this eruption have on the air temperature near the Earth’s surface one year later?”

1. Volcanic eruptions do not affect air temperature

2. Only the air in Europe would be warmer
3. Most of the Earth’s air would be warmer

4. Only the air in Europe would be colder

5. Most of the Earth’s air would be colder.

Answer 5 is correct. Looking at the students’ answers from the post-test, although more students answered E correctly, there was an 8% increase in students that answered 3. It is possible that the students must have retained a misconception about the effects of volcanoes on the Earth’s atmosphere as more answered that the earth would be warmer than colder. The students apparently associate heat with volcanoes and do not correctly understand that ash could block sunlight and cause the entire earth to cool. It is also possible that the students did not understand how exactly the air temperature rather than the solid earth itself might be affected if they associate volcanic eruptions with heat. Looking at the even distribution of the scores (Figure 16), another possibility is that the students answered randomly. In the geologic past the temperature on the Earth’s surface could be influenced by numerous factors. It is not likely to conclude that a volcanic eruption in Europe, albeit a large ashy one, can necessarily be interpreted to have a decisive influence on Earth’s surface temperature one year later.

Question 10 (Figure 17) seeks to determine students’ understanding of basic mineralogy and mineral identification. For this question, the number of students selecting the correct choice of: “No. Tony would not be able to see if the rock contains iron, even with a microscope” decreased between pre-test and
post-test from 22.0% to 12.2%. Most students for both pre-test and post-test chose “Yes, Tony could use a microscope to see if the rock contains very small pieces of iron.” In the Physical Geology class there is limited to no microscope work, so it is unlikely that students would have gained any knowledge concerning microscope use during the class and may not have been clear about how that may affect mineral identification. Question 10 reads as:

“Tony has a black rock that does not reflect light. He cuts it open and the inside is the same as the outside. Can Tony determine if this rock contains iron simply by looking at it?

1. Yes. The rock is black and therefore does not contain iron.

2. Yes. If the rock contains iron, Tony would see silver specks in the rock.

3. Yes. Tony could use a microscope to see if the rock contains very small pieces of iron.

4. No. Tony would not be able to see if the rock contains iron, even with a microscope.

5. No. Tony cannot look at the rock since it does not reflect light and is therefore invisible.”

The correct answer is 4.
Students were provided hand samples of multiple iron-rich minerals and rocks during the lab classes on rock and mineral identification. Throughout the lab classes on rocks and minerals, and also covered in lecture, was an emphasis

![Bar chart](https://via.placeholder.com/350)

**Figure 17.** Student performance on GCl question 10. Most students selected 3, “using a microscope to identify iron”. Since there is no microscope work in the course, students were somewhat at a disadvantage to answering this question correctly. Notably in the post-test over 6% of students indicated the rock would be invisible, clearly representing some misconception on the meaning of “invisible”.

not to use color in mineral identification but apparently students did think that color was an indicator of mineralogy with over 30% answering 2 as the correct answer in the post-test. The student answers here indicate that a section on petrographic mineral identification may be appropriate to help explain mineral identification further to students.
Only a few students, 11.3% on the pre-test and 6.4% on the post-test, selected 5, that the rock was invisible since it did not reflect light. Selecting this statement indicates students still have misconceptions on the reflection of light and meaning of invisible. No concept of “invisible rocks and minerals” was ever mentioned during the class. It should be considered a positive outcome that the percentage of students answering 5 decreased on the post-test.

Question 11 (Figure 18) was selected because it tests student know on a common ocean surface processes that the instructor considered to be basic to Physical Geology. Also the question had one straight-forward answer with reasonable distracters..

Question 11 reads as:

“What causes most of the waves in the ocean?

1. Tides
2. Earthquakes
3. Wind
4. Tsunamis

Wind, choice 3, is the correct answer.”

Question 11 had the distinction of showing the highest increase in correct answers from pre-test to post-test. For the pre-test about 42% of the students answered correctly (Figure 18). This compares with 68% students with correct
answer in the post-test, an increase of twenty-six percentage points. It is worth noting that HCC is located on the west-central coast of the Gulf of Mexico, where wind wave generation is a common phenomenon. For example, weather

![Bar chart showing student performance on GCI question 11.](image)

**Figure 18.** Student performance on GCI question 11. Although Question 11 did not have the highest percentage of correct answers students did very well on the question and there was a notable increase in correct answers between the post-test and pre-test. Several possible reasons for the successful outcome include the straightforward wording of the question and its answers, student familiarity with ocean processes, and instructor’s background in coastal geology.

channels often link wave conditions to wind conditions. In addition, the instructor has a background in coastal geology and may thus emphasize coastal processes more in class. Coastal field trips are required for both the face-to-face and online courses. Students in the face-to-face class are required to participate in a field trip to an estuary/tidal flat on Tampa Bay. Students in the online class are
required to complete a virtual field trip on coastlines and coastal processes of Florida. Therefore, students are exposed several times to the wind-wave generation concept which probably resulted in the significant post-test improvement for this particular question. Interestingly, almost a quarter of students still do not answer this question correctly. Of those that did not answer correctly, most selected A, tides. Tides are another very common oceanographic phenomenon, which might be the reason for the confusion. Overall the student answers to this question seemed to indicate that the question was a reasonable measure of a positive increase in student learning during the class.

Question 12 (Figure 19) is designed to test student understanding of erosion and how plate movement affects mountains. Included with the question is a sketch of two mountains. In the sketch Mountain II was shorter and wider than Mountain I. The sketches and questions are:

“During a recent trip to Canada, a traveler visited two mountains made up of the same type of rock. The sketches below represent the outlines of two mountains. Which of the following reasons best explains the difference in the two drawings?

1. Mountain I is older than Mountain II
2. Mountain II is older than Mountain I

3. Mountain I is on a continent that is moving faster than Mountain II is on

4. Mountain I is on a continent that is moving slower than Mountain II is on

5. Mountain I has experienced more erosion than Mountain II.

The correct answer is 2, “Mountain II is older than Mountain I”.

The rationale for answer 2 as the correct choice is that erosion has resulted in a change in the shape and height of the older mountain, thereby giving a relative age between the mountains. With more erosion the older mountain would expect to not have a sharp peak or be as topographically high. Notably the question includes that the mountains are both composed of the same type of rock and thereby should weather at the same rate. Most of the students chose selection 1, 2, or 5 indicating that they recognized the rate of plate movement should be the same for both mountains since they are adjacent to each other. The students likely recognized that some other process besides plate tectonics must be responsible for the differences in morphology between the two mountains and that the dominant mechanism was weathering.

Although the correct answer (2) was the most often chosen answer by the students, almost as many students selected 5 as their choice in the post-test (25.2%). The large number of students selecting 5 could be a reflection of their understanding that erosion can change the shape of mountains, although
not the correct change for the question, as this concept is emphasized throughout Physical Geology. This question provided a challenge for students in Florida as the majority of them have never visited mountainous terrain and are unfamiliar with basic mountain morphology.

Figure 19. Student performance on GCI question 12. Most students recognized that weathering was the process most responsible for the difference in the shape of the mountains. Most answered the question correctly choosing 2 but a number of students also selected 5 as a choice.

Question 14 (Figure 20) is another question on plate tectonics. On the surface the question appears to be straightforward, testing the most important mechanism for plate tectonics. Students in Physical Geology class are exposed to mechanisms for plate movement and in the class the role of gravity (answer 4) was mentioned. But the most important mechanism described during the class
was mantle convection, not one of the choices. Therefore although students may have either misinterpreted the question or retained misconceptions about plate movement after the course it is difficult to tell. Question 14 reads as:

“What is the best explanation for the movement of tectonic plates?

1. Lava moves the tectonic plates
2. Currents in the ocean move the tectonic plates
3. Earthquakes move the tectonic plates
4. Gravity moves the tectonic plates
5. Magnetism moves the tectonic plates

Answer 4 is the correct answer.

Question 14 showed the second highest increase in percentage points correct (nine) between the pre-test and post-test. Although Question 14 had an increase in correct answers, still 78% of the students answered incorrectly, which cannot be considered a good performance when the considerable class-time spent on plate tectonics is taken into account.

