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Development Of A Transferable Student Engagement And Knowledge Retention Framework For The Earth Sciences

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DEVELOPMENT OF A TRANSFERABLE STUDENT ENGAGEMENT AND
KNOWLEDGE RETENTION FRAMEWORK
FOR THE EARTH SCIENCES

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Dedication

This work is dedicated to my grandfather, G.V Apte who exemplified lifelong learning and explored new ideas and thoughts till he left the earth when he was a 103 years old, and my parents Capt. V.K Palsole and Veena V. Palsole, who supported all of us in any quest for learning.

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KNOWLEDGE RETENTION FRAMEWORK
FOR THE EARTH SCIENCES

by

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DISSERTATION

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I would like to thank my advisor Dr. Laura Serpa for being willing to take me on as a doctoral student and encouraging my implementation of new teaching strategies in the courses of study. I particularly am appreciative of the liberal doses of patience and support throughout what was no doubt a vexing process.

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ABSTRACT

The earth sciences play an important role in engaging students in science and in science, technology, engineering and mathematics (STEM) disciplines, because of the integrative nature of the disciplines. It then becomes important for us to provide an engaging experience for students taking earth science courses, because it serves a dual purpose of possibly increasing new majors in the discipline and helping to create a science literate population.

Given that a majority of students in the larger introductory courses are non-majors, it behooves us to explore alternative engagement techniques and measure their efficacy in student engagement, which in turn can help inform instructional design for advanced geoscience courses.

This study focused on creating a highly engaging course using inquiry based learning scenarios inter-spread throughout the semester along with heuristic quizzes (a series of questions in a specific sequence that map to a process) with very specific feedback that help students understand the development of the earth processes. Along with the heuristic quizzes, the course was transformed into an active learning based hybrid course, where the didactic content was uploaded and made available to the students using a learning management system and class time was spent working on application exercises that were developed by me. I chose specific scenarios and processes that the students could possibly encounter in the greater El Paso region to provide a local and situational aspect to the exercises.

The course and instructional design process followed a period of 18 months with each semester providing data to jigsaw into the final design. Student performance data, both qualitative (self efficacy, self reported engagement) as well as quantitative scales (performance on assessments, course grades) was collected over the entire development period. Comparative data

of the hybrid course and a traditional course indicate improved student performance in the active learning course over the traditional course. The data also indicate that the students had greater content retention 8 week after the course had ended in the hybrid course over the traditional course. The study then presents a nascent model for the design of earth science courses.

Some parts of this work have been presented at the annual meeting of the Geological Society of America, October 2013 and at the annual meeting of the American Geophysical Union in San Francisco, December 2013.

The author of the dissertation was responsible for all the design, data collection and analysis involved in this research

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COMPUTER-AIDED HEURISTIC QUIZZES AS A TECHNIQUE FOR ENHANCING STUDENT LEARNING OF PROCESS IN GEOSCIENCES.

Abstract

The lack of student preparation is a vexing problem for practitioners of active learning techniques. The traditional way to ensure that students are prepared for the in-class activity is to administer an in-class pop quiz or to have the students take online quizzes as a way to generate some recognition of content. We redesigned an active and blended introductory geology course as a way to meet the demands of our 21st-century students, who are well connected to technology, and need a high degree of engagement. We leveraged the technology to build heuristic quizzes (HQs) that are highly structured and model a process (formation of karst, for example) or sets of earth processes that we needed the students to know before in-class activities. The quizzes can be taken multiple times and provide process-specific feedback, thus serving as a heuristic to the students in order to ensure they have acquired the necessary competency needed for doing well on application exercises. The results demonstrate that the technique is highly effective for student preparation and leads to long-term gains in subject matter retention.

Introduction

One of the key issues that surfaces in teaching introductory geoscience courses in both traditional and active learning formats is the lack of student preparation prior to class. While this is an issue for almost every instructor irrespective of the modality of teaching or subject, it is a

major impediment to the use of active learning and inquiry-based strategies since they require a greater amount of student participation. Any student-centered classroom requires a well-prepared group of students who can then engage in active learning and application of knowledge (Murck, 1999). This a priori knowledge can be gained by reading the textbook and any other ancillary instructional materials that provide base knowledge which can be used for the higher order tasks in Bloom's Taxonomy of analysis and synthesis (Anderson et. al, 2001).

The problem of a lack of preparation can be solved by implementing regular formative assessments that can help students diagnose and mitigate any knowledge gaps before class (Sadler, 1989). Formative assessments with contextual feedback have been shown to be of great value to help prepare students for tasks and become self-directed learners (Nicol & McFarlane Dick, 2006). In addition, Gibbs and Simpson (2004) have outlined an assessment framework that creates conditions to support student learning via assessment to include ungraded or low stakes attached to the assessment and an opportunity to take the assessment multiple times. Application of these concepts in the form of quick online quizzes as a way to improve student learning in the geosciences has been well demonstrated by Veal et. al (2004) and Slater et. al. (2008), where these quizzes formed an integral part of the redesign strategy.

We know from previous studies that testing, especially memory testing (Roediger & Karpicke, 2006), is enhanced by retrieval practice (Karpicke & Roediger, 2008), and multiple failure rates (opportunities for practice) may actually enhance retrieval capacities (Kornell, et. al, 2009). In addition to these studies, Butler (2010) has shown that providing learners with repeated testing opportunities is better than providing multiple studying opportunities.

Various techniques have been used to ensure students are prepared with basic understanding of content knowledge before coming to class. One of these techniques I utilized

involved giving students a readiness assessment the day before the class to ensure they have some idea of their knowledge gaps and can bridge the gaps before coming into an application exercise. In addition, I decided to administer practice tests to the students by drawing questions from a large databank.

Many repetitive, formative testing procedures can be easily facilitated by the use of technology (Benson, 2003), and in addition, studies have shown that computerized assessment tests are a useful way to administer formative assessments (Wang, 2007) that can be used by the students to learn by identifying gaps and being able to aid in their recall by going through the quizzes as many times as needed to acquire mastery. This mastery has been shown to translate to better performance in the classroom (Gibbs and Simpson, 2004; Hannah et. al., 2014).

Keeping this in mind, I designed a series of online quizzes with very low stakes where the questions in the quiz mapped to specific processes, and were presented in a set sequence (“heuristic quizzes”). This series of quizzes was interspersed throughout the semester in order to help students practice their knowledge throughout the course. In the first iteration, I did not assign a grade to each individual question in the quiz, instead choosing to assign a grade to the overall quiz. (For example, the students were asked to achieve a minimum score of 80 on the quiz. They could take the quiz as many times as needed until they scored 80 or better, in which case they could stop since that score was taken to be indicative of mastery of content.) While this technique worked reasonably well, I realized that students who scored an 80 on the first try, did not necessarily show high marks on concept application exercises. At the same time, my data also showed that students who repeated the quiz showed a better understanding of process. This then meant, I had to encourage the students to take the quiz multiple times. In addition, I needed to also acknowledge the effort put in by the students as they took the quiz multiple times. To help keep the students

motivated to attempt multiple takes, I designed a schema that rewarded the students who took the quiz multiple times with a few extra points for taking the quiz again even after scoring an 80 (students earned 3 extra points for the next score that was above 80). Students who scored a 100 the first time were also encouraged to test their knowledge by taking the quiz again since the quiz was composed of 30 questions randomly pulled from a databank of 50 questions. The extra points served as an added incentive for the students who scored a 100 on their first try to take the quiz again as a demonstration of the mastery of the depth of their knowledge.

The student results on in-class application exercises markedly improved by about 10% on the average, after the creation and administration of the formative quizzes. While this was a gratifying result, a deeper look at the questions the students raised in class, the hints given in the classes while the students were working on case-based problems, and points lost, indicated that there were epistemic problems experienced by the students in truly understanding the detailed processes and timeline associated with geological phenomena. Libarkin and Kurdzeil (2006) have shown that this is the result of an inherent ontological problem that causes a disconnect between the students' understanding of the deeper underlying process in geological phenomena. This lack of understanding of the process was amply demonstrated when assignments were changed slightly to reflect modifications in processes. For example, while students could do a decent job pointing out geological structures that indicated evolution of a convergent boundary, they needed coaching to provide evidence of tectonic activity on a fictitious planet. This discovery informed us that while this technique worked to ensure that the students understood the basic definitions of terms and had recognition of various landforms associated with plate boundaries, they were clearly missing a deeper understanding of the exact geological processes that were involved in the development of the landforms.

This understanding led us to examine the creation of a process-oriented formative assessment that would help provide the definition and recognition of terms along with developing a deeper understanding of geological processes. This paper provides the design process, strategy, and results from the development of process-oriented quiz implementation.

Background

In the last decade, there has been a great amount of importance placed on developing scientifically literate students and helping increase scientific literacy among the population (AAAS, 1995; deBoer, G.E., 2000). Hodson (2003) makes the case for curricular change in order to update students' engagement in science literacy, which will have tremendous consequences for the future. It has been shown that earth system sciences, by their very nature, offer a conceptual theme for engagement versus a disciplinary theme (Meyer, 1995), a theme echoed by Barstow et. al. (2001), who make the case for an earth science standard to be the base for engaging students in system thinking. They pointed out that the key advantage of the earth sciences is that they provide a way for engaging students in systemic scientific thinking in a situated environment, which has been demonstrated to be a highly effective strategy for learning. Given all this research, I felt it was imperative for me to ensure that the students leave my class with systemic science and process thinking skills. Process thinking skills are defined as the analytical ability to dissect a process and its content, and be able to think critically of effects of external influences that may affect a change. One key element of the design was the need to ensure that the students came prepared to class. Technologies can help create "any place, any time" engagement with students in a variety of ways.

I chose to use our learning management system (LMS) in order to build a series of quizzes that provided targeted assessments with a direct connection to the application exercises. The first set of results were interesting in that they proved the hypothesis that enabling retrieval practice among students led to better performance on the in-class exercises. At the same time, while the results were positive, it also became apparent that the students were missing out on the systemic connections between each part of the geological processes, a fact well documented by Manduca et. al (2007). This result led me to introspect about using the quizzes as a true formative assessment and also serve as a heuristic to enable the student learning of process.

Cepeda et. al (2008) have demonstrated that recall drops when there is a long gap between learning new content and application; therefore, we created heuristic quizzes that engaged students in content that was applied within a gap of a week. We felt that a fairly prompt application of the concepts also helped to engage the students conceptually and to build confidence among the students.

Devising the Heuristic Quizzes

Developing the heuristic quizzes was a challenge in itself. While the geological processes are fairly continuous, I had to develop a way to break each process into 4-5 steps in order to enable the generation of each quiz. Each quiz then consisted of stepwise quiz questions that would lead to an understanding of the process. The identification of the key steps was crucial since each step had to be articulated and jigsawed to ensure that the student developed a full understanding of the process and also the timelines involved in the development of geological features. It was this understanding that they would be able to use to demonstrate conceptual understanding on

application exercises. I developed quizzes mapped to specific feedback so the students would be forced to think about the steps in the process and not proceed with the next question in the quiz until they got the exact sequence of development correctly.

So, for example, when covering a chapter on karst formation with an accompanying in-class problem on sinkhole formation, the process of karstification was broken down into the following discrete steps with an underlying timeline:

1. Formation of carbonic acid by dissolution of atmospheric CO₂ in rainwater
2. Seepage of water into existing cracks and dissolution of limestone (or other soluble material) to widen the cracks (timeline of 2-5 million years)
3. Dissolution of the carbonate bedrock with accumulation of weak carbonic acid to form deeper channels in 5-12 million years
4. Formation of underground drainage systems, allowing more water to flow and accelerate the formation of karst in 12-15 million years
5. Development of a cave system and the potential for sinkholes (>15 myr)

These quiz questions were offered in the exact sequence of the process, with feedback provided for wrong answers and correct answers. In addition to the topic to be discussed, the quiz also included questions that tested on previously covered concepts and any supporting ideas (for example, sedimentary rocks in the case of karstification) that were related to the topic. This was done to ensure that the students also got the ancillary content that related to the process, like drainage development and erosion, which play a role in understanding of the process.

I identified the key processes and concepts that the students needed to take away from the course and developed heuristic quizzes for each identified area. Figure 1 provides a generalized process I followed for creating the heuristic quizzes on each topic.

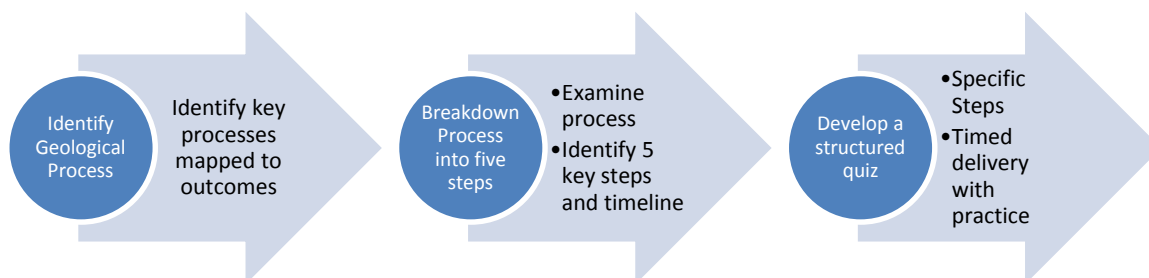


Figure 1: Diagram depicting the generalized process followed for heuristic quiz development

Implementation

This technique was first devised in the fall of 2010 in an Introductory Geology course. This was devised after looking at the student performance data in online discussion posts and in-class activities that clearly pointed to: (a) the students' lack of preparation; (b) a gap in the understanding of the process; and (c) importantly, a grasp of the length of geological time. A "traditional" formative quiz that consisted of questions randomly pulled from a larger databank showed some improvement in the scores of the students that took the quiz but failed to resolve the larger issue of the gap in understanding of process and timescales. I devised one quiz that applied the technique outlined in Figure 1 to help students understand the process of plate tectonics. I also encouraged the students to take the quiz before coming to class with the promise of extra points added to their final score if they took the quiz and scored an 80, including getting a specific set of

questions right. I mapped the results of the quiz to the students' performance on individual and team assignments that were designed as application exercises that used the concepts learned in the quizzes.

I subsequently added 2 more quizzes to the testing regime in the spring and fall of 2011, making sure to use the previously built quiz to get some alignment in the performance data. One small change I made in the fall of 2011 was necessitated by a change in the learning management system used at the institution.

In the first iteration of the quiz, I wrote a simple protocol in JavaScript, which was embedded in the online quizzing engine that cycled the students back into the testing loop until they got the process right. While this was vexing to the students, I felt that it served the purpose of focusing their attention on the quizzing process and learning the process, which would help them with enhancing their problem-solving abilities in the application exercises. I used the same technique in the spring of 2011. But in the fall of 2011, a learning management system (LMS) (in this case Blackboard CE 8) update caused the script to stop working, and with no end in sight, I devised a strategy to achieve a similar outcome by giving students detailed feedback on each wrong answer and providing reinforcement of concepts in the quiz by repeating questions twice. Research has shown the efficacy of well-designed multiple choice quizzes (Marsh *et. al.*, 2007; Rawson & Dunlowsky, 2011). So in addition to providing detailed feedback to the students, I also asked them to take the quiz at least two times if they scored anything less than an 80, which would ensure that they would be exposed to the process materials at least twice. I incentivized the retaking of the quizzes by providing points on the final score of the quiz and points for taking the quiz a number of times. This game-like strategy (Deterding *et. al.*, 2011) enabled us to engage the students in the heuristic activity and improve their performance in the application exercises.

During the first administration of the quizzes, I observed that the students who took the quiz multiple times, showed reasonable gains of approximately 5% in their scores first three tries, and then the quiz scores dropped by about 3% for each iteration after that. In a small percentage of the population, the scores increased throughout. In addition this observation, I also noticed that students who attempted the quizzes without a gap between each attempt, scored poorly by as much as 15% on each successive attempt. Studies by Cull (2000) and Roediger and Butler (2011) have shown that a gap between multiple retrieval practice with feedback leads to better gains. So following these data, I forced students to take a ten minute gap between each attempt. I felt this helped the students “digest” the materials in the previous attempt and also helped reduce the rote nature of test taking.

The final implementation of the heuristic quizzes was in the spring of 2012, where I devised 5 heuristic quiz sets that interwove between the application exercises to provide scaffolding for performance discovery and improvement.

Results

I first devised and implemented this technique in the fall semester of 2010 in one section of an introductory course that was cross-listed with a graduate course. The first step consisted of adding a pre-assignment quiz that pulled questions randomly from a relevant databank and quizzed the students with minimal feedback. I decided to embed the questions within a larger quiz that tested them on topics that were covered previous to the tested topic and ancillary questions that related to the tested topic (for example, the quiz on karstification included a quiz on depositional environments, which was covered before the karst lectures, and on erosion and mass wasting that

came along with and after the karst assignment). I created two application assignments that were based on their knowledge of karst formation and measured their performance on the application exercise before and after the heuristic quiz. I performed a simple F-test on the test scores to see if there was any difference in the scores. A comparison of the student scores on the application exercise after taking a heuristic quiz was found to be significantly higher, approximately 10% higher on average in comparison to their scores on the exercise without a heuristic quiz. In addition, what was interesting to note was that the variance in scores on the application exercise was substantially reduced after a heuristic quiz, telling us that the student scores elevated across the board as a result of the heuristic quiz. This could be linked to a better grasp of the content and process, leading to learning gains. Table 1 provides detail of the results of the F-test.

Given the broad variance in the performance on the application exercise, I used a two-tailed t-test as a way to compare the differences in performance. While the t-value shows that the no difference hypothesis failed, thus proving the positive effects of the heuristic quizzes, in subsequent analysis, it was concluded that the F-Test was more indicative of the performance differences due to a more robust analysis of variance (Spatz, 2011).

Table 1: F-test results for the first trial semester

F-Test Two-Sample for Variances		
	Without HQ	With HQ
Mean	14.88	16.71
Variance	10.69	5.61
Observations	45	45
Df	44	44
F	1.90275031	
P(F<=f) one-tail	0.01770124	
F Critical one-tail	1.65093453	

Based on the success of the first heuristic quiz in the fall of 2010, I added 2 more quiz sets in the spring 2011 and fall 2012 semesters that mapped to application exercises that used the concepts in the classroom, ultimately culminating in the creation of 5 quizzes administered throughout the semester in the spring 2012 semester. Based on performance observation and feedback, I made a few modifications to the heuristic quizzes. These included a reduction in the number of items in the weekly quizzes and tighter alignment with the larger integrative application exercises spread throughout the semester. Figure 2 gives the schema I used through the 4 semesters of development. It is worth noting that I used the same assignments in each semester, which provides aligned comparative data on student performance based on the quizzes.

Table 2: t-test results for the first trial semester

t-test: Two-Sample Assuming Unequal Variances		
	Without HQ	With HQ
Mean	14.88	16.71
Variance	10.69	5.61
Observations	45	45
Hypothesized	0	
Df	80	
t Stat	-3.02	
P(T<=t) one-tail	0.0016	
t Critical one-tail	1.6641	
P(T<=t) two-tail	0.0033	
t Critical two-tail	1.9900	

I averaged the student scores over the 4 semesters on assignments that were worked on before taking a heuristic quiz and after a heuristic quiz, and the hypothesis holds true over the 4-semester period. These data show the significant impact on student learning and retention brought

forth by the use of the heuristic quizzes. The data show that students overwhelmingly performed better on the application exercises after taking a heuristic quiz by almost 20% overall. In addition to this gain in learning, the differences in learning were magnified in the variance observed among the population scores. This reduction of variance shows that the quizzes help in increasing the learning gains among students.

Table 3: F-test for the entire sample size spanning four semesters

F-Test Two-Sample for Variances		
	Without HQ	With HQ
Mean	14.33	18.7
Variance	13.35	4.66
Observations	141	141
df	140	140
F	1.97888	
P(F<=f) one-tail	0.015201	

In addition to the student performance data, I also surveyed the students to find out if they found the quizzes to be useful. The surveys indicate that a majority of the students found the quizzes “burdensome” or “tough,” reflecting a general attitude observed when any modality of learning is changed in the classroom. But the attitudes of the students changed especially when: (a) they were presented with the data on their improved scores and (b) the thought process of the quizzing mechanism was explained to them. This was true in the 3 semesters where I increased the number of heuristic quizzes from 1 to 3 in spring 2011 and fall 2011 and 5 in spring 2012. Overall, the results were consistent with our hypothesis in developing the quizzes in that they would help with recall and understanding of process.

Discussion and Conclusions

The results of the broad-scale application of the heuristic quizzes tell us that the technique worked among all the students irrespective of age or gender. In almost every case that was examined in the study over four semesters, I found an improvement in scores after the quiz was taken. Taking the quiz multiple times also showed a positive correlation with the percentage change in score. I felt that incentivizing the acquisition of points by taking the quiz multiple times played a larger role in the success of that strategy because the competitive aspects of engagement did help encourage students to take the quizzes. I also discovered that letting the students take the quiz multiple times and score points for attempts proved to have a positive influence on the scores of the students who took the quizzes multiple times. Data also indicated that while scores on the quiz increased on average for each iteration, there was plateauing of the scores when the test was taken beyond 4 times, possibly indicating test fatigue. Based on this discovery, I changed the number of attempts available to the students in spring 2012 to 4 as a way to enable enough attempts to ensure learning but not too many, which would cause information fatigue.

The most positive response from the students came when I was transparent about any issues with quizzes and when I shared performance data and all grading rubrics were made available. For example, as part of the transparency, if I discovered a problem with a quiz based on item analysis, I disclosed the fact to the students and adjusted feedback. After the initial resistance to change, I found that most of the students were willing to engage in the excitement of the competitive nature of the “points race” after I added a leaderboard (with anonymized names) and shared successful behaviors online in a discussion board.

The development of the quizzes was a time-consuming process and took a few tries to get the sequencing right in developing the question sets and figures. At times, I borrowed publisher

content, but it had to be curated to ensure proper sequencing within the heuristic quiz and to afford students multiple chances of acquiring content and process knowledge. Overall, this exercise did not save the developers any time, but I feel it contributed positively to the students' learning experience and retention.

The telling portion of content retention was evidenced by the administration of a geoscience concept inventory (GCI) quiz to the class of spring 2012 with a fully developed set of quizzes and application exercises. The students in the class scored an average of 27.2 points out of a 20-point total (30 questions worth 1 point each), showing their knowledge of a majority of the concepts covered in class. This inventory demonstrated that the students retained some content knowledge covered at the beginning of the semester to enable them to score well in a test towards the end of the semester. This test was again administered 8 weeks after the semester ended. While only 60% of the students took the GCI quiz again, they scored an average of 22 points, which pointed to a reasonable amount of retention of concepts 8 weeks after the semester had ended versus the national retention rate of 40% posited in science literature (Hake, 1997; Handlesman et al, 2007).

In conclusion, I feel that the development of heuristic quizzes was a robust intervention technique and made a significant contribution to help scaffold learning, thereby helping students develop a robust knowledge of geological processes. Our initial hypothesis of these quizzes serving as a heuristic was borne out by student performance in the class, but more significantly in the retention of content after the semester had ended. I feel this technique can have a valuable and positive impact on teaching of process related disciplines. Future studies will include the generalization of the technique with application to a variety of scenarios that focus on teaching process, providing wide applicability in varied academic settings.

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DEVELOPING AN INTEGRATIVE AND ACTIVE LEARNING CLASSROOM FOR STUDENT ENGAGEMENT: IMPLICATIONS FOR FIRST GENERATION STUDENT SUCCESS.

Abstract

I redesigned an introductory geology class that served a largely minority and first generation population of students and turned it into an active learning student-centered classroom. This redesign was a deliberate attempt to engage a minority first generation population of students in science, technology, engineering and math (STEM) disciplines. I built a series of active learning exercises that are integrative in nature and help the students develop inquiry and integrative problem solving skills. The students acquire didactic content via self-guided inquiry exercises online, so that class time is spent on problem solving activities that integrated active learning strategies and inquiry-based learning.

Measurement of student performance and knowledge retention showed that students exposed to an active learning classroom performed better on a standardized geoscience concept inventory test with demonstrable learning gains. This paper outlines the design process, shares some examples of the active learning activities and presents the results of the endeavor.

Introduction

It has been established that entry level geosciences courses, due to their integrative nature (Mayer, 1995), could serve as ideal entry points for students to be exposed to and to explore

disciplines in science, technology, engineering and math (STEM). In addition, research has shown that how we teach the geosciences in courses has far reaching implications on student retention in STEM disciplines (Herbert, 2006; Manduca & Mogk, 2006). One of the challenges facing teachers of early geoscience courses is that they are typically considered to be “easy classes”, and more often than not, are taken to fulfill a science requirement in the core curriculum.