Examining the answers in detail it is possible students may have simply guessed when the answer presented most often in class was not given. Between the pre-test and post-test, less students answered 1 “lava” in the post-test (16%) versus the pre-test (19%). Similarly fewer students selected answer 2
“ocean currents” on the post-test (7%) than the pre-test (12%) although that percentage indicates at least some students do not have a clear understanding of “currents” and possibly associate currents only with water movement. Answer 3, earthquakes, showed only a slight decrease in answers, 13% pre-test and 12% post-test. The incorrect answer 5, magnetism, had a slight increase in incorrect answers from 41% to 43%. Therefore, students are leaving the class with a misconception that magnetism is a driving force of plate tectonics. Students recognize that magnetism is a part of plate tectonics theory but
incorrectly assume that it is driving force. Student misconceptions associated
with magnetism have been identified by other GCI studies (Libarkin, et al, 2011).
For this question we argue that although 4 may be the best answer out of the five
choices, it is not the dominating driving force of plate movement. Therefore, the
correct answer does not necessarily reflect a solid understanding of the driving
force of plates.

Question 15 seeks to test both knowledge of earth history and also
knowledge of the earth’s size. Both topics were covered as part of the class,
although in a Physical Geology course specifics of historical geology are not
generally emphasized. Notably Question 15 offers four answers instead of five
as most questions do, and therefore gives students a higher probability to guess
and randomly select the correct answer. Question 15 is:

“How big was the planet Earth when dinosaurs first appeared?

1. Smaller than today

2. Larger than today

3. Same size as today

4. We have no way of knowing it”

Although a high percentage of students chose the correct answer of “same size
as today” in both pre-test and post-test, the percentage of students answering
correctly actually decreased 10%. Almost a fifth of students selected that there
was no way to know the size in both the pre-test (16.9) and post-test (18.0%).
This answer may reflect student reasoning that since man and dinosaurs did not co-exist there is no way to accurately know the size of the earth.

Figure 21. Student performance on GCI question 15. Most students correctly chose “same size” as an answer although that percentage decreased slightly between the pre-test and post-test. The answer “we have no way to know the size” may reflect student reasoning that there were no humans present with dinosaurs and therefore no way to accurately measure the size.

Question 16 is another tectonics-related question focused on earthquakes. Students did well overall on the question selecting the correct answer 69.7% on the pre-test and 74.6% on the post-test. Question 16 reads as:

“Which of the following best describes what scientists mean when they use the word “earthquake”?”
1. When an earthquake occurs, visible cracks appear on the Earth’s surface.

2. When an earthquake occurs, people can feel the Earth shake.

3. When an earthquake occurs, man-made structures are damaged.

4. When an earthquake occurs, energy is released from inside the Earth.

5. When an earthquake occurs, the gravitational pull of the Earth increases.

The correct answer is 4.

After the correct answer, the next higher percentage of students selected “when an earthquake occurs, people can feel the earth shake”. Students may not recognize that although that statement may be true, earthquakes can occur without humans feeling the effects. This answer may reveal a misconception of students and provides guidance for an increased emphasis on how earthquakes are defined. The other answers were chosen somewhat randomly with only a small number of students (less than 2%) selecting “man-made structures are damaged”. This question appeared to accurately test the student’s knowledge and students apparently are entering the class with some correct background knowledge on this topic.
Figure 22. Student performance on GCI question 16. The majority of students chose the correct answer in both the pre-test and post-test indicating that most students’ understanding of the definition of earthquakes is fairly strong. Answer 2 “people can feel the earth shake” likely represents a misconception that an earthquake must be felt by humans.

Questions and Associated Student Answers to Multiple-Response Items

Multiple-response questions are valuable in that they significantly reduce the likelihood that a student may randomly guess the answer. In other words, a random guess can yield a 25% correct answer for a four-choice question. A negative aspect of these type questions is that a partial correct answer, e.g., not selecting all correct answers, is regarded as incorrect answer. Students may also find this type of question more difficult as they are typically not given the exact number of correct answers. With single-response questions students know
that only one answer is correct. Therefore these questions would be expected to have a higher percentage of students getting the question wrong.

Question 1 seeks to test students on their concepts of earth history and age-dating techniques. The age of the earth and different dating techniques including associated error on absolute dating techniques was covered in the course content. Even with instruction the question still had the highest percentage of incorrect answers in the pre-test and second highest in the post-test (Figure 23). Question 1 reads as:

“Some scientists claim that they can determine when the Earth first formed as a planet. Which technique(s) do scientists use today to determine when the Earth first formed?

1. Comparison of fossils found in rocks
2. Comparison of layers found in rocks
3. Analysis of uranium found in rocks
4. Analysis of carbon found in rocks
5. Scientists cannot calculate the age of the Earth

The correct answer for the question is 3, analysis of uranium. Looking at the student answers, 35% of the pre-test students and 42 % of the post-test students gave the correct answer, an increase of 20%. However, they also gave one or more incorrect answers and therefore missed the question. The most often given answer was 5, “Scientists cannot calculate the age of the earth” with 95% of the pre-test and 96% of the post-test students giving that as their answer. With such
a large number of students selecting this as an answer, obviously students feel that there is no reliable way to accurately date the age of the earth. Their answers likely reflect the idea that scientists are able to date rocks with isotopes but these dates have an uncertainty associated with them. Therefore strictly speaking, we argue that answer E is not completely wrong. It may reflect the critical thinking of students.

Figure 23. Student performance on GCI question 1. Question 1 is a multiple-response item but only had one correct answer, “uranium”. The use of uranium isotopes was covered along with other age-dating techniques in the class but less than 10% of students in the post-test and a small number in the per-test were able to correctly give the answer. A large number of students in both pre-test and post-test chose the option “Scientists cannot calculate the age of the earth”. This large number of answers may stem from the idea that scientists are able to date rocks with isotopes but the dates have an uncertainly associated with them.
Question 2 (Figure 24) is a multiple-response question that tests the concept of erosion rates. Erosion, weathering, and other surface processes were covered in detail in the class. Although only a small percentage of students scored correctly on the question by selecting all correct answers, the answers given indicated that students did have some correct understanding of erosion processes. The majority of students were able to identify that rock type (over 90%) and climate (over 70%) played a role.

Question 2 reads as:

“Which of the following can greatly affect erosion rates? (Students are asked to select true or false.)

1. Rock Type
2. Earthquakes
3. Time
4. Climate

The requirement for a correct answer is to choose 1 and 4 as true and 2 and 3 as false. There were a low number of correct answers for Number 2 with 10.3% correct in the pre-test and 6.3% correct in the post-test. Although fewer students selected both correct answers on the post-test, it is notable that a higher number of students selected 1 and 4 as answers for the post-test. One of the distracters uses the word “rate” which may be a source of confusion in answering the question. Use of the term “rate” may imply to some students a time rate.
One interesting outcome is the large percentage of students that answered “earthquakes” as a factor. The percentage actually increased slightly between the pre-test and post-test (49.7% to 55.3%). These answers indicate some misconception that students bring to the class concerning earthquakes and erosion has persisted throughout the class. Future efforts should be made to identify what these misconceptions are and steps should be taken to reinforce correct concepts with instruction.

Figure 24. Student performance on GCI question 2. Only a very small number of students scored correctly on Question 2 with the number decreasing from approximately 10% in the pre-test to 6% in the post-test. This may be attributed in part to the difficulty of the question and the use of the word “rate”. About half the students selected earthquakes as a factor in erosion rates in both pre-test and post-test (49.7% to 55.3%). Clearly students must have retained some sort of misconception with earthquakes and erosion.
Question 6 (Figure 25) tests students on their knowledge of glaciers. For students in Florida, completely unfamiliar with glaciers, approximately 20% of students were able to identify all three answers correctly with a slightly higher number of students in the post-test answering correctly. Question 6 reads as:

“Where do you think glaciers can be found today?

1. In the mountains
2. At sea level
3. At the South Pole
4. Along the equator only
5. Anywhere except along the equator”

Figure 25. Student performance on GCI question 6. Only 20% of students gave the three correct answers to have the question scored right but over 70% were able to identify the South Pole as a location likely to have glacial formation.
In order to be scored correctly students were required to answer 1, 2, and 3. Examining the student responses, over 95% correctly answered that 4 would not be correct, along with over 70% that noted 5 would not be correct. A substantial increase (10%) of students answering 1 between the pre-test and post-test indicates that some students did become more aware that glaciers can form in mountains. Also over 70% of students correctly identified the South Pole. Since this test was administered to students that live at or near sea level in Florida, it is likely that their perception of “sea level” may be influenced by their everyday environment where glacial formation at sea level does not occur.

Question 7 (Figure 26) is another question that tests student knowledge about earthquakes. As previously noted, students are likely to rely on movies for their scientific resources and earthquakes are a popular choice for a disaster movie. The question reads as:

“Which of the following are associated with events that cause large earthquakes?