A recent survey of undergraduate students found that the introductory courses tend to have a blend of geoscience majors (26% on the average) and non-majors (74% on the average), which also results in a mix of motivation (Gilbert et. al., 2012) in the classroom. This mixed motivation presents a challenge for instructors because motivation has been shown to be a bigger factor for student success in such courses, than a-priori skills (Covington, 2007; Pekrun, 2007, and Zusho et al. 2007). Coupled with these data was the complexity added by our dominant Hispanic demographic, which was an average of 80% minority students, with approximately 60% of them being first-generation or the first member in their family to go to college. Our demographics and the need to increase student interest and retention at this critical point in their studies fueled the need to implement a successful instructional strategy in freshmen geoscience courses.

The work in this paper was developed at a mid-sized urban public university located on the border of US and Mexico. This institution is a designated Minority Serving Institution (MSI) with an 86 % Hispanic population, with a substantial number of them being first generation students. The term “first generation” is defined as the first member of the family to attempt post high school degree acquisition (Kuh, 2007). First generation students face challenges in performing well and engaging well academically, due to a lack of intergenerational college experience that cannot be passed on to them (Lohfink & Paulsen, 2005) . This then means that we must provide support structures to ensure their success academically and increase their engagement.

Sonia and Stebleton (2012) have shown in their research that first generation students suffer from a lack of peer to peer and social network (social capital) based engagement. Therefore, any opportunity that provides them with increased engagement with peers and faculty is shown to have a positive experience in their academic pathways. Active learning strategies can take various forms, and some of them include the involvement of students in active application exercises, collaborative assignments and peer discussions (McConnell, 2003; Prince, 2004; Hake, 1998). These strategies thus increase student opportunities for peer-to-peer and faculty interactions, as they work on problem solving and collaborative thinking. This increased interaction thus mitigates the lack of such opportunities in their initial start at the university and helps increase retention. Other research on active learning strategies and first generation student engagement by Pascarella et. al. (2004) and Braxton et. al. (2000) shows that incorporating active learning strategies has strongly positive outcomes on first generation student retention and success.

Given the importance of the course to build a scientifically literate population, to recruit new students into the program and possibly to serve as an entry point for new students to STEM disciplines, I decided to “pull apart” the course and redesign it to make it more student-centered. This meant rethinking the delivery mechanisms and engagement strategies that would make the course highly appealing to different modalities of learners. Understanding that the use of technology can play a large role in multiple modalities of engagement (Waxman et. al., 2002), I decided to redesign the course and leverage the technology in the form of our learning management system as a way to engage the students in didactic content acquisition and discussion, while using the classroom for problem-solving and application exercises.

The active learning strategies outlined in the study, and the supporting online components were developed and tested over a period of three semesters before being incorporated into the final

version of the course. This paper mainly focuses on the development of the in-class activities and the effectiveness of these strategies in the fully deployed course in Spring 2012. It is hard to isolate the effects of only the active learning strategies in the course, so I took a holistic approach and looked at all aspects of student engagement to include observational analysis, test scores and performance on metacognitive self assessment tests. The results show that the students found these interactions to be highly engaging and useful in helping them to pull the seemingly disparate parts of the course content together. The additional benefit of these integrative assignments was that the students could see the interconnectedness of geological process and their application to solving real world problems.

Course Context and Background

The Introduction to Earth Sciences course serves as an entry level course in the geosciences and fulfills the role of a required science course in the core curriculum. The course is typically taken by freshman students and, in some cases, transfer students, as part of their core curricular requirements. Overall the goals of the courses irrespective of the teacher are to engage and introduce the students to the earth sciences, in addition to general scientific reasoning and thinking. This course is typically the first contact with STEM disciplines that non-majors have, which makes it a very important course which can have far reaching impacts on the general understanding of STEM disciplines among non-majors.

This particular course had been designed with a modular approach that created general themes by clustering topics into categories that have a strong degree of fit. Table 1 provides the

general schema of the course. The idea behind the modularization was that I could then help drive thematic assessment that was continuous in nature and would help tie broader ideas about earth processes together.

Table 4. Generalized course schema

Module 1 A framework for studying the earth	Introduction, nature of science, geology and geological investigations, geologic time
	Plate tectonics
	Minerals, igneous rocks and volcanoes
Module 2 Shaping our environment	Mass wasting ,weathering and soils
	Sedimentary rocks and rivers
	Shorelines and oceans
	Deserts and wind
	Ground water and water resources
Module 3 Deep processes	Metamorphic rocks and deformation
	Earthquakes and Earth's interior
	Convergent boundaries

Development and Implementation

McConnell et. al, (2003) have identified various active learning strategies suitable for use in a geoscience classroom. Previous successful work has ranged from the use of highly structured collaborative in-class activities (Arthurs and Templeton, 2009), collaborative exams (Eaton, 2009), problem based learning using real life examples (Dadd, 2009), a case based curriculum that promotes inquiry (Goldsmith, 2011) and an active inquiry-based pedagogy (Apedoe et. al., 2006). In addition to the active learning strategies, Semken (2005) showed that place based education could help engage minority populations in exploration of the geosciences, which provides an intriguing idea for implementation in a classroom. Hiebert et. al (1996) have shown that one of the key elements to inquiry-based learning is for the curriculum developers to problematize the

activity which can help the learners push at their boundaries of knowledge which can lead to discovery and learning.

Taking into account the research, I decided to develop assignments that used all elements of active learning by making them situated as much as possible in our local environment or an area for which the students cared greatly. Our approach was inquiry-based, so that I could guide the learners in problem development through the use of questioning strategies designed to lead to exploration and problem-solving.

I posit that one element that is missing from a lot of classroom activities is the relevance of the content to the students' lives. Context can be built in a variety of ways. I chose to use the context of the popularity of the Crime Scene Investigation (CSI) shows on television to get the students excited about applying the concepts that they learned via the online lectures, book readings and discovery exercises.

I carefully designed the in-class exercises so they were integrative in nature and helped the students through (a) developing the problem correctly (b) working their way through the problem and asking the right questions that would help them solve the problem (c) working their way through data acquisition (by direct inquiry with the instructor or by exploring ancillary resources) and navigating their way to the derivation of a solution. I were less concerned with the students coming up with an exact solution, but more focused on ensuring their thought process was made transparent for further development.

For the first iteration of the course, I designed two very simple exercises that were integrative in nature and had the students work on them individually and in teams to come up with the solution. I saw very quickly that the students did seem to get the idea of the law of original horizontality and cross cutting relationships, but as was observed by Manduca and Mogk (2005),

they seem to have trouble with simple spatial relationships. So I designed the first exercise to help them understand and solve a problem by applying the principles alone in order to understand spatial context in problem-solving. These exercises were repeated and added to for each iteration of the course resulting in a bank of exercises that was worked on by the students. Each exercise mapped to a subject that was in the course modules and used previously learned concepts in an applied setting.

As a focus for this brief paper, I am going to center on the implementation of this strategy in the final iteration of the course. It is also for the same reason that I am going to provide examples of the activities the students worked on during class time. Some of the activities varied in each iteration of the course since they were derived from currently occurring geological phenomena, so as to engage the students in active science.

The Activities

Activity 1: This activity was conducted in the first week of class and designed to engage the students in active learning and set the tone for their expected involvement in the class. Students were presented with a map of the east side of town and were asked to solve the following problem: A border patrol agent found a strong smell of gasoline coming from the canal near Example Park. He noticed that the water in the canal had a slick and a strong smell of gasoline. Further investigation lead to the discovery of a larger part of the canal showing the presence of gasoline. The city of the Southwest shut down the park and led an investigation with all the signs pointing to the culprit being the refinery located within a half mile of the slick.

The refinery insisted that their internal investigation did not reveal any leaks and there must be another origin for the leak.

You are brought in as a consulting scientist to help resolve this issue. You will work on this in two steps

Step 1: Working on your own, identify the key question that you need to answer and what data would you need to work out a solution. Turn your paper in with your name on it.

Step 2: Get together with your team and check if all of you are in agreement with the exact problem. If not, discuss and develop the problem. Identify the key data you need to solve the problem and the key steps you will need to take to acquire and evaluate the data to develop a solution.

Activity 2 (maps to module 1 and was repeated for 3 semesters in total): The second assignment we designed was to help our student use the concept learned in the principles of geology (the law of original horizontality, law of cross cutting relationships). The key idea behind the development of this exercise was to engage the students in applying the concepts in the field. Knowing that a majority of the students were non majors, we decided to make the assignment generally applicable to everyone.

A colleague who is at an archaeological dig in Crete (does that make him a cretin?) has sent us the following sketch. The sketch shows a body buried in the ground. The problem is that they don't know if this sketch was created by the artist standing on top looking down, looking at the body sideways or from another angle. Since the burial has great significance in their understanding of this newly discovered city, it is of crucial importance that they know which side of the sketch is up. You are a consulting geologist who has been hired to help solve the problem. Work individually and in teams in the following steps to come up with a solution.

Step 1. Take 7 minutes to work individually and mark which side was up on one sheet of paper. At the end of this time period, turn the paper in with your name on it.

Step 2: Take 12 minutes for a team discussion on which side was up and for a short rationale to be developed and written down. Spend some time discussing this with your team. There is only one correct answer, so a wrong answer will penalize everyone.

The instructors walked around the class and facilitated the discussion.

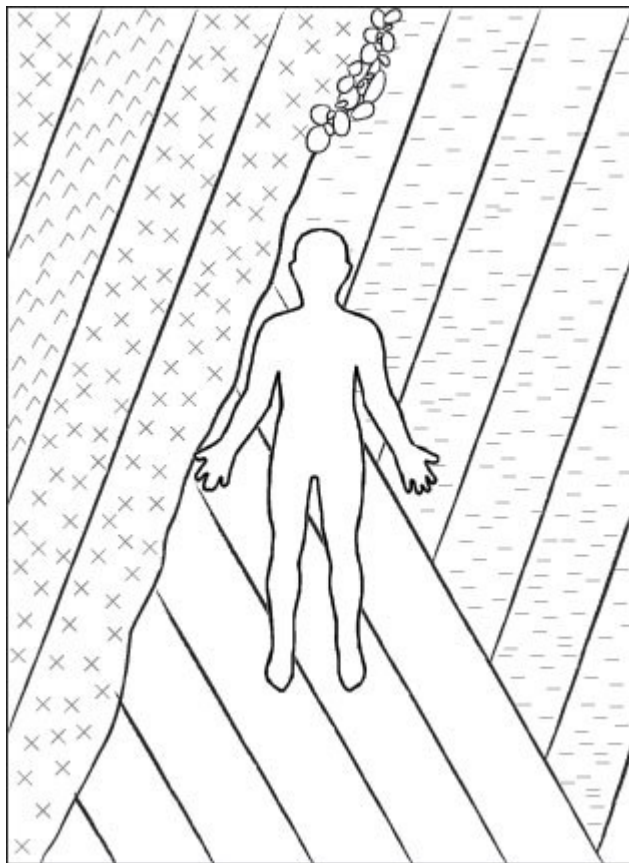


Figure 2. Active exercise designed to have students apply principles to derive a solution

I very quickly discovered that the students absolutely did not like the assignment because it required them to engage and use the knowledge that they had not expected to apply. I led the teams in a discussion followed by a short lecture on the topic of sedimentary rocks.

Activity 3 (maps to module 1 and was repeated for 3 semesters in total): I had noticed that while the students were able to correctly label parts of a diagram showing subduction, they seemed to still not understand the process and the evidence that was collected as proof of plate tectonics. So the next assignment was designed to generate reflection and discussion about the proof for plate tectonics on an imaginary planet.

Loco Space Ventures has hired you as a consulting geologist to lead the first research team to land on planet Pelota X. The key work for the mission is to see if the dynamic processes are similar to Earth. You are also in charge of selecting a site to setup the first office for LSV – LLC on Pelota X.

- a) What evidence would you look for to see if Pelota X has active plates and a mechanism like plate tectonics in place?
- b) What if Pelota was completely flat?
- c) How would you go about selecting a site to setup the first office for LSV on planet Pelota X?

Activity 4 (maps to module 2 and was repeated for 3 semesters in total): The overarching objective of this exercise was to have the student use critical inquiry and concepts of mass wasting to solve a hypothetical crime scene. Their goal was to work individually and in teams to prove or disprove foul play in the scenario setup as the follows.

Park rangers in the Franklin Mountain Park have discovered a body lying by the trail. The body is a male who appears to be in his 40's and from the first look appears to have been caught

in a landslide. One of the rangers who had taken a course in geology many years ago felt that there was no cause for a landslide and perhaps this was foul play, with the murderer causing a landslide to cover up their nefarious deed.

Loco Space Ventures has been contracted to supply a team of geologists (you and your team) to prove or disprove this theory.

What kind of data would be you need to analyze this situation and make a ruling. Remember, the ruling has to be based on facts ascertained from the data you get.

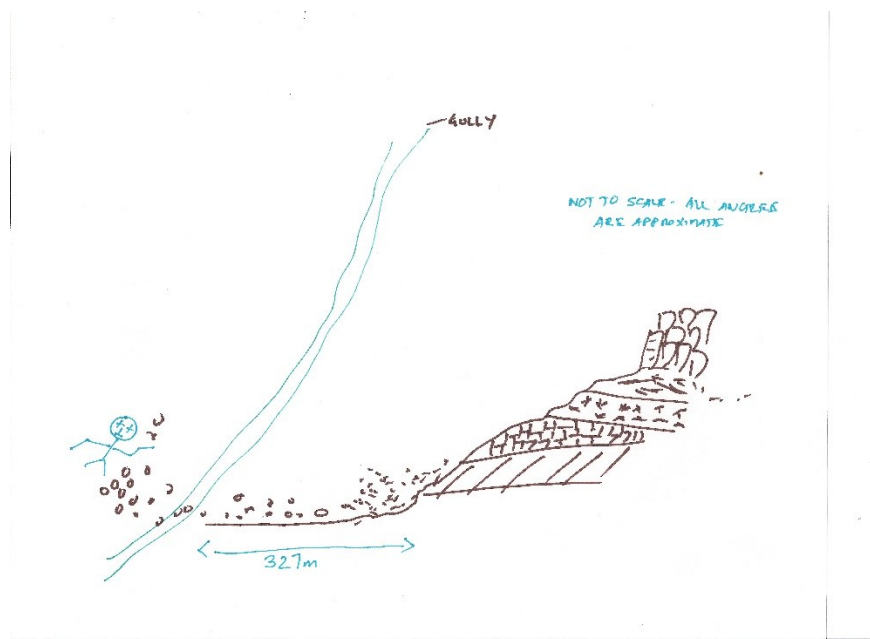


Figure 3: Sketch for integrative assignment on mass wasting

The assignment followed a similar structure as the previous assignment with the students working individually and then in teams to identify the answers. One small variation I added to this assignment in the last implementation was that I turned this into a competition. Each team had to come up with a short presentation using markers and large sketch pads that were provided by the instructor. Each team had 3 minutes to make the case for their work and the entire class voted on

the best project which won an extra 3 points. I found that this extra layer of competition, coupled with collaborative work, generated a larger sense of excitement in the class than I had experienced before.

Activity 5 (mapped to module 3). In this activity I took advantage of the earthquake in Acapulco to engage the students in applying the basic concepts of tectonics and earthquake seismology covered in class and designed a talking points communicate that needed to be scientifically accurate, yet approachable. This was important to ensure that the students understood the concept of scientific stewardship (Lutz and Srogi, 2010) and the importance of communicating scientific concepts to non-scientists. In this exercise they again worked individually and in teams to develop the communicate.

Why was there an earthquake in Acapulco? Looking at the tectonic map in your book, can you identify the chief culprit in this earthquake?

Caltech seismologist Pablo Ampuero said Tuesday's 7.4 earthquake near Acapulco, Mexico, could provide insight into future quakes that might occur in the Pacific Northwest, Canada or Alaska. Why do think that is?

Due to the obvious economic impact of this earthquake on tourism, you have been brought in as a consulting scientist to help educate the tourists who are currently there, and who are now considering canceling their reservations for travel, about this occurrence.

Your job is to develop a one page talking points communicate that can be distributed to tourists who are visiting Mexico.

Assessment

Various authors have pointed out the difficulty of assessing efficacy of active learning techniques and educational techniques in general in controlled environments (Prince, 2004; Berliner, 2006) and point to using broad ways of assessing the efficacy of active strategies. I designed the assessment in a few different ways in an attempt to capture the usefulness and

effectiveness of an active classroom. Measuring the absolute efficacy of one technique in a redesign is a challenge since I was not able to completely isolate the effects of active learning by itself. So to meet to goal of holistic assessment, I designed a variety of smaller assessments to give us a picture of overall efficacy of the active learning strategies. Michael (2006) has pointed out through his work in measuring efficacy of active learning techniques that these techniques are constructivist in nature and an important part of the success is student cognition of the strategy used for knowledge building. Using this idea as one of the anchors for assessment, I used a combination of classroom observation and concept testing to gain an understanding of the efficacy of the strategies. In addition, I administered a modified learning gains instrument designed to help students assess their learning gain.

Pre and Post Concept Tests

To gain an understanding of the students' performance on content and concept acquisition, I administered a pre- and post-concept test for each course where I used the engagement activities. The pre-test was administered online in the early part of the semester and the post-test questions were at times administered by embedding them into part of the regular quizzing regime. This short test was comprised of 15 questions selected from the Geoscience Concept Inventory (GCI). The GCI has been shown to be a reasonably predictor of students conceptual understanding (McConnell et. al. 2006), and was used to serve as a measure of a gain in student understanding in the active classroom.

In addition to the students' performance on the GCI I calculated the learning gain for each question. Hake's (1998) study of over 6500 students in introductory physics introduced the idea of learning gains %, which was shown to be a very reliable metric of student improvement.

Goldsmith (2011) demonstrated that this was a reliable measure in geoscience courses. I calculated the %g for each question in aggregate for each class so as to protect the students' privacy. So the comparison then is on aggregate class performance on each question that tested concepts from the class and active learning exercises. The learning gain formula can be expressed as:

$$\%g = (\text{post test score} - \text{pre-test score}) / (\text{maximum score} - \text{pre-test score})$$

Classroom Observation

The instructor(s) made a concerted effort to track student work, reactions and enthusiasm in the active learning exercises in the “build up” phases of activity development (the build up phases are the initial semesters where I introduced a few activities into the regular class). While I kept notes and had comparative conversations, I did not follow a structured measurement instrument to measure student enthusiasm and engagement.

In the final class for the study (Spring 2012) that combined online course content with the in-class active learning exercises, I had two graduate students in the education program serve as observers for all the active learning exercises. The students observed the individual and team work and the interplay between team members and marked their general observations using a modified observation protocol based on an observation rubric from the Science Education Resource Center (SERC). The observers were asked to not participate in any discussion or even help save a discussion that may be going off on a tangent. Their job was purely as documenters of the process and the students were also made aware that they were not available for questions. These sheets were analyzed to gather information on observed student interactions and collaborative

negotiations in the in-class activities. In addition to these formal observers, I had the opportunity to host new faculty who were hired in the department of geological sciences as observers to gain some understanding of an active learning classroom and strategies that would engage students.

General Post Course Self Assessment

The post course assessment consisted of a series of questions that were derived from the Self Assessment of Learning Gains (SALG) questionnaire. The Spring 2012 class took a longer version of the SALG, which contained the list of questions administered to the students in the Spring 2011 and Fall 2011 sections respectively. This sample can provide a longitudinal look at student engagement in learning strategies. I asked a total of 16 questions that asked the students to identify what they found most helpful about the strategies, the structure of the class, the key takeaways from the class and whether they saw the connective nature of the course content to real world problems. I will share the results of 6 questions that are the most pertinent to this study.

Results

All of the four courses in this study had a similar makeup in terms of ethnicity and gender. The ethnicity ranged from 76-80% of the students being Hispanic with approximately 50% of them being first generation students. The courses tended to be almost evenly split in terms of genders except the spring 2011 class had a larger female population by 12% than the average of the other semesters. This was not found to be statistically significant in mapping student success at any level.

Pre-Post Concept Test Performance

A total of 27 students took the pre and post test in the Spring 2011 semester, 39 in the Fall 2011 semesters and 22 in the Spring 2012 semesters. While a larger number of students took the post test, I only analyzed data for students who took both the pre and post test. Overall the data show that the students did show gains in concept acquisition by the use of active learning strategies. Students across the board showed an increase in conceptual understanding and this was borne out even in the Spring and Fall 2011 courses where the activities were episodically embedded in the course vs the Spring 2012 semester which used a larger number of activities embedded into the course as part of the redesign. What is interesting to note is the gains in questions 7, 8, 9, 10 and 12 are larger than the other questions which follow the national norm. These questions on the concept test map directly to the learning activities on mass wasting and plate tectonics that help students apply the concepts that were tested on those questions.

Table 5: Learning gains in students across three semesters

Question	Spring 2011	Fall 2011	Spring 2012
1	0.38	0.35	0.63
2	0.40	0.08	0.43
3	0.00	0.33	0.50
4	0.41	0.38	0.78
5	0.36	0.36	0.54
6	0.43	0.57	0.62
7	0.68	0.72	0.78
8	0.54	0.33	0.20
9	0.50	0.33	0.73

10	0.56	0.75	0.75
11	0.25	0.38	0.64
12	0.59	0.40	0.57
13	0.27	0.43	0.73
13	0.14	0.57	0.69

Classroom Observations

The in-class observations provided the best evidence of student engagement and the need for incorporating active learning strategies into the classroom. When I introduced the learning activities in the classroom, the students were very unsure of their expectations. But after I had a dialogue going, they reluctantly started working on the problem with the enthusiasm steadily building as I walked around and engaged the class in the thinking exercise. I also discovered that students need a lot of coaching in problematizing the task at hand so they could develop the appropriate questions that would lead them through the discovery process and the potential solution.

The observers in the Spring 2012 class were very useful in providing an observed value of student engagement. One of them had the following observation on a question that asked about student engagement

Q: “What is the evidence of student engagement and interest in the activity on the Mexican Earthquake”

The students were slow to respond to the activity, but they started attacking the problem as a data problem with identifying the epicenter, magnitude, location and then figuring out that they could find a tectonic map of the world on the world wide web. The students were communicating about

diagrams they were finding and ultimately the discussion centered around diagramming the plate boundaries and seeing the possibility of the frequency of earthquakes. In turn this lead to a discussion about finding historical data to do some analysis to see the chances of earthquakes happening again so as to draft the talking points memo. All this happened in a span of 20 minutes and I am sure they were talking about it after class”

The visiting faculty observers commented that to them the class looked chaotic the first time they came to observe the class, but realized that the students were engaged in the problem and the competitive aspects of the exercise.

Post Course Assessment

The data from the assessment of learning point to a majority of the students (94%) found the peer interactions to be more useful (marked as great help and much help on the Likert scale) than any other activity in class. This was followed closely by 84% saying the hands-on classroom activity and the in-class group work (marked as great help and much help) in the class. This activity did not in any way help increase their contact with their peers outside of class significantly since only 31% of the students said they found any benefit to working with peers outside of class.

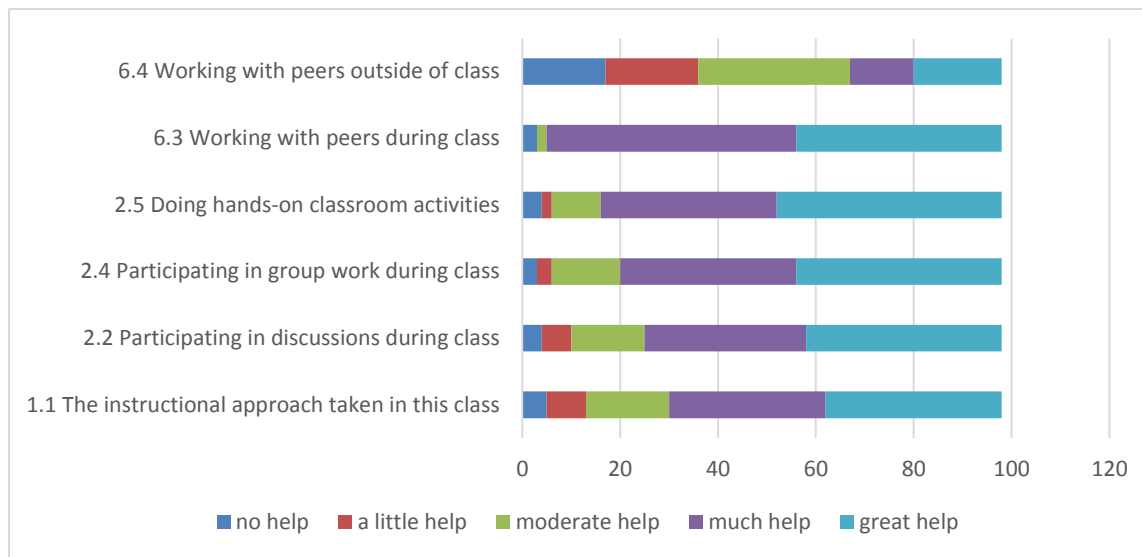


Figure 4 Student Responses to How Much Did the Following Aspects of the Class (N=98)

A follow-up informal focus group of the students indicated that they did not think of the online discussions as peer interaction, which was an interesting interpretation and merits some attention in future work.