1. Buildings falling
2. Weather changing
3. Bombs dropping
4. Continents moving
5. Earth’s core changing”

In the case of Question 7, although it is a multiple-choice question, there is only one correct answer, 4 “continents moving”.
Figure 26. Student performance on GCI question 7. Over 80% of the students selected “continents moving” as the correct answer but did not score the question correctly because they selected at least one additional answer. About 70% of students selected “weather changing” as an answer indicating some misconceptions about causes of earthquakes.

A low percentage of students actually chose 4, continents moving, as the only correct answer (16.7% pre-test and 12.9% post-test). Although over 80% selected it as one of their choices, the question was not counted as correct since an additional choice chosen. Student answers included a high percentage of students that selected 3, “bombs dropping”, and 1, “buildings falling”. Assuming students are aware that bombs and buildings falling are not natural occurrences, it is probable that students misinterpreted the question and included man-made disturbances that shake the ground as part of the answer. If that is the case then the answers of 1 and 3 could be considered correct. The word “large” was
probably included in the question to distinguish natural and manmade earthquakes but students did not all make that distinction. Of interest (and concern) is the large number of students that selected “weather changing” as a cause of earthquakes (71.8% on the pre-test and 69.0% on the post-test). Clearly students have some misconception about the influence of weather on earthquakes that should be identified. Weather was not a topic covered in Physical Geology.

Question 9 (Figure 27) tests students on their knowledge about the earth’s interior and heat flow. The structure of the earth’s interior and heat flow are topics discussed throughout the class with the cause of the earth’s heat discussed specifically in the plate tectonics section. The question reads as:

“Which of the following are actively contributing to the heat inside the Earth?

1. Gravitational energy from the Sun
2. Energy from the Earth’s formation
3. Heat energy from the Sun
4. Energy from radioactivity”

Similar to other multiple-response questions students are required to select using true or false which answers are correct. The only correct answer is 4, “energy from radioactivity”. Similar to other multiple-response questions only a very small number of students correctly identified only 4 as the answer. In this case the pre-
test had a higher percentage of students correct (12.3%) in comparison to the post-test (8.2%) but both are still low percentages of the students overall.

![Figure 27. Student performance on GCI question 9. For question 9 both pre-test and post-test had a low percentage of students answering the question correctly. The word “actively” may have been overlooked by some students that also answered 2, “energy from the earth’s formation”. Students must have some misconception concerning the gravitational energy from the sun.](image)

One key word in the question is “actively” as answer 2 is correct but not “actively” occurring. Students likely have some misconceptions concerning the sun’s gravitational energy which should be explored. The force of the sun’s gravity is discussed in class in regards to its role in tides but is not discussed relative to the earth’s interior.
Question 13 (Figure 28) tests students’ understanding of surface processes of weathering and erosion. These processes were thoroughly covered in the course and should be familiar to students as everyday geologic processes. Scores for the question were very good as in both the pre-test and post-test. Question 13 reads as:

“Which of the following are considered common mechanisms for weathering and erosion?”

1. Wind
2. Rain
3. Earthquakes
4. Volcanoes
5. Rivers

To score the question correctly students must name 1, 2, and 5. For both the pre-test and post-test approximately 41% of the students correctly identified all three mechanisms and only those three. This percentage remained the same from pre-test to post-test. Approximately 95% of students in both the pre-test and post-test correctly identified “rain” (water) as a common mechanism in weathering and erosion. Notable are the over 60% of the students that selected either earthquakes or volcanoes or both as a mechanism for erosion and weathering. The question may have identified some misconceptions students
Figure 28. Student performance on GCI question 13. More than 40% of students selected the three correct answers for this question on both pre-test and post-test with no improvement between the two. Possible misconceptions concerning the role of volcanoes and earthquakes in erosion are noted as more than 60% of students selected one or both of the choices.

**Instructor-Specific Test Questions**

Overall the GCI test results indicate no difference in scores between the pre-tests and post-tests and in many cases the post-test scores were lower. Similar results were also reported by other studies (Libarkin and Anderson, 2005). Since most students completed all assignments and seemed to work diligently during the class, it was puzzling that there was little to no difference
between the GCI pre-test and post-test. It is also baffling that the average student score reflected less than 30% correct answers. In order to investigate why student scores did not change, an alternative instructor-specific pre-test/post-test was developed and the results were compared with the GCI test. The motivation for the development of the instructor-generated test was to determine if there were indeed differences between the instructor-specific pre-tests and post-tests or if the findings of the GCI would be confirmed. It is reasonable to assume that the instructor would have a much stronger influence on the specific test than the GCI test. The specific test would directly reflect the instructor’s teaching style, philosophy on content delivery, and ways of asking and answering questions, while the GCI may not.

The following question serves as an example. The same question (Question 14) is also asked in the GCI with slightly different phrasing. The question reads:

What drives plate tectonics? (Q9)

A. Magnetic reversals
B. Mantle convection
C. Solar energy
D. Volcanism

The answer is B, mantle convection. The results of the pre-test were 60.6% correctly identified mantle convection, 28.3% answered magnetic reversals, and 11.1% selected volcanism (Figure 29). No one selected solar energy on either
the pre-test or post-test. The post-test scores were improved with 83.5% of students answering mantle convection correctly. Magnetics was selected by 15.2% of the students, considerably lower than the over 40% of students that

Figure 29. Student performance on instructor-generated question. In the pre-test 60.6% of students correctly identified mantle convection as the answer. The number answering correctly rose to 83.5% in the post-test (Final Exam). No one selected solar energy on either the pre-test or post-test.

selected it on the GCI but still indicative of the previously mentioned misconception about role of the earth’s magnetic field in plate tectonics. A possible reason that such a high percentage of students selected magnetism on the GCI may be that the most straightforward answer of mantle convection was not given.

Overall improvement in performance on the instructor-specific test was obvious (Figure 30) with a shift to higher scores on the post-test. The average
for the pre-test was 43.5 and the average score for the post-test improved to 76.3, in other words an improvement from an F average to a C average. This contrasts substantially with the 30% correct percentage of the GCI. The 32.8 point difference between the pre-test and post-test average of the instructor specific test confirms markedly better student learning.

Figure 30. Student performance on the instructor-generated pre-test and post-test. There was a dramatic improvement in student scores between the pre-test and post-test indicating that a significant amount of student learning did occur during the class.

These results illustrate the difficulty of writing general non instructor-specific questions to assess student learning. This difficulty has also been recognized by the creators of the GCI and they have appealed to the
geosciences community for assistance in developing and testing effective questions. From this study, these specific suggestions should be considered:

1) Expand the number of questions to more than 16, as it is difficult to evaluate a semester-long course in only 16 questions.

2) Reconsider the scoring on multiple-response questions. Partial credit could be given for getting one answer correct even if others were required. This would recognize that students have at least a partial understanding of the concepts.

3) Expand the number of questions to consider more on sedimentary geology. There are a number of questions on earth history but not many on sedimentary geology.

4) Divide the GCI into multiple sub-discipline tests consisting of the 16 questions as has been done in other science disciplines (biology, physics). Students could take several concept inventories throughout the semester when they had finished the applicable course materials.

5) Research common incorrect answers and identify which misconceptions students are most likely to have to give that answer. Provide instructors recommendations of learning activities to reinforce the correct concepts.
Limitations of Study

The following items should be considered possible limitations of this study:

1) The population of the study was restricted to students taking Physical Geology at one public community college, Hillsborough Community College in Tampa, Florida.

2) The student populations of online and face-to-face classes are likely not identical in all characteristics, as students are not assigned randomly to the face-to-face and online courses. Students who choose to register for online courses may thus be more computer-proficient and able to work more independently than the face-to-face students.

3) The only comparisons between student performances in the face-to-face classes and online classes relate to the four instructor-generated tests. No other graded assessments were considered in this study.

4) The comparison of student performances regarding different term lengths was conducted only among the online course offerings, as face-to-face courses were not offered in different length terms.

5) The question subset from the Geoscience Concept Inventory was assigned as an extra credit opportunity to the students, and extra credit was awarded solely based on its completion, and not on their scores. The instructor-generated comparison test was also graded on completion, and was assigned as a pre-test. In both cases, students earned points for completing the assessment. In contrast, the post-test was given as the
Final Exam, and was scored based on number of questions correctly
answered. Given these differences in implementation it is possible
students did not expend similar effort on the GCI and instructor-generated
comparison tests as they did on their final exams.