Conclusions

Overall the data seem to indicate that the active learning exercises helped the students engage better with the content and importantly develop a sense of community by the nature of the required collaborative work. The students benefited from active learning strategies even when they felt it was too hard, and they started with a lot initial resistance in making the shift from passive to active learning.

Students in active learning based courses performed significantly better than their peers in traditional courses. In addition to better performance on testing, the active learning based students

also showed better long term knowledge retention and showed an heightened sense of application knowledge than the traditional students.

One of the goals of this project was to see how the strategies could be transferred for other instructors to use. I discovered that while the strategies did work to some extent in another class, instructor-led facilitation played an important role in the success of this implementation, which leads us to believe that there is an opportunity for creating a faculty development workshop on facilitating conversations in the classroom.

I found it useful to take a measured approach to development of an actively engaged classroom, by taking a stepwise approach to assignment development and testing. This approach to development let us test materials and improve strategies after incorporating them in small chunks in other classrooms before moving to a fully active classroom. While this approach served our purposeful development plans, our implementation data and anecdotal evidence suggest that students need a lot of support in moving from being passive learners to active learners, and the sooner they get used to being actively engaged in the classroom, the better the results. This then implies that a continuous implementation of active learning strategies throughout the semester will lead to better outcomes rather than an episodic implementation of these strategies. Episodic implementations can cause these strategies to fade into memory, leading the students back into passive learning habits which are hard to break.

This observation has implications for developing and adopting active learning strategies in the teaching of introductory courses. Given that overcoming initial resistance is the key to success, a worthwhile strategy for a new practitioner could be to start off small by developing, incorporating and testing a few exercises that increase in application complexity in the initial semester and then slowly add more assignments (when appropriate) in subsequent semesters, as the instructor

develops a comfort level with facilitation of the exercise which will ultimately lead to the students making the transition from passive learning to taking agency in their own learning.

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THE WHOLE ENCHILADA: A HYBRID MODEL FOR A FRESHMAN LEVEL INTRODUCTORY GEOLOGY COURSE.

Abstract

This paper describes the timeline of development for a hybrid courses that interweaves online content and interaction with an active learning classroom. The process learning is reinforced by the use of heuristic quizzes that help students learn the process. A comparative analysis of student performance on a geoscience concept inventory (GCI) administered at the end of the semester, shows that the students in the hybrid scored approximately 10% higher than students in a regular course. In addition to this, we also saw significant student retention of content among the students in the hybrid course measured by the GCI administered 8 weeks after the end of class. We observed student resistance to the changed learning environment, but the data show that the overall learning gain makes it worth the effort in helping the students work through their initial resistance to the active environment.

INTRODUCTION

Curricular design and earth science literacy have been on the forefront of recent conversations about increasing enrollments and retention in the earth sciences. While these ideas have been gaining ground by the evidence of increased funding in the geosciences by national agencies, there has also been the realization that how we teach the geosciences is equally valuable, can make a great contribution to retention efforts, and has far reaching effects in outreach to decision and policy makers (Herbert, 2006; Manduca & Mogk, 2006) In addition to teaching

geosciences to the majors, most departments also face the challenge of providing engaging content to non-science majors who take a course to fulfill core requirements. Research has demonstrated that students with set goals do not value introductory courses in their curriculum (Husman et. al., 2007). So it behooves us as engaged members in the education arena to redesign and develop courses that are engaging and lead to increased motivation and demonstrable outcomes. Studies have also shown that traditional lecture based models do not lead to student engagement or content retention (Handelsman et al., 2007; Hake, 1997) and therefore we must move from the traditional lecture-based “sage on stage” model to a constructivist model (Vygotsky, 1933) that is focused on learner-centered teaching and active learning.

In essence, for learning to happen, we need to ensure that the students have a solid knowledge base that provides recognition and definition of terms, the opportunity to practice thinking and engagement and reflection to ensure a thinking process rooted in lifelong inquiry.

This study then focuses on the results from the creation and delivery of an engaging course using inquiry-based learning scenarios inter-spread throughout the semester along with heuristic quizzes that help student understand the development of the earth processes. Student performance data have been collected along with data on metacognition by administering a Self Assessment of Learning Gains (SALG) instrument. These data have been analyzed to provide a holistic look at student success in technology mediated, active learning environments. This redesigned hybrid course has been compared with a traditionally taught course to provide a comparative analysis of student outcomes and content retention between a traditional course and an active learning based hybrid course.

Through the inquiry-based analysis of data and observational analysis, I aim to propose a nascent framework for the development and delivery of technology enhanced hybrid courses in anticipation of greater student learning outcomes, content retention and potential time saving on instructional time in the delivery of redesigned courses.

BACKGROUND

There has been substantive research collected on the teaching of science over the last many years. The key elements that are borne out by the various studies show that active learning strategies are highly effective ways to enhance student engagement (Handelsman et al., 2007, Hake, 1997). Within the larger context of active engagement and learning (Michael, 2006), there are specific strategies that have been identified as key factors that lead to increased learning outcomes. These pedagogical strategies include peer engagement (Crouch and Mazur, 2001), collaborative and cooperative learning (Fagen et. al, 2002; Beichner and Saul, 2003; Osborne, 2010), group learning (Hui-min & Jackson, 2010), guided inquiry (Leech, et. al, 2004; Weaver, et. al, 2008), adequate and heightened faculty interactions and timely feedback (Chickering & Ehrman, 1987; Fink, 2003; Gillespie, 2005).

These broad applications of learning strategies to science instruction have had an impact on teaching of the earth sciences. There has been a realization that the earth sciences are a highly integrative science that teach broad based scientific reasoning and critical thinking (Herbert, 2006) and as such need to adopt and adapt scientific engagement strategies designed to enhance student retention of content and engagement. Over the last decades many strategies have been implemented in earth science classrooms to help students with understanding the earth's processes and to become part of an informed public.

Previous research has demonstrated that the use of active learning and other engagement strategies has positively affected student learning outcomes (McConnell, et. al, 2003, 2009). Arthurs and Templeton (2009) have shown that collaborative learning strategies coupled with homework assignments to help student practice concepts has led to better student learning outcomes in environmental geology courses. Others have proposed and shown that the understanding of ontological levels of incoming students can help with the design of scaffolded learning which demonstrably helps students bridge the gap between their starting level and desired course outcome (Libarkin & Kurdziel, 2006). In addition to understanding the students' levels of ontological knowledge are elements of ongoing student engagement within the context of geosciences courses. Success strategies include the creation of a case based curriculum where students are engaged in problem-solving activities via case studies (Goldsmith, 2011), use of learning journals which reflectively connect knowledge acquisition (Park, 2010), and various active learning techniques. Other applications of learning theory include leveraging elements of situated cognition and situated learning theory (Lave, 1988; Lave and Wenger, 1991) to design active learning strategies that help student explore their locale, which leads to higher learning since students are affected by their place and environment (Semken, 2005, 2011; Semken and Freeman, 2007, 2008). Other research has shown the importance of students building a sense of self and motivation via helping them learn via the affective domain (Hoeven Kraft et. al., 2011). Data also indicate that helping students build visualization skills leads to better learning gains (Murphy, et. al., 2011). In addition to these strategies, Apedoe et. al (2006) and Miller et. al (2010) have also demonstrated the high degree of learning efficacy achieved in introductory geology classrooms by adoption of inquiry-based strategies. Overall prior research points to the learning gains that are

achieved by the application of learning theory to geoscience education, and serves to inform the instructional strategies adopted in the learning design of this study.

While working on the instructional efficacy realized by active learning came the additional realization that most of our students are non-traditional and are highly connected via technology. A recent survey of students at the university showed that over 60 % of them have and use mobile technologies, and consider the use of technology as beneficial to their learning. While this was not a primary goal in redesign, I realized that I could leverage this connectivity and make use of technology to engage the students outside the physical classroom and build a stronger learning community. This resulted in the decision to develop this course as an active learning based hybrid course (a hybrid course is defined as a course that is 50% online and 50% face to face).

INSTRUCTIONAL STRATEGY AND DESIGN

The development of instructional strategies took a layered approach in order to create a supportive learning environment that focused on knowledge development, application of knowledge in a motivational environment that focused on prompt feedback. While the prior research on teaching in the earth sciences and sciences in general served as the guiding framework for instructional development, the main attempt in this design was to develop a constructivist classroom in physical and virtual settings.

The decision to turn this into a hybrid course was brought about by our observation of the changing, technology enabled student on our campus. In addition, various studies have also shown that hybrid courses can help mitigate the challenges of delivering courses to a diverse contingent of students who may have diverse backgrounds and learning styles (Dziuban et. al, 2004; Sharp, et. al., 2006, Vaughan, 2007). The overall design of the hybrid course was somewhat influenced

by the work of Garrison and Kanuka (2004) who point out that while accessibility and the potential cost efficacy of hybrid courses are of value, what must be kept at the forefront is the greater value of the transformative potential of hybrid courses. Graham and Robison (2007) have also shown that leveraging the transformative potential of hybrid courses is of the essence to have any meaningful effect on our students' academic lives.

Brooks and Brooks (1999) make a case for a classroom that engages the students in developing conceptual knowledge and practicing the application of skills. So keeping the basic principles of constructivist philosophies (Vygotsky, 1988) and evidence for case based situated cognition in mind I followed a phased approach to developing assignments and incorporating them into a developing curriculum. This gave me a chance to create new assignments or online materials and test them in phases for their efficacy in our students learning enhancement. This phased in testing allowed us to microtest all the materials before they were put together for the creation of the hybrid course. Using the revised Bloom's Taxonomy for learning (Anderson and Krathwohl, 2001) and the revised taxonomy for Digital Learning (Figure 1) as a basic guide to develop learning objectives and learning goals was the first step in the design process. The key element of Bloom's Taxonomy that was taken into account was that while the taxonomy is arranged to imply a stepwise progression to developing higher order thinking skills, the practical implementation of the taxonomy takes into account the entire taxonomy as a desired framework for student development and not a linear progression.

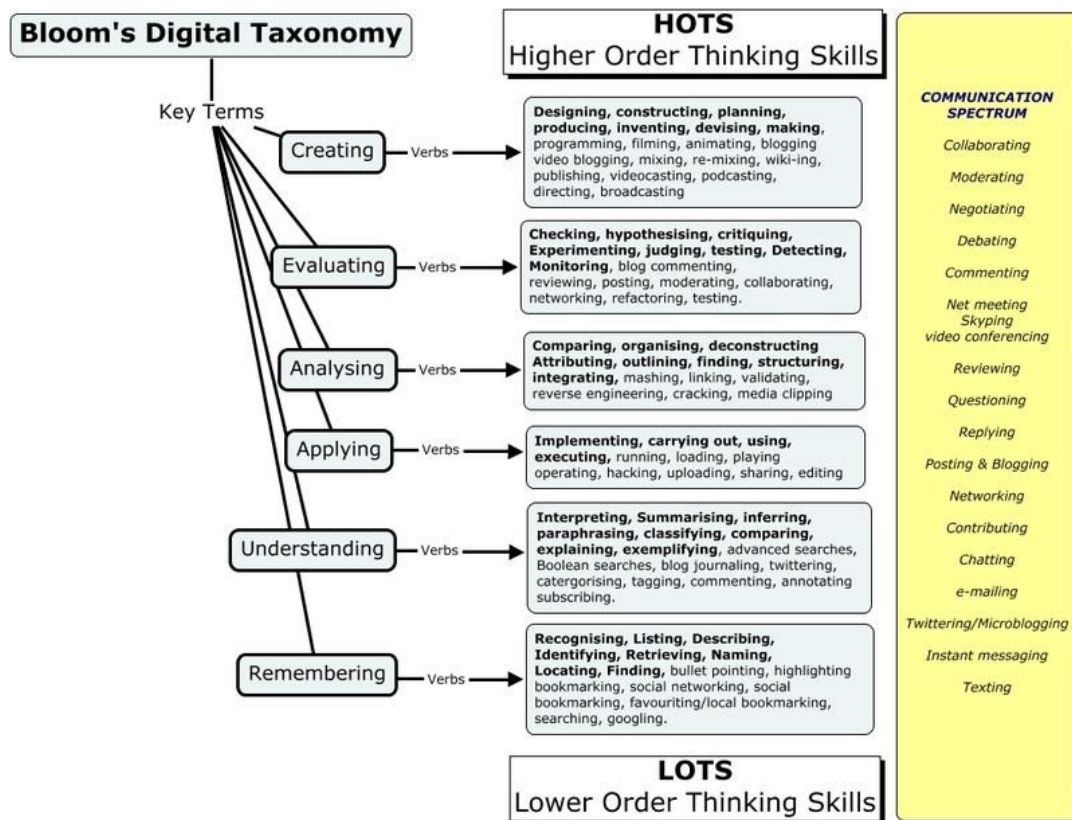


Figure 5: Blooms Taxonomy mapped to skills in digital environments (Churches, 2005)

Course Development

The course development and deployment cycle was completed in 3 phases. Phase 1 which was the concept phase began in the Fall semester of 2010 with the conceptualization of the student interaction and some background observation on student knowledge gaps in the classroom. This phase was implemented with the creation of two integrative in-class assignments that were developed to help the students with an application perspective after they had acquired basic knowledge in class. In addition to these assignments, I also developed the first set of structured online quizzes that were provided to the students as a way to practice content recall and testing. The use of these quizzes and assignments provided a baseline for student engagement, and the data were cycled into the design for the future redesigns. For instance, when I first introduced an in-

class application exercise, I faced a tremendous amount of resistance from the students since it required them to move from passive learning to taking agency in making their learning visible. I also realized that some of this resistance was due to lack of preparation before class. This resulted in us creating a set of pre-class quizzes that the students had to take early in the week which ensured a minimal amount of preparation. In addition to this, I decided to explain the reason for doing the active engagement exercises, which did not necessarily overcome the resistance, but did help some of the motivated students understand the reasoning and elicited good participation. The other major change I implemented was the embryonic idea of heuristic quizzes. I had realized that while the quizzes were helping with student preparation, they needed some scaffolding with concept building. This led us to redesign the quizzes to stepwise match the processes the students were having problems with (plate tectonics and the length of geological time, for example) and offer them as practice quizzes to help the students. I found this approach to have some success and resulted in a targeted development for Phase 2.

Phase 2, which was the development phase, took place over Spring 2011 and Fall 2011 when application exercises were developed for use in-class and assignments were developed for collaborative and cooperative work among the students. In addition, recent research had demonstrated that retrieval practice showed a high degree of learning gains among students who were non-majors as well as majors (Karpicke and Blunt., 2011). This research provided the framework for the refinement of heuristic quizzes (heuristic quizzes are formative assessments that serve the purpose of helping the students practice content retrieval and process learning) that helped the learners' cycle through geological processes before being engaged in activities that led to analysis and synthesis in the cognitive domain.

Having the experience of student resistance in Phase 1, I decided to educate the students about active and inquiry-based learning at the very start of the class, and the language was repeated in all the online materials (lectures, extra notes) and each class, even when I did not have an activity for that particular class period. I found that setting up higher expectations of an active vs. a passive classroom helped set the tone for the students and increase their willingness to participate in their own learning enhancement.

In addition to introducing the students to the concepts of active and inquiry based learning, I also wanted to ensure that the students were trained in the use and development of rubrics since all the discussion board postings and some in-class exercises were scored using a rubric. So to get them enthused about working on rubrics, I decided to have them define criteria to evaluate what would be a perfect enchilada. The students worked on the different components of forming an enchilada and the criteria for evaluation the various elements of a dish. I felt that appealing to a common food item would make it interesting and help drive home the point of the construction and function of rubrics. The usefulness of this techniques was borne out by highly positive feedback from the class.

Phase 3, which was the implementation phase, consisted of developing a hybrid course that incorporated all the learned elements from student feedback from the previous phases and research into various techniques used for student engagement. This final version of the implemented course then consisted chiefly of a combination of online lectures with embedded assessments, heuristic quizzes that helped the students learn process and the in-class active learning exercises which used a case based, inquiry-based approach to cement conceptual understanding among the students.

Table 6. Table showing the 3 phases of development and the micro tested items

	Fall 2010	Spring 2011	Fall 2011	Spring 2012
Concept Applications	◇◇	◇◇◇	◇◇◇	◇◇◇◇
Discussion Boards		○○○○○	○○○○○ ○○	○○○○○ ○○○○○
Heuristic Quizzes	□	□□□	□□□	□□□□
Online Lectures		△△	△△△ △△△	△△△△△ △△△△
	Concept Phase	Development & Testing Phase		Implementation phase

I took a lot of care to ensure that each of the elements of the course worked well and informed each other for different and interconnected cogs of the course. Reflective analysis and student performance data showed that the active learning exercises seemed to play a larger role in student engagement and success as compared to the heuristic quizzes and online lectures. Figure 6 demonstrates the interconnectedness of the three elements of the course with the effectiveness of the technique represented by the size of the cogs in the figure.

In addition to these three elements, I also added online discussion boards seeded with questions following schema outlined by Tu & McIsaac (2002) and Maor (2003) who suggest using currency of topics and short discussion labels as a way to get students engaged in the discussion boards. The discussion board served to ensure that the students were engaged in the content outside of classroom and were having meaningful explorations of subject matter, with a chance for earning a grade and reflection.

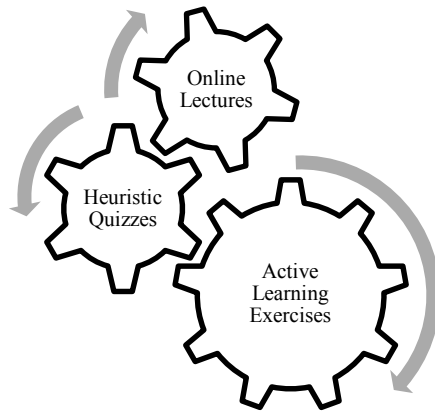


Figure 6. The interconnectivity of the three elements of the redesigned course

Design of the hybrid course followed the integrative model proposed by Palsole and Brunk (2011) where each interaction in the online and face to face portions of the class inform each other and are woven together as highly connected genetic strands rather than being treated as disconnected elements of engagement. The interactive flows in the courses modules were modeled after the experiential learning model for blended courses demonstrated by Palsole and Miller (2006) where experiences in the online world serve as the model of thought in the physical (face to face) portions of the course. While these models were designed chiefly to help create faculty development opportunities, I felt that they provided a good grounding in design to ensure that the online and face to face portions of the course work well together.

COURSE DEPLOYMENT

The fully developed course was deployed in Spring 2012. The course was broken into 3 principal modules which were created by clustering geological processes which had the most common thematic elements, and thus could be used to build a framework.

Table 7. Table showing the 3 phases of development and the micro tested items

Module 1 A framework for studying the earth	Introduction, nature of science, geology and geological investigations, geologic time
	Plate tectonics
	Minerals, igneous rocks and volcanoes
Module 2 Shaping our environment	Mass wasting ,weathering and soils
	Sedimentary rocks and rivers
	Shorelines and oceans
	Deserts and wind
	Ground water and water resources
Module 3 Deep processes	Metamorphic rocks and deformation
	Earthquakes and Earth's interior
	Convergent boundaries

Each module was built as a stand alone thematic module with the lecture topics arranged in the order outlined in Table 2. Each topic followed a similar construct with the start of the topic providing an introduction to the topic, a quick formative assessment to help the students gauge their knowledge of the topic, a lecture that consisted of short video clips and text based content developed by the authors and a reflective assignment which consisted of a discussion board posting.

Since one of our aims was to create a population more literate in earth sciences and who could appreciate the field, I chose to ensure that the in-class exercises were place bound and had characteristics of our vicinity. So for example when designing exercises for module 2, I chose to focus on ground water issues or concepts of mass wasting, which are observable here vs. any focus on glacial geology. I felt that this focus on phenomena that could be observed or experienced locally helped engage the students and motivated them to work on the inquiry-based problem-solving exercises.

All the students were broken into teams of 5 picked randomly by putting numbers in a box and having the students pull out numbers and identify their teams. Each team had a discussion

area and a shared file area created to enable collaborative work. Teams were required to post a response to assigned reflection topics individually in the discussion boards, and also respond to each member of the team. The discussion board postings were due two days before the class meetings with responses to each team member due the day before the meetings. The students were provided with a grading rubric for the discussions derived from a set of rubrics downloaded from the Science Education Resource Center (SERC) site at Carleton College. In addition to the provision of the grading schema, I had realized that the students were unused to working independently online. So to ensure their success, I provided a recommended work chart outlined in Figure 3. The work chart gave them a recommended weekly structure to follow, and the end of the semester evaluations reflect that a majority of the students appreciated the extra coaching.

Sun	<ul style="list-style-type: none"> •Take knowledge quiz and heuristic quiz •Continue reading and engaging in lecture content and exercises
Mon	<ul style="list-style-type: none"> •Discussion board postings due by 5:00 PM •Continue reading, take heuristic quiz as needed
Tue	<ul style="list-style-type: none"> •Respond to discussion board posting by midnight
Wed	<ul style="list-style-type: none"> •Read instructor responses to discussion boards before class •In-class : individual and team activity, mini lecture and discussion
Thu	<ul style="list-style-type: none"> •Reflection discussion board posting •start reading next weeks lecture, read discussion questions due on Tuesday
Fri	<ul style="list-style-type: none"> •Share a geology news article of the day and its importance. Points awarded for best entries.
Sat	<ul style="list-style-type: none"> •Start reading next weeks lecture •Read chapter from textbook , vote for geology article of the day.

Figure 7. Recommended weekly work schedule provided to the students

In addition to the focus on developing activities that appealed to the students' sense of place or involvement in pop culture, I also ensured that the online components of all the weekly topics fed into the planned in-class engagement and vice versa. The latter piece was very important

since earlier experiences had shown us that the students' need to experience a continuity between each contact, whether virtual or live so they start seeing the course as a learning experience in its totality, rather than a fragmented experience where online components are purely lecture based and have little to no bearing on the active learning exercises. In turn, all the activity in class needed to be reflected upon to actuate deeper thinking and help develop appreciation of the geological process and the problem-solving aspect of the field. Figure 4 provides a general schematic of the first week, which exemplifies our efforts for each covered topic.

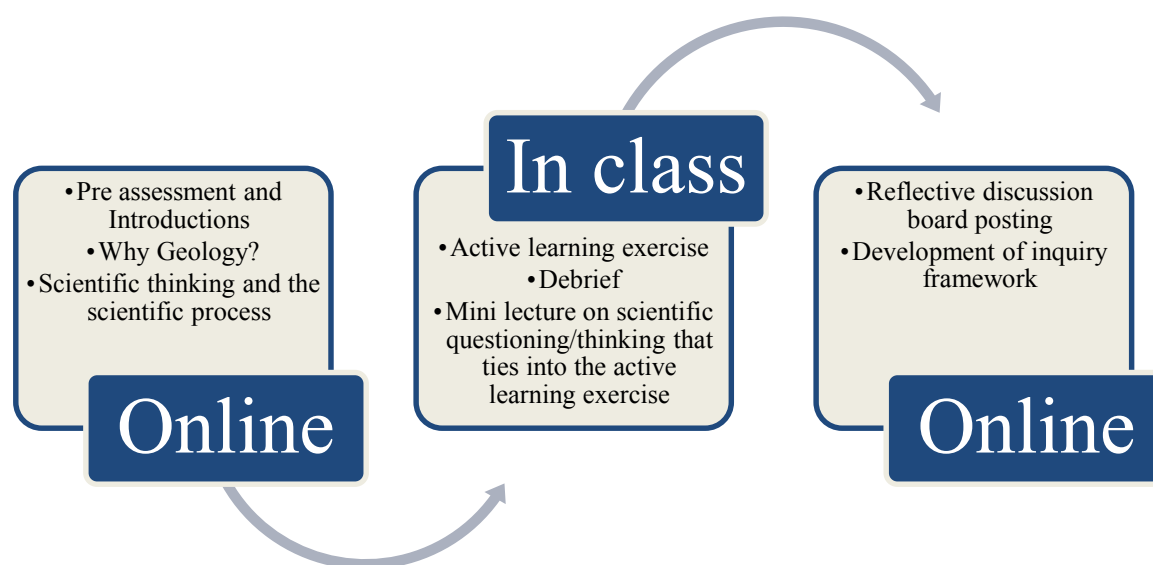


Figure 8 The interaction schematic for the first week. This models the weekly activity for all topics with designed inquiry-based exercises.