6) Testing methods were necessarily not identical in the face-to-face and
online courses. Face-to-face students take their tests in a traditional
classroom using pencil and paper. Online students take their tests using a
computer at a location of their choosing. The time allotted for tests in both
delivery types are identical. However, students taking tests online do not
have the opportunity to go back and revisit questions.
Chapter 7: Conclusions

Assessment of student learning is a complicated multi-faceted process but is vital to quality teaching. Instructors need to know that the students are learning and understanding what is being taught. Student learning may be affected by differences in delivery methods and differences in class term length. Students may enter the class with misconceptions that can interfere with learning. Because there are so many measures of learning, it is hard to decide which measure is the best. The approach taken here uses the student test scores as they appear to be the best direct measure.

Although distance learning courses have long been offered in colleges, the number and type of courses offered was limited. With the increased accessibility of the Internet to the public and increased ownership of personal computers, the stage was set for the explosive growth in online learning. Along with this growth have been concerns about the quality of the Internet-based courses and if student learning is comparable to face-to-face classes.

In the studies reported above, students in the face-to-face classes did slightly better overall on class tests than the online students (73.07% versus 71.62%) but the difference is not statistically significant. Therefore, throughout
three years, spanning six semesters and over 300 students, no difference in overall student performance is seen between students taking the class face-to-face and students taking the class online, based on class tests. The delivery method does not have significant influence on student test scores as demonstrated by similar average score per term, similar standard deviation, and similar normal distribution pattern. Therefore in this study the delivery method used for Physical Geology does not appear to affect student test performance.

Based on the three-year nine-semester study involving 491 students in an online general education physical geology course, overall student performance evaluation based on four tests was largely similar during the sixteen-week fall and spring terms as compared to the nine-week summer terms. Term length does not have a significant influence on student performance, as demonstrated by similar average test scores per term, similar standard deviations, and similar distribution patterns. Student score distributions mimic a normal distribution reasonably well. Although student scores during the summer term of 2011 were noticeably higher than the remaining eight terms with rather similar student performance, an ANOVA statistical analysis determined there was no difference. Therefore it is reasonable to conclude that term lengths do not have significant influence on student performance in an online general education physical geology course. The comparatively shorter timeframe may be an advantage in that it allows students to more easily retain materials learned during the summer term and compensate for the shorter time interval to absorb the knowledge. Students may also take fewer classes during the shorter summer term than
during the longer fall and spring terms, allowing them to be better focused on the classes.

The average student score during the three fall terms is the lowest, followed by the average of the three spring terms, while the average summer term yields the highest score, although the difference is quite small. This small difference may be caused by the fact that the fall terms tend to have the most first-semester-in-college students, whereas the summer terms tend to have a greater number of more experienced transient students from four-year universities and upper-class students, suggesting that student experience and seniority may have some influence on their performance.

Since the basic purpose of Physical Geology is to teach students about geology in the context of developing critical thinking skills for using science, it is important to know that students are learning the subject material and learning to use critical thinking skills in science-based problem solving. Instructors should know if students are learning what we think they are learning. The ideal way to evaluate student learning would be a completely validated standardized set of questions that tested thoroughly students’ geologic knowledge. The Geoscience Concept Inventory was developed with the goal to try and fill this need.

Based on a set of sixteen GCI questions selected by the instructor, no difference in student performance was found between pre-test and post-test in terms of average score and score distribution. The average score on the GCI for both pre-test and post-test represents approximately 30% of correct answers.
which would correspond with a letter grade of F. The highest score for both pre-
test and post-test was 69%. On average students performed better on single-
response questions than on multiple-response questions. Five of the seven 
questions with the highest positive difference between pre-test and post-test 
were single-response questions. Some misconceptions were identified by the 
GCI; however, little to no improvement was noted in the post-test. It is likely that 
the answers provided do not represent the most important aspects of the 
question, and that some of the choices may not be clear to students.

In contrast to the GCI, remarkable improvement in student learning is 
illustrated by the instructor-specific test. There may be a number of reasons for 
this. Students may have adapted more to the individual instructor’s test writing 
style and teaching style throughout the semester. The pre-test and post-test for 
the instructor-given tests were assigned as a grade, perhaps prompting the 
student to take the test more seriously and consider the answers more carefully. 
The questions written are instructor-specific and course-specific, meaning that 
the students likely were introduced to the concept with more clear emphasis and 
multiple times. Most questions on the instructor-generated test were single-
response questions which generally result in more correct answers.

This study illustrates the difficulty of writing general non-instructor specific 
questions to assess student learning. This difficulty has also been recognized by 
the creators of the GCI and they have appealed to the geosciences community 
for assistance in developing and testing effective questions.
As this study has shown, it is important for instructors to know that their students are learning the subject materials they are teaching. The delivery method and length of term do not appear to matter in the Physical Geology course. Student achievement is the same in both face-to-face classes and online courses. Student achievement is the same in semester-long courses as it is in shortened summer terms. What does make a difference is the instructor recognizing possible misconceptions and working to clarify those concepts to the students. The GCI was useful in identifying misconceptions but was not as good a predictor of student achievement as the instructor-generated class tests. Continued research into student misconceptions and activities that help dispel the misconceptions is a natural outcome of this study.
References


Appendix A: Geoscience Concept Inventory Questions

1. Some scientists claim that they can determine when the Earth first formed as a planet. Which technique(s) do scientists use today to determine when the Earth first formed?

   Choices: True, False.
   A. Comparison of fossils found in rocks
   B. Comparison of layers found in rocks
   C. Analysis of uranium found in rocks
   D. Analysis of carbon found in rocks
   E. Scientists cannot calculate the age of the Earth

2. Which of the following can greatly affect erosion rates?

   Choices: True, False.
   A. Rock type
   B. Earthquakes
   C. Time
   D. Climate

3. Some people believe there was once a single continent on Earth. If this single continent did exist, how long did it take for the single continent to break apart and form the arrangement of continents we see today?

   A. Hundreds of years
   B. Thousands of years
   C. Millions of years
   D. Billions of years
   E. It is impossible to tell how long the break up would have taken

4. Some people believe there was once a single continent on Earth. Which of the following statements best describes what happened to this continent?

   A. Meteors hit the Earth, causing the continent to break into smaller pieces
   B. The Earth lost heat over time, causing the continent to break into smaller pieces
   C. Material beneath the continent moved, causing the continent to break into smaller pieces
   D. The Earth gained heat over time, causing the continent to break into smaller pieces
   E. The continents have always been in roughly the same place as they are today
5. Some people believe there was once a single continent on Earth. Which of the following statements best describes what happened to this continent?
A. All solid, rigid rock beneath the continents and above deeper, moving rock
B. All solid, rigid rock beneath the continents and oceans and above deeper, moving rock
C. All solid, rigid rock that lies beneath the layer of loose dirt at the Earth’s surface and above deeper, moving rock
D. All solid, rigid rock and loose dirt beneath the Earth’s surface and above deeper, moving rock
E. The rigid material of the outer core

6. Where do you think glaciers can be found today?
Choices: True, False.
A. In the mountains
B. At sea level
C. At the South pole
D. Along the equator only
E. Anywhere except along the equator

7. Which of the following are associated with events that cause large earthquakes?
Choices: True, False.
A. Buildings falling
B. Weather changing
C. Bombs dropping
D. Continents moving
E. Earth’s core changing

8. A large, ashy volcanic eruption occurs in Europe. Which effect would this eruption have on the air temperature near the Earth’s surface one year later?
A. Volcanic eruptions do not affect air temperature
B. Only the air in Europe would be warmer
C. Most of the Earth’s air would be warmer
D. Only the air in Europe would be colder
E. Most of the Earth’s air would be colder

9. Which of the following are actively contributing to the heat inside the Earth?
Choices: True, False.
A. Gravitational energy from the Sun
B. Energy from the Earth’s formation
C. Heat energy from the Sun
D. Energy from radioactivity
10. Tony has a black rock that does not reflect light. He cuts it open and the inside looks like the outside. Can Tony determine if the rock contains iron simply by looking at it?
A. Yes. The rock is black and therefore does not contain iron
B. Yes. If the rock contains iron, Tony would see silver specks in the rock
C. Yes. Tony can use a microscope to see if the rock contains very small pieces of iron
D. No. Tony would not be able to see if the rock contains iron, even with a microscope
E. No. Tony cannot look at the rock since it does not reflect light and is therefore invisible

11. What causes most of the waves in the ocean?
A. Tides
B. Earthquakes
C. Wind
D. Tsunamis

12. During a recent trip to Canada a traveler visited two mountains made up of the same type of rock. The sketches below represent the outlines of these two mountains. Which of the following reasons best explains the differences in the two drawings?

A. Mountain I is older than Mountain II
B. Mountain II is older than Mountain I
C. Mountain I is on a continent that is moving faster than the continent Mountain II is on
D. Mountain I is on a continent that is moving slower than the continent Mountain II is on
E. Mountain I has experienced more erosion than Mountain II

13. Which of the following are considered common mechanisms for weathering and erosion?
Choices: True, False.
A. Wind
B. Rain
C. Earthquakes
D. Volcanoes
E. Rivers

14. What is the best explanation for the movement of tectonic plates?
A. Lava moves the tectonic plates
B. Currents in the ocean move the tectonic plates
C. Earthquakes move the tectonic plates
D. Gravity moves the tectonic plates
E. Magnetism moves the tectonic plates

15. How big was the planet Earth when dinosaurs first appeared?
A. Smaller than today
B. Larger than today
C. Same size as today
D. We have no way of knowing

16. Which of the following best describes what scientists mean when they use the word “earthquake”?
A. When an earthquake occurs, visible cracks appear on the Earth’s surface
B. When an earthquake occurs, people can feel the Earth shake
C. When an earthquake occurs, man-made structures are damaged
D. When an earthquake occurs, energy is released from inside the Earth
E. When an earthquake occurs, the gravitational pull of the Earth increases
Appendix B: Data used in Study
## Face-to-face Average Test Scores

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Appendix C: Course Syllabi and Schedule
PHYSICAL GEOLOGY FACE-TO-FACE SYLLABUS

GLY 1010
Physical Geology
Spring 2011

Class Schedule:  Face-to-face: Monday/Wednesday 11am-12:15pm

Course Description:
Covers basic geology and concepts and principles. Topics include origin and structure of the earth, processes involved in shaping the earth’s crust, the nature and classification of earth materials, and the dynamic interactions of the lithosphere with the hydrosphere and the atmosphere that produce characteristic landforms.

Co-requisite: GLY 1010L

Course Objectives:
1. Describe the scientific method and discriminate between scientific and nonscientific information.
2. State the age of the Earth as determined by scientific means and divide geologic time into the established Eras, Periods, and Epochs of the Geologic Time Scale.
3. Describe the structure of an atom and discuss how atoms bond, relating this to the structure and properties of minerals.
4. Define what a mineral is and describe the relationship of minerals to rocks.
5. Describe the Rock Cycle, listing and relating its products and processes.
6. Describe how igneous rocks may be characterized by their texture, composition, and provenance.
7. Describe the origin of magma and the nature of intrusive and extrusive igneous processes and landforms.
8. Describe the Earth’s differentiated structure and list the names and properties of the Earth’s internal layers.
9. Describe and discuss the basic tenants of the theory of Plate Tectonics, including the origin of the theory, the types of plates, and the nature and consequences of their interactions.

10. Relate the theory of Plate Tectonics to the locations and occurrence of geologic hazards including earthquakes, tsunamis, and volcanic activity.

11. Describe the Hydrologic Cycle, both in general terms, and how it specifically relates to geologic processes.

12. Describe the formation, properties and classification of sedimentary rocks.

13. Describe the processes involved in metamorphism and discuss the textural and mineralogical changes that occur in metamorphic rocks.

14. List and describe the major types of crustal deformation and associated geologic structures.

15. Define and describe the processes of weathering, erosion, and mass movement (mass wasting).

16. Describe fluvial processes and landforms.

17. Describe the processes effecting shorelines and the resultant shoreline features.

18. Describe the distribution and movement of water in the earth’s crust, relating this to Karst topography and other hydrogeological features such as springs, hot springs and geysers.

19. Describe the origin and nature of glacial landforms and the circumstances that have been hypothesized to explain the Pleistocene glaciations. Describe the role of wind as a geomorphic agent, listing the major types of aeolian erosional and depositional features, and the location of their occurrence.

**Required Text Books:**

- *Understanding Earth*, 6th edition, by Grotzinger and Jordan
- *Notes and Study Guide*, by M. Caldwell

**Online Classroom:**

A classroom website is available for student use at: [online@hccfl.edu](mailto:online@hccfl.edu). The classroom gradebook will be kept on the website so that students can access grades at any time. You may also use the classroom email for communications.
and to upload assignments. The extra credit quizzes are accessed through the classroom and narrated powerpoint lectures are posted for each chapter.

In order to login please follow these directions:

1) Go to the HCC website at: http://www.hccfl.edu

2) Click on the link at the upper right area of the website that says: online@hcc

The direct link is: http://www.hccfl.edu/distance-learning/dl-splash.aspx

3) Click on the uppermost link in the shaded box.

4) Follow the directions for login; you must know your student ID number; if you have problems, please contact the help line number listed on the login page or HCCLive available from the HCC homepage.

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**Academic Dishonesty Policy:**

Students enrolled in online courses are expected to exhibit academic honesty. Copying or sharing of work is not allowed. Use of outside resources during tests is not permitted. All writing assignments must be written in your own words.

**Attendance Policy:**

Students are expected to attend each class meeting and attendance will be recorded. Please arrive prior to the start time of each class. During the class students are asked to refrain from using cell phones for calls or text messages.

**Instructional Methods:**

The grades of the course will be based on four test grades weighted at 16% each. Four tests will be given along with an optional cumulative final test. The grade on the cumulative exam may be used to replace your lowest test grade. There are no makeup tests given so if you miss a test, then you must take the final to replace the grade. The tests will be composed of multiple choice, fill-in-the-blank, short answer, or some combination of these question types. You will need a scantron for each test.
A Powerpoint Presentation on a geological feature and a field trip to Upper Tampa Bay Park will be required. The Powerpoint presentation consisting of 10-15 slides describing the geology of a specific geologic feature will make up 16% of the class grade. The Field Trip to Upper Tampa Bay Park will make up 5% of the class grade.

The remaining 15% of the grade will be based on in-class worksheets/writing assignments throughout the term. These assignments will be weighted at one point each some must be completed during class time (11am-12:15pm). If you miss a class time in which a worksheet/assignment was given, you receive a zero for that assignment. No late assignments will be accepted. Throughout the term sixteen worksheets will be assigned. If you complete all sixteen, then one will count as extra credit.

Grading for the class will be calculated as follows:

- Test I 16%
- Test II 16%
- Test III 16%
- Test IV 16%
- In-Class Exercises 15%
- Presentations 16%
- Field Trip 5%

The optional final exam may replace the lowest lecture test. It will be weighted at 16%.

**Gordon Rule Assignments:**

The Gordon Rule Requirement for this class will be fulfilled by summaries of the review questions for the class. The review questions can be found at the end of the chapter outlines. There will be four sets of review questions (one for each test). The summaries will be due the class period one week before each of the tests. Please make a copy for yourself before turning in the paper. The answers should be written in the student’s own writing style and should answer at least twenty review questions. The reports should be typed and contain correct grammar and sentence structure. If the reports are turned by the respective due dates, up to 3 additional points may be added to your test as extra credit (maximum of 12 points). Those papers with incorrect grammar and not
containing sentences will not be awarded extra credit. Note that only the typed summaries turned in on time will be counted for extra credit. Late reports or those not typed are not eligible for extra credit. Even if you choose to not earn extra credit at least one set of review questions must be submitted prior to the final class in order to fulfill the Gordon Rule requirement. No review questions will be accepted via email. You must correctly upload the questions onto the classroom website.

**Extra Credit:** Review quizzes are available for each of the chapters on the online@hcc classroom webpage. Although participation in these quizzes is optional, extra credit is available for correctly completing the answers on the quizzes. To access these quizzes, go to the HCC home page. Then click on: online@hcc link (upper right of page). From that link follow the directions to log-on and click on: the first link (near the middle of the page). You will see a list of your classes so click on GLY 1010. From the homepage you should go to the Review Quiz link.

**Request for Accommodations:**

If, to participate in this course, you require an accommodation due to a physical or learning impairment, you must contact the Office of Services to Students with Disabilities. The office is located in the Student Services Building, Room 208. You may also reach the office by telephone at (813) 253-7031 {voice line}; (813) 253-7035 {TTD}

**Tentative Class Schedule M/W:**

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<td>Chapter 2</td>
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<td>Chapters 3 &amp; 4; Test I Review Questions Due</td>
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<td>14</td>
<td>Chapter 7</td>
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<td>Mar  2</td>
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<td>30</td>
<td>Mid-term Break</td>
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<td>April 4</td>
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<td>9</td>
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PHYSICAL GEOLOGY ONLINE SYLLABUS

GLY 1010

Physical Geology Online

Spring 2011

Class Schedule: Online

Course Description:

This course covers basic geology and concepts and principles. Topics include origin and structure of the earth, processes involved in shaping the earth's crust, the nature and classification of earth materials, and the dynamic interactions of the lithosphere with the hydrosphere and the atmosphere that produce characteristic landforms.