ASSESSMENT

The assessment of the efficacy of a hybrid course with active learning strategies vs a traditionally taught course was conducted using three methods. The first was student learning outcomes as measured on a standardized test created from questions extracted from the Geoscience Concept Inventory (GCI). McConnell et. al (2005) have shown that the GCI is a reliable indicator of student geoscience knowledge and conceptual understanding, and as such can be used as a

comparative measure. In addition to the GCI, I also administered a metacognitive test using question gleaned from the Self Assessment of Learning Gains (SALG) inventory. The SALG has specifically been developed to measure the degree to which the course has affected student learning as self reported by the student. While the SALG on its own may not be the best indicator, I feel confident that coupled with the GCI, it provides a nuanced look at course delivery effects on student learning outcomes. And lastly I also tested our hypothesis that for students in hybrid courses, the use active strategies in class could possibly produce better retention of course content after the semester has ended, as compared to students in the traditionally taught class.

The courses are not equal in size, but they provide a good first look at effectiveness since the traditional course did not use any technology (other than PowerPoint) and the test course was developed as an active learning enabled hybrid course. Both the courses also have similar demographics with approximately 80% of the students being Hispanic, 47% first generation and 56% female. This is a close approximation of the student body at the university, and thus provides an interesting look at pedagogical effects.

The questions on the GCI were administered towards the end of class and again 8 weeks after the class had ended in an attempt to gain some understanding of student retention of content which was one of the key goals and hypothesis of the redesign. There were a total of 28 questions on the GCI that was administered to both the classes. Both the classes took the GCI by hand, since that was the mode chosen for the regular class. The students were given 45 minutes to complete the test. To ensure reduction of selection bias, all the questions on the GCI were chosen by a faculty member who was very familiar with the GCI, but was not involved in teaching either course. The faculty member was very familiar with the overarching goals of the introductory

course and was provided a copy of the syllabus of each course to ensure that the students were tested on the common factors of the course.

The GCI at the 8 week post semester end mark was administered online to all the students in both courses. The students had to elect to take the test again and there may be some selection bias that affects the scores. But the scores provide a broad look at retention effects in courses that use active learning strategies and technology vs. traditional courses.

RESULTS

Self Assessment of Learning Gains (SALG): A derivative version of the SALG instrument was administered to both the traditional and the hybrid course. The instrument focused on student perceptions of their performance based on delivery method and any gains in their understanding and confidence in using the concepts acquired in the courses. While a self reported confidence metric is not necessarily indicative of learning, there is some early research (Bell and Federman, 2010) that shows that it can serve as a good predictor of student engagement. In addition, the questions provide some insight into what the students view as valuable for learning.

Overall the SALG results are quite interesting since they overwhelmingly point to the students' experiences in the active learning classroom being more desirable. In addition to the clear indication of a preference, the students also felt that the participation in the active learning classroom helped them see the earth sciences as a field that helps solve real world problems: an issue that is very important if we are to engage new students in the earth sciences and increase earth science literacy among the population.

It is interesting to note in Table 3 that the students point to seeing the fit of the class better in the hybrid course, which is a probable result of the deliberate design discussed earlier. In

addition, the students also show a clear preference for hands on activity vs. passive learning. This change is significant given the steep resistance curve I faced in the development phase (Phase 2) of the course and demonstrates that students' value increased communication about the value of active learning and are willing to participate in meaningful activities, as long as they hold value for them.

Table 8. Student responses to question about aspects of class that helped their learning.
HYB=Hybrid class; REG=Regular class

	no help		a little help		moderate help		much help		great help		not applicable	
	HYB	REG	HYB	REG	HYB	REG	HYB	REG	HYB	REG	HYB	REG
The instructional approach taken in this class	0%	14%	10%	19%	5%	37%	20%	16%	65%	11%	0%	3%
How the class topics, activities, reading and assignments fit together	0%	14%	10%	17%	5%	47%	35%	14%	50%	9%	0%	0%
Listening to discussions during class	15%	40%	15%	20%	25%	11%	20%	13%	25%	13%	0%	5%
Participating in group work during class	0%	30%	0%	6%	15%	5%	45%	9%	40%	10%	0%	39%
Doing hands-on classroom activities	5%	4%	0%	20%	10%	24%	20%	12%	65%	11%	0%	30%

Geoscience concept inventory and end of semester grade results.

I analyzed data from the final grades in both the courses and the GCI which was administered to both classes. The traditional class had an N=111 and the hybrid course had an N of 20 (it was 21 till the last week of the semester when a student took a medical withdrawal so I removed the data from the calculations which did not have a major effect on the results). Since both the classes followed different testing and engagement regimes, I could not do any aligned testing during the semester so therefore have to rely on the results of the GCI administered at the end of the semester. The hybrid course had a mean score of 23.15 and the regular course had a mean score of 19.50. Due to the difference in the population sizes and unequal variances, I chose to run a Welch's t-test on the student data which returned a significant t value at a $p > 0.5$. This showed us that there is a significant difference in the student performance in the hybrid vs. the regular course, even when accounting for the variance and difference in sample sizes.

In addition to this I also looked at the final grade distribution in both the classes vs the GCI scores which I normalized by converting them to letter grades. So for example, I took the scores for each student on the GCI and converted them into percentage scores, and then a letter grade following the grading schema used for both the classes as outlined in the syllabus. Both the classes used the following schema

A=90+% points, B=80-89.99% points, C=70-79.99%points, D=60-69.99%., F=score<60%.

This provided us a way to see if the scores on the GCI, which is a standardized instrument with questions that were randomly chosen, were predictive of student learning as reflected in the final grades. Graphing the results provided some interesting trends in the data. Notethe grade distribution in the GCI matches the final grades in the hybrid course with the trend lines running fairly close to each other, indicating that the GCI is in some sense a possible predictor of the final

grades, while the plots from the regular course show that the GCI is not a good fit for the final grades and is not necessarily reflective of the final grades of the course.

These differences could point to the nuances in grading that creep in for classes that are based on high stakes grading vs. a continuous grading cycle typically followed by courses that apply active learning strategies.

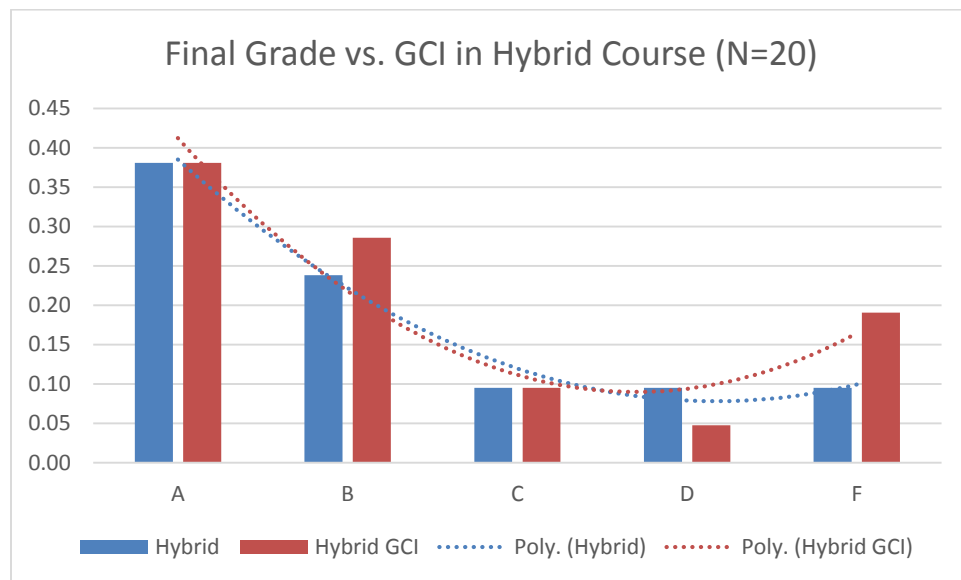


Figure 9 : Bar graph showing comparative grade distribution of final grades and the GCI with second order polynomial trendlines for the hybrid course.

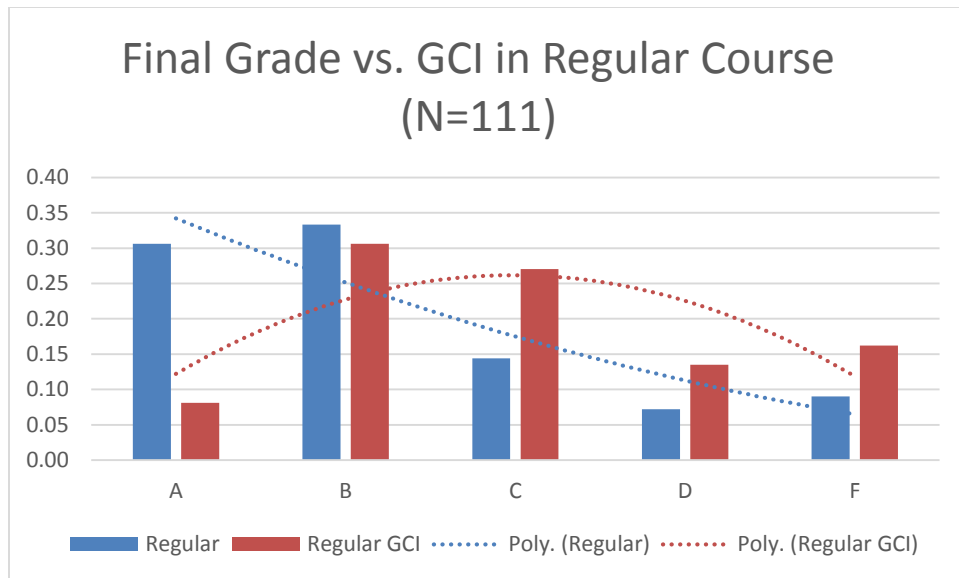


Figure 10 Bar graph showing comparative grade distribution of final grades and the GCI with second order polynomial trendlines for the regular course.

Post semester GCI results

One of my hypothesis was that students in an active learning hybrid classroom would have longer retention of course content than those in a traditional classroom. To study the hypothesis I sent the same GCI instrument to all the students in the hybrid and traditional classroom via e-mail with a note requesting their participation and explaining the reason for the retest. This retest was administered by creating the GCI in Qualtrics, an online survey tool. I chose to use this tool because it prevents ballot stuffing (only the person who gets the e-mail can take the survey and the survey cannot be shared). Since I had also set this up as a secure survey that required a UTEP login, I am fairly certain that there is a low risk of the results being skewed by a different person

taking the test. The students were given 45 minutes to complete the quiz, which was the same amount of time allocated for the quiz, when they took it at the end of the semester for the first time.

A total of ten students from the hybrid course, representing a 50% return, took the CGI and 22 students from the regular course, representing a 21% return on the survey. The mean scores had dropped, as was expected. The average mean for the hybrid courses now was 20.7 for a drop in scores of 2.45 points. For the regular course the mean now was 16.22 points which showed a total drop in scores of 3.29. These data demonstrate that at the simplest level the students in the hybrid course had better retention 8 weeks after the semester ended as compared to the students in the regular class. What was interesting to note was that there were students who got C's in both the classes who took the GCI again, and the variation in their individual scores was lower than the class mean. This could imply that the C and D students retain a baseline of information that does not show significant change over time. Our data are too sparse to currently explore this premise and this could be an interesting study for the future.

DISCUSSION AND CONCLUSION

Hybrid courses especially those that embrace active learning techniques for the face to face time, show great promise to change student engagement in the earth sciences. Given the shrinking base of earth scientists and the dearth of new undergraduates in the field, it behooves us to examine ways to engage a new group of students who are highly connected and networked.

Throughout the course development we noticed that the slower approach did help some issues I discovered early on, chief among them being the students being unprepared to take responsibility for their own learning. In addition to that, our assumption that the students would be reasonably fluent in the use of the technologies was a wrong assumption. I realized very early

on that I needed to provide some tutoring to the students and that could be easily achievable by creating a series of low stakes assignments designed to help them use the tools in Blackboard.