Co-requisite: GLY 1010L

Course Objectives:

1. Describe the scientific method and discriminate between scientific and nonscientific information.

2. State the age of the Earth as determined by scientific means and divide geologic time into the established Eras, Periods, and Epochs of the Geologic Time Scale.

3. Describe the structure of an atom and discuss how atoms bond, relating this to the structure and properties of minerals.

4. Define what a mineral is and describe the relationship of minerals to rocks.

5. Describe the Rock Cycle, listing and relating its products and processes.

6. Describe how igneous rocks may be characterized by their texture, composition, and provenance.

7. Describe the origin of magma and the nature of intrusive and extrusive igneous processes and landforms.

8. Describe the Earth's differentiated structure and list the names and properties of the Earth's internal layers.
9. Describe and discuss the basic tenants of the theory of Plate Tectonics, including the origin of the theory, the types of plates, and the nature and consequences of their interactions.

10. Relate the theory of Plate Tectonics to the locations and occurrence of geologic hazards including earthquakes, tsunamis, and volcanic activity.

11. Describe the Hydrologic Cycle, both in general terms, and how it specifically relates to geologic processes.

12. Describe the formation, properties and classification of sedimentary rocks.

13. Describe the processes involved in metamorphism and discuss the textural and mineralogical changes that occur in metamorphic rocks.

14. List and describe the major types of crustal deformation and associated geologic structures.

15. Define and describe the processes of weathering, erosion, and mass movement (mass wasting).

16. Describe fluvial processes and landforms.

17. Describe the processes effecting shorelines and the resultant shoreline features.

18. Describe the distribution and movement of water in the earth’s crust, relating this to Karst topography and other hydrogeological features such as springs, hot springs and geysers.

19. Describe the origin and nature of glacial landforms and the circumstances that have been hypothesized to explain the Pleistocene glaciations. Describe the role of wind as a geomorphic agent, listing the major types of aeolian erosional and depositional features, and the location of their occurrence.

**Required Text Books:**

Understanding Earth, 6th edition, by Grotzinger and Jordan

GLY 1010 Notes and Study Guide, by M. Caldwell

**Grading System:**

100-90% A
89-80%  B  
79-70%  C  
69-60%  D  
less than 60%  F  

**Schedule of Assignments:**

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<tr>
<th>Assignment</th>
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<th>Chapters Covered</th>
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<tr>
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<tr>
<td>Test I Review</td>
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<td>Discussion Board I</td>
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<td>Virtual Field Trip I</td>
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<td>Worksheets 5,6,7,8</td>
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<td>Test II Review</td>
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<td>Discussion Board II</td>
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<tr>
<td>Test II</td>
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<tr>
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<td>Worksheets 9,10,11,12</td>
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<td>Worksheets 13,14,15,16</td>
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<tr>
<td>Discussion Board IV</td>
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<tr>
<td>Test IV</td>
<td>4/15-4/16</td>
<td>18,20,21,23</td>
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Final Exam 4/29-4/30 Cumulative

Any late assignments will be reduced in grade by 20 points per week. No work will be accepted more than one week late. Any test taken late will result in a deduction of 25 points per week. No makeup tests allowed more than one week past the closing date.

**Course Grading:**

Total of 1,000 points:

Four Tests (150 points each) 600 points

Eight Discussion Boards (15 points each) 120 points

Powerpoint Presentation (120 points)

Sixteen Worksheets (5 points each) 80 points

Two Field Trip Reports (40 points each) 80 points

Optional Final Exam (150 points) which maybe be used to replace lowest test grade

Any extra credit points earned will be added to the 1000 point total.

Please allow one week for grading to be completed.

**Academic Dishonesty Policy:**

Students enrolled in online courses are expected to exhibit academic honesty. Copying or sharing of work is not allowed. Use of outside resources during tests is not permitted. All writing assignments must be written in your own words.

**Attendance Policy:**

Students are required to log in a minimum three times a week to complete assignments, participate in discussions, and check email. Students are required to respond to the discussion board no later than five days after the instructor’s posting. Because of the nature of the online course, students are expected to keep up with the readings, participate in the online discussions, and take the tests by the designated completion date. Any late work will be assessed a penalty detailed above. Students are required to read all announcements posted by the instructor.

**Instructional Methods:**
Required:

Tests

Four Tests will be given, weighted at 15% each. An optional cumulative final exam may be used to replace your lowest test score. The tests and final exam will be a combination of multiple choice, short answer, and fill-in-the-blank questions. All tests and exams will be administered online. Please make sure you have a reliable internet connection prior to beginning the tests. If you do not have a reliable connection, please plan to take the tests at one of the HCC campuses. Preparation for the tests and final exam should include the following:

1) Reading and studying the textbook

2) Viewing Powerpoint presentations for each chapter

3) Complete online learning activities for each chapter including flashcards and quizzes.

4) Complete questions in instructor-written study guide for applicable chapters.

Discussion Boards:

Participation in an online discussion board of geologic topics is required. The Gordon Rule requirement for this course will be fulfilled by the discussion board questions. For the discussion boards, students will be given essay-type questions and asked to respond. The answers should be in paragraph form with correct sentence structure and grammar. Each student should write in his or her own writing style. Plagiarism of the works of others should not be done. Students are asked to post a response to both the instructor’s postings and postings made by other students (a minimum of two postings). If you do not post at least the minimum number of postings (two), points will be deducted. In order to count as a posting, you should have a minimum of 50 words per posting. If your writing has spelling or grammar errors, points will be deducted. Students are required to respond to the discussion board no later than five days after the instructor’s posting. If you do not respond within the first five days, points will be deducted. No postings will be accepted after the due date as the late penalty (20 points) is more than the value of the discussion board (15 points).

Worksheets:

Sixteen worksheets are posted under assignments, three per test. Students are required to complete the worksheets and either upload the completed worksheet as a Word file or the answers for the worksheet as a Word file. No submissions
will be accepted after the due date as the late penalty (20 points) is more than the value of each of the worksheets (5 points).

**Virtual Field Trips:**

Two virtual field trips are assigned which may be viewed in the virtual classroom. These will open when we cover the corresponding chapters to the topic. Students are required to complete questions relating to the field trips. The links to the narrated field trips and questions can be found at: “Chapter Resources”.

**Powerpoint Presentation:**

A Powerpoint Presentation on a geological feature will be required. The Powerpoint presentation consisting of 10-15 slides describing the geology of a specific geologic feature. Please see the supplementary attachment for specifics about the presentation and a list of topics. Your topic choice will be due prior to the presentation date.

**Discussion Boards:**

The Gordon Rule requirement for this course will be fulfilled by the discussion board questions. For the discussion boards, students will be given essay-type questions and asked to respond. The answers should be in paragraph form with correct sentence structure and grammar. Each student should write in his or her own writing style. Plagiarism of the works of others should not be done.

**Late submissions:** Any late assignment will result in a penalty of twenty points. Submissions more than one week late will not be accepted. For example, if you are one day late with a field trip, the highest grade you can receive is 20 out of 40. Assignments and tests are due at 11:30pm on the due date. Those submitted afterwards will be considered late.

**Optional Extra Credit:**

**Review Questions**

There will be four sets of review questions (one for each test) available for extra credit due one week before each of the tests. You do not have to use paragraph form but the answers should be written in the student’s own writing style and should answer at least twenty review questions. The reports should be typed, in complete sentences, and contain correct grammar and sentence structure. If the reports are turned by the respective due dates, up to 3 additional points may be added to each test as extra credit (maximum of 12 points out of 1000). Those papers with incorrect grammar and not containing complete sentences will not be
awarded extra credit. Late reports are not eligible for extra credit. At least one of the set of Review Questions must be turned in for the Gordon Rule requirement.

**Review Quizzes**

In addition to the review question for the Gordon Rule, students may earn extra credit points by completing the Online Review Quizzes. Any points earned will be added to the 1000 point total. These will be open throughout the time we are covering that set of material but will close the evening before each of the exams open. Therefore the review quizzes will close on Thursday evening before each of the tests and will not re-open. Please make note of the date each closes and plan your work accordingly.

**Help with online@hcc (WebCT) or technical issues:**

If you require assistance with the use of online@hcc, please go to the home page of the online@hcc website and information about how to get help is available. The link is on the same page and right below where you login. Alternatively you may access the help site from the HCC home page through HCCLive.

**Privacy Statement:**

Students using online formats for study at HCC do so in a respectful, protected environment. However, this learning environment may at times be viewed by faculty (both current and those learning to become online facilitators), Distance Learning staff, and other experts, who are working with us to maintain the highest quality online courses. Please understand that this is not a secure, private environment.

**Request for Accommodations:**

If, to participate in this course, you require an accommodation due to a physical or learning impairment, you must contact the Office of Services to Students with Disabilities. The office is located in the Student Services Building, Room 208. You may also reach the office by telephone at (813) 253-7031 {voice line}; (813) 253-7035 {TTD}
Appendix D: Permissions

Permission to use Geoscience Concept Inventory

Re: GCI
Julie Libarkin [libarkin@msu.edu]

You replied on 3/28/2012 8:37 AM.

Sent: Wednesday, March 28, 2012 3:52 AM
To: Caldwell, Marianne
Cc: Emily Geraghty Ward [emily.ward@rocky.edu]

Marianne:

I do remember you, and appreciate your help on our project! I am excited to hear you are writing up your dissertation - if you have any questions about analysis of the GCI, feel free to ask.

The GCI is essentially an open source instrument, so anyone is welcome to use the questions. This is a good reminder to me that I need to post a statement about use of the GCI.

You might be interested in our much improved online system for using the GCI: https://www.lecturetools.com/ci

Take care and good luck,
Julie
Permission to use GCAGS paper

Marianne O'Neal-Caldwell Jul 3 (9 days ago) to pubsales,

Hello Amanda,

We spoke on the phone earlier today. I am requesting permission to use a paper from the GCAGS Transactions in 2006 in my dissertation. I am the first author on the paper and it is entitled "Regional Overwash from Hurricanes Frances-Jeanne and Ivan".

Thank you,

Marianne O'Neal Caldwell

Ph.D. Student

pubsales pubsales@beg.utexas.edu Jul 10 (2 days ago) to me

Hi Marianne, Please consider this e-mail as your permission to use the material you cited. We would appreciate acknowledgment of the source (GCAGS Transactions, v. 56, pages xx—yy)), but if it’s too late to do that, never mind.

Sincerely,

Amanda

Amanda R. MastersonManager, Publications Sales for GCAGS, GCSSEPm, and UTBEGUT Bureau of Economic GeologyBox X, University StationAustin, TX 78713-8924 pubsales@beg.utexas.edu
Regional Overwash from Hurricanes Frances-Jeanne and Ivan

Marianne O’Neal-Caldwell, Ping Wang, Mark Horwitz, James H. Kirby, and Swagata Guha
Coastal Research Laboratory, Department of Geology, University of South Florida, Tampa, FL 33620

Abstract

Four strong hurricanes impacted a large portion of Florida coast within a month during the summer of 2004. Hurricane Ivan impacted nearly the entire Florida panhandle coast causing tremendous overwash deposits. Hurricanes Frances and Jeanne, impacting nearly the same location along south Florida Atlantic coast, also resulted in substantial overwash deposits. Overwash from Hurricane Charley is limited. This study compares the overwash deposits from Hurricanes Frances-Jeanne and Ivan. The overwash deposits from Frances and Jeanne are relatively restricted in aerial extent, being localized north of the eye and mostly within 30 km. In contrast, overwash deposits from Ivan are far more extensive, stretching over 120 km from the eye. Overwash from France-Jeanne typically transgressed into the backbarrier mangrove swamp and displays a tongue shape. The shape and extent of the overwash fans/tongues are influenced by the vegetation density. The extensive overwash from Hurricane Ivan typically does not display an overall fan shape. The different overwash extents and sedimentological characteristics are influenced by both hurricane intensity and pre-storm morphology, particularly the latter for this case.
INTRODUCTION

Storm overwash comprises one of the major processes controlling barrier-island morphology (Leatherman, 1977; Leatherman and Williams, 1977) and stratigraphy (Leatherman and Williams, 1983; Morton, 1978; Sedgwick and Davis, 2003). The tremendous overwash deposit induced by the hurricanes in 2004 provides an excellent opportunity for an in-depth study on regional overwash processes and stratigraphy.

Sallenger (2000) developed an impact scale incorporating both storm and morphological factors. Four parameters, $D_{\text{HIGH}}$, $D_{\text{LOW}}$, $R_{\text{HIGH}}$, and $R_{\text{LOW}}$, are used to evaluate the level of morphological impact. $D_{\text{HIGH}}$ is the elevation of the highest part of the “first line of defense” (e.g., the foredune ridge). $D_{\text{LOW}}$ is the elevation at the base of dune. For beaches without a foredune ridge, $D_{\text{LOW}} = D_{\text{HIGH}}$. $R_{\text{HIGH}}$ and $R_{\text{LOW}}$ are representative high and low elevations of the landward margin of swash. When $R_{\text{HIGH}}$ is lower than $D_{\text{LOW}}$, swash regime, the first and least severe impact level occurs. When $R_{\text{HIGH}}$ is lower than $D_{\text{HIGH}}$ but higher than $D_{\text{LOW}}$ (on beaches with foredune ridge), collision regime, the second impact level occurs with extensive dune scarping. Overwash does not occur under these two impact scales. When $R_{\text{HIGH}}$ is higher than $D_{\text{HIGH}}$ but $R_{\text{LOW}}$ is lower than $D_{\text{HIGH}}$, overwash regime, the third impact scale, occurs (Morton and Sallenger, 2003). The fourth and most severe impact, the inundation regime, occurs when $R_{\text{LOW}}$ exceeds $D_{\text{HIGH}}$. All four regimes occurred at a regional scale along the northern Florida coast accompanying the passage of Hurricane Ivan (Wang et al., in press).
The first major hurricane in 2004 was Charley, making landfall on August 13th along the southern end of the barrier-island chain along Florida west coast (Fig. 1). Although a Category 4 at landfall, the small and rapidly moving Charley only caused minor morphological impact. Frances made landfall at the southern end of Hutchinson Island along Florida Atlantic coast on September 5th as a strong Category 2 hurricane. Just 3 weeks later, on September 26th, Jeanne, a large category 3 hurricane, made landfall at almost the same location as Frances. On September 16th, just west of Gulf Shores, Alabama, Ivan made landfall as a strong Category 3 hurricane. Ivan was a very large slowing moving storm with an eye 75-95 km wide.

The objectives of the study were 1) to examine the different characteristics of overwash deposits on Florida barrier islands from the 2004 hurricanes, 2) to evaluate the factors influencing the volume and extent of overwash, and 3) to apply the Sallenger model (2000) to characterize the 2004 storm impacts and predict future impacts.

**STUDY AREAS**

Regional extents and sedimentological characteristics of overwash deposits caused by Hurricanes Ivan, Frances, and Jeanne are examined in this study. The study of the Frances-Jeanne overwash is focused at two sites on Hutchinson Island (Fig. 1). The study of the widely spread overwash from Hurricane Ivan was conducted at four sites on Santa Rosa Island (Fig. 1).
The East Coast of Florida is oriented north-south along the Atlantic Ocean. The average (from 1988 to 2001) monthly wave conditions measured by the NDBC (National Data Buoy Center) station 41009, 37 km East of Cape Canaveral at 42 m water depth, is shown in Figure 2. The monthly average significant wave height ranges mostly from 1 to 2 m. The waves are higher during the winter time from October to March, averaging around 1.4 m. During the summer months from April to September, the waves are calmer, averaging around 0.9 m. The maximum wave height, reaching 10 m, measured during summer months is apparently related to hurricanes. The maximum wave height during winter storms reaches up to 6 m. The highest wave recorded at this station (to the north of the storm tract) during Frances was 7.5 m. The gage stopped functioning shortly after that and was repaired after Jeanne.

This stretch of Florida Atlantic coast is heavily developed. A tremendous amount of sand was washed over parking lots and into lower housing units. The study area is located in an undeveloped area with mangrove swamps landward of the beach and the narrow low dunes. The sediments have a large variability in size and texture with a high concentration of shell debris.

The Northwest Coast of Florida, commonly called the Florida panhandle, presents a different coastal environment as compared to the Atlantic coast. The panhandle coast is oriented east-west along the Gulf of Mexico. The continental shelf is wide and shallow. Figure 3 summarizes the average monthly wave conditions at NDBC station 42039 (from 1995 to 2001), 210 km east southeast of Pensacola at a water depth of 290 m. The significant wave heights average
around 1.2 m during the winter months and 0.8 m during the summer months. The maximum wave height approaching 10 m measured in September is apparently related to hurricanes. A wave height of 16 m was measured during the passage of Ivan (Wang et al., in press). It is worth noting that this gage is over 200 km offshore, the nearshore wave conditions are also significantly influence by local wind conditions and may be quite different from the offshore conditions.

The panhandle barrier islands are characteristic of homogeneous sediment, both texturally and size-wise. Over 98% of the sediment is quartz sand with over 75% of the sediment ranging from 0.2 to 0.4 mm (Stone and Stapor, 1996). Shell concentration is typically low. A small amount of heavy minerals can be found (Staper, 1973). Although typically low concentrations, the heavy minerals are crucial for separating and identifying sedimentary layering.

**METHODOLOGY**

This field-oriented study is conducted from three approaches. The first approach focused on collection of existing remote sensing data, including pre- and post-storm aerial photos. This is followed by field observations and some pre- and post-storm morphological surveys. The third approach focuses on the collection of subsurface data. Overall, 68 cores, 6 trenches, and approximately a total of 30 km of GPR (Ground Penetrating Radar) profiles were collected. Analyses of this large dataset, especially interpretation and correlation of the GPR profiles, are currently underway. The current paper focuses on regional examination and
comparison of the overwash deposits along the Florida panhandle and Atlantic
coasts, based mostly on aerial photos, pre- and post-storm field observations,
trenches, and cores. The Sallenger (2000) scale is used to classify the hurricane
impacts. Detailed analysis and discussion of the regional GPR profiles are
beyond the scope of this paper.

RESULTS AND DISCUSSION

Significant differences in terms of regional distribution and sedimentological
characteristics are observed comparing the overwash deposits by Hurricanes
Ivan and Frances-Jeanne. In the following, the similarities and differences of the
Atlantic and panhandle overwash deposits are examined and the controlling
factors are discussed.

Overwash Intensity and Regional Distribution

Despite being struck by two consecutive hurricanes with in one month, regional
distribution of the overwash deposits along the Florida Atlantic coast is much
limited, as compared to the post-Ivan situation along the panhandle coast. The
Frances-Jeanne overwash is largely local and mostly within 30 km from the
hurricane eye. Inundation, defined here as nearly complete removal (or burial) of
the dune-wetland system, did not occur. The overwash did not extend across the
entire barrier island (Fig. 4), except at one narrow location. The Ivan inundation
and overwash, on the other hand, extended over 120 km from the hurricane eye.
Regional inundation occurred within 60 km from the eye, along with tremendous
amount of sand being washed across the entire barrier island and into the back-barrier bays (Fig. 5). Along developed sections of the coast, a tremendous amount of sand, often over 1 m thick, was washed over parking lots, roads, and lower units of houses during all three hurricanes.

The environment immediately landward of the beach is dominated by dense mangrove swamp along the studied Atlantic coast, while along the panhandle coast, dunes of various sizes, heights and vegetation coverage, and coastal marsh dominate. This different back-barrier environment has significant influence on the overwash morphology. The dense mangrove swamp limited the landward extent of the washover. At places with less dense vegetation, washover extended further landward, forming many tongue-shaped sand bodies (Fig. 6). Therefore, the vegetation density had considerable influence on the extent and shape of the overwash deposits at a local scale. Only the large densely vegetated (with trees and bushes) dunes survived the extremely powerful Ivan overwash and inundation within 100 km from the hurricane eye (Fig. 5). Lower dunes with grass-type vegetation and the low-lying marsh environment were largely overwhelmed by the hurricane and had little limiting effects on the overwash morphology. Therefore, the Ivan overwash, within 100 km from the eye, is regionally extensive and massive and does not demonstrate fan or tongue shape, except locally at the landward tip. Pre-storm morphological constrain increases further away from the hurricane eye, as expected. Overwash fans in between dunes become more common further away from the eye.
Two episodes of overwash were apparent along the studied Atlantic coast, as indicated by the two lobes, one by Frances and one by Jeanne (Fig. 6). Their regional extents are similar. At the two studied locations, the Frances overwash extended further than the Jeanne overwash. At places where Jeanne overwash extends further, Frances overwash may be simply buried.

**Sedimentological Characteristics**

The sedimentological characteristics of the Frances-Jeanne overwash were studied at two locations (Fig. 4). At location 1 (L1), the overwash extended into a mangrove swamp. At location 2 (L2), the overwash extended into a lake, which is an unusual case. Overall, the overwash deposits ranged from 0.5 to over 1 m thick. The bottom of the overwash is obvious at L1, indicated by the organic-rich sand of the mangrove swamp (Fig. 7). The base of the overwash is not obvious at L2 due to the homogeneity of the sediment (Fig. 7). Two layers of shell debris containing large (>0.5 mm) pieces can be distinguished from most of the cores from L1, likely representing the two overwash events of Frances and Jeanne. Fining upward graded bedding with the coarse shell layer at the bottom can be distinguished. The overwash sediments at L2 are more homogeneous with much less large shell pieces. The two overwash events cannot be distinguished in the overwash fans into the lake. Fine scale laminations are difficult to distinguish due to the coarse poorly sorted nature of the sediment with high shell debris concentrations. However, various features including plane bedding, inclined bedding, and scour holes can be distinguished from the GPR profiles (Horwitz and Wang, in press).
Overwash deposits of over 1.2 m thick are measured along the Florida panhandle after Ivan impact based on pre- and post-storm surveys (Wang et al., in press), cores, and trenches. The base of the overwash deposits can be distinguished using several pieces of evidence. Buried non-decayed vegetation provides the most straightforward evidence for the overwash deposits (Fig. 8). Layers with relatively concentrated organic material or bioturbation traces also provide solid evidence. Concentrated heavy minerals can also be used to determine the base of the overwash, as well as the sedimentary structures within the overwash deposits. Due to the homogenous nature of the sediments, the bases of the Ivan overwash are difficult to distinguish at many places, e.g., over low dune field and over bayside beach and into the back-bay. Sedimentological features at two overwash fans are discussed in detail in Horwitz and Wang (in press). Overall, horizontal bedding dominates the overwash platform. Inclined bedding, sometime at a high angle (avalanche bedding), is common in the vicinity of the landward end of lobes (Fig. 8).

CONCLUSIONS

Tremendous overwash deposit occurred during the 2004 hurricane season. Although directly impacted by two consecutive hurricanes within one month, the overwash deposits along the Florida Atlantic coast are much less widespread as compared to the Ivan-induced overwash along the Florida panhandle. The different overwash extents are influenced not only by the hurricane intensity but also by the morphological characteristics of the coast. The latter may have a
more significant influence for this case. Factors controlling overwash deposits can be divided into two categories: hurricane related oceanographic factors and non-hurricane related pre-storm morphological factors. The hurricane-oceanographic factors include strength, size, and moving speed of the storm and characteristics of the continental shelf. These factors control the driving mechanisms including the elevated storm water level (storm surge, wave setup, and swash runup) and the height of storm waves. The morphological characteristics of the receiving environment also have significant influence on the overwash intensity. These factors include height and longshore-crossshore extension of the dune field, density and type of vegetation over the dunes, width of the barrier island, and density and type of vegetation in the back-barrier environment. The morphological factors determine how the overwashing forces is received and dissipated, and therefore, how the overwash deposits are formed. The two overwash events due to Frances and Jeanne can be distinguished both morphologically and stratigraphically.

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Figure 1. Study areas and the hurricane tracks. Note that Hurricanes Frances and Jeanne made landfall at nearly the same locations.
Figure 2. Average monthly wave conditions along the studied Atlantic coast (from 1988 to 2001). The error bars indicate one standard deviation and the diamond represents the maximum wave height.

Figure 3. Average monthly wave conditions along the Florida panhandle coast (from 1995 to 2001). The error bars indicate one standard deviation and the diamond represents the maximum wave height.
Figure 4. Overwash caused by Frances and Jeanne and the two study locations.
Figure 5. Extensive overwash along the Florida panhandle coast. Photos from the western end of Santa Rosa Island (Ft. Pickens State Park).

Figure 6. Overwash into mangrove swamp. The insert shows the two episodes of the overwash by Frances and Jeanne, respectively.
Figure 7. Cores from study locations 1 and 2 (Fig. 4). Note the two distinctive layers, separated by a coarse shell layer, in cores from location 1 (L1_1 and L1_2). The scale bar is in 10-cm divisions.
Figure 8. A trench from the panhandle study area. Note the buried fresh vegetation in an upright position. The scale is in inches (1 inch = 2.54 cm). The total thickness of the overwash deposit is about 1.2 m.