I also tried to test the transferability of the content and the in-class exercises and realized that while the online portions of the course (lectures, interactive exercises, discussion board posting prompts) could easily be transferred and scaled, the in-class exercises required strong facilitation skills and a desire to inculcate a culture of questioning in the classroom. This change among students from being passive learners to actively engaged, questioning learners, can be quite disconcerting to instructors who are used to a traditional model of teaching via lecture. As much as this is for students, it requires a tremendous amount of change for faculty.

And last but not the least, I felt that once the course was built over the period of 18 months with modules that had been tested and tweaked to make them as error free as possible, it saved the instructor time during the Spring 2012 since now he could focus on student engagement rather than course management and mundane instructional delivery.

While this study has shown the positive effect of active learning strategies in a hybrid format, there is still further research needed to identify the key elements of design which have the maximum impact on student learning. A further study that can isolate the effects of the techniques by replicating the study in a matched context would be of additional value in helping build a model for the future.

Some recommendations I have for new practitioners to the field of active and blended learning are (a) to plan early and plan well. Create a schedule for the first delivery of the class with small activities and stick to it. I found that even small changes in the schedule can be disruptive to students and derail the work. (b) Make sure that each topic is dissected appropriately into smaller segments to enable designed learning that seamlessly integrates

learning spaces, whether online or offline. (c) I strongly encourage a phased approach to development. A phased approach helps you identify all the support that you will need to have in place for the students, and also helps you isolate the areas that the students have the most problem understanding and develop a mitigation plan by use of online resources and active learning strategies.

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APPENDIX A : PUBLISHERS PERMISSIONS

Section 1 of this dissertation titled “Computer-Aided Heuristic Quizzes as a Technique for Enhancing Student Learning of Process in Geosciences” has been submitted for publication to the Journal of Computers and Education. The full text of the copyright policies of the journal can be found here <http://www.elsevier.com/journal-authors/author-rights-and-responsibilities>. The publisher allows the use of the accepted and published manuscript for full inclusion in a thesis or dissertation.

Sections 2 and 3 will be prepped and submitted to the Journal of Geoscience Education. Included below is the verbatim exchange between the author of this dissertation and Dr. Kirsten St. John the editor of the Journal.

From: St John, Kristen E - stjhnke [mailto:stjohnke@jmu.edu]
Sent: Sunday, June 15, 2014 9:31 AM
To: Sunay Palsole
Cc: Journal of Geoscience Education
Subject: Re: Use of dissertation chapter as paper

Dear Sunay,
It is ok to include an article that you publish in JGE as a chapter in your dissertation, as long as it is fully cited.
Kind regards,
Kristen

Sent from my Verizon Wireless 4G LTE DROID

Sunay Palsole <sunay.palsole@utsa.edu> wrote:

Dear Dr. St. John,

I have a query regarding the use of a paper I am preparing to submit to JGE and its use as part of my dissertation. I would like to use the paper verbatim as a chapter (rather in lieu of a chapter) in my final dissertation, and wanted to confirm that I can do so before I proceed further with preparing the work for journal submission.

I apologize for bothering you, but I could not find any information on this on the JGE site.

If I should be contacting someone else, I would greatly appreciate any direction/redirection.

My best regards,

Sunay

Sunay Palsole
The University of Texas at San Antonio

(210) 458-5868

APPENDIX B: GEOSCIENCE CONCEPT INVENTORY USED FOR TESTING

1. Which of the following responses best summarizes the relationship between volcanoes, large earthquakes, and tectonic plates?
 - A. Volcanoes typically occur on islands, earthquakes typically occur on continents, and both occur near tectonic plates
 - B. Volcanoes and large earthquakes both typically occur along the edges of tectonic plates
 - C. Volcanoes typically occur in the center of tectonic plates and large earthquakes typically occur along the edges of tectonic plates
 - D. Volcanoes and large earthquakes both typically occur in warm climates
 - E. Volcanoes, large earthquakes, and tectonic plates are not related, and each can occur in different places
2. 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
3. If you could travel millions of years into the future, how big would the planet Earth be?
 - A. Smaller than today
 - B. Larger than today
 - C. Same size as today
 - D. We have no way of knowing
4. What happens to the volume of water that passes from groundwater to streams during a prolonged drought?

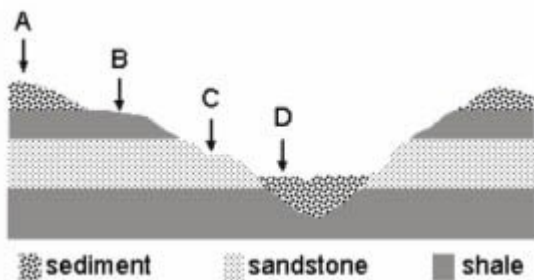
- a. it increases
- b. it decreases
- c. no change

5. How far do you think continents move in a single year?

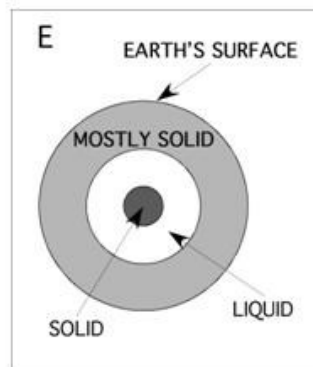
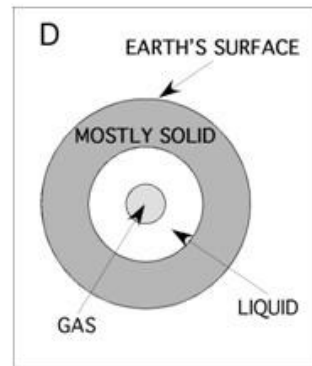
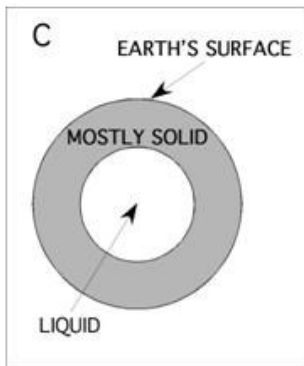
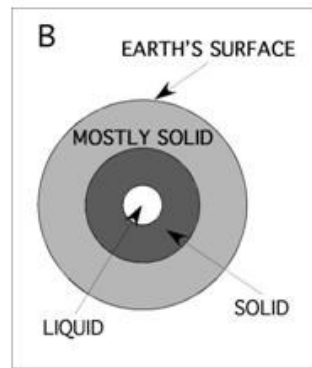
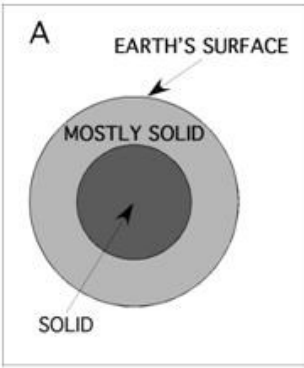
- A. A few inches
- B. A few hundred feet
- C. A few miles
- D. We have no way of knowing
- E. Continents do not move

6. The cross section below simplifies the groundwater resources in a county in a Midwest state. Which location would have the potential for the best groundwater production?

- A. Sand and gravel on hilltop
- B. Shale bedrock
- C. Sandstone bedrock
- D. Sand and gravel in stream valley



7. 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
8. Which of the following do you believe is most closely related to what you might see if you cut the Earth in half?



A.

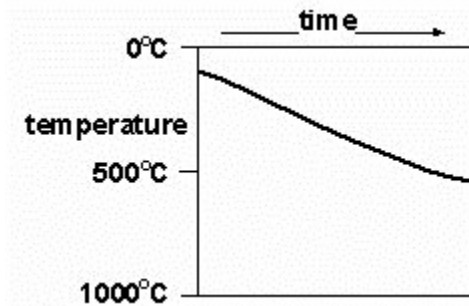
B.

C.

D.

E.

9. The graph below illustrates how the temperature changed with time for part of the rock cycle. Which of the following processes is best represented by the graph?



- a. sediment is lithified to form sedimentary rock
 - b. sedimentary rocks are converted to metamorphic rocks
 - c. metamorphic rocks are uplifted to Earth's surface
 - d. magma cools to form plutonic igneous rock
 - e. sedimentary rock is converted to magma
10. An ice cube melting in hot tea is analogous to which igneous process?
- a. fractional crystallization.
 - b. assimilation.
 - c. partial melting.
 - d. intrusion.
11. In an arid climate like El Paso, which process contributes the greatest volume of water to streams?
- a. human activity
 - b. overland flow
 - c. groundwater discharge
12. What is the most likely cooling rate and composition of a light colored, small grained igneous rock?
- A. Cooled rapidly, low silica
 - B. Cooled rapidly, high silica
 - C. Cooled slowly, low silica
 - D. Cooled slowly, high silica
13. What determines the magnitude of an earthquake?
- a) The type of plate boundary where the earthquake occurs.
 - b) The amount of energy released by the movement on a fault.
 - c) The amount of damage that occurs as a result of the earthquake.
 - d) The depth of the earthquake focus below the ground surface.

14. What principle would be the best to apply to determine the relative order in which rock units A and B in the image below were formed?

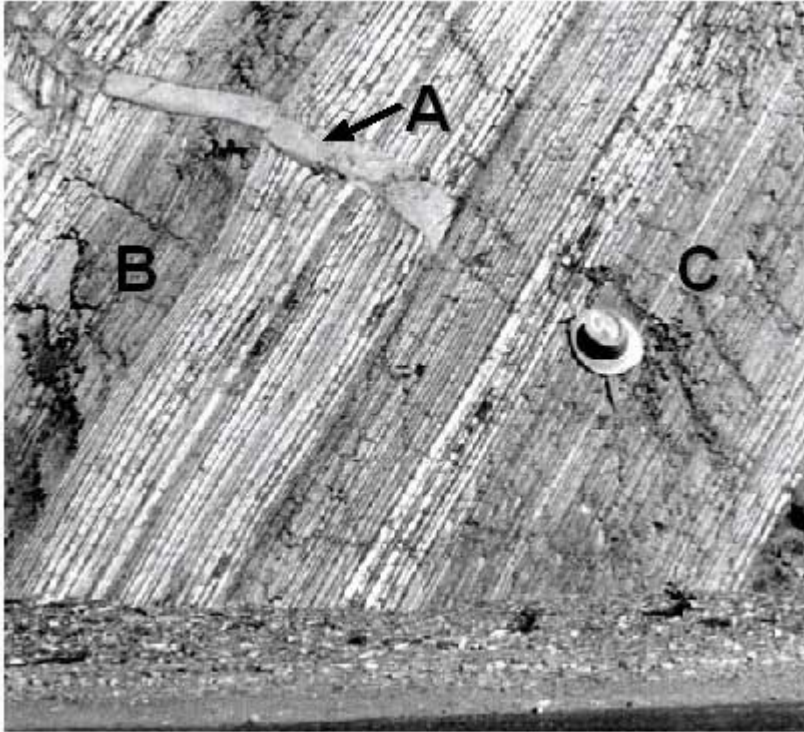
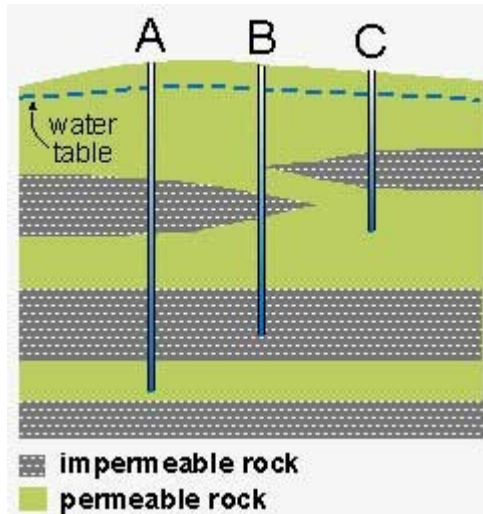


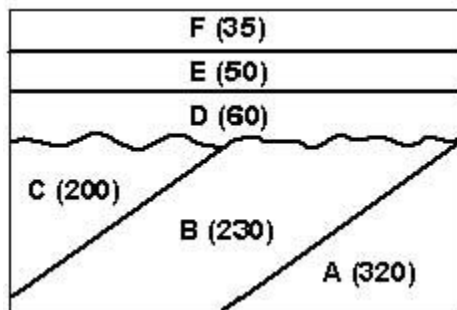
Image courtesy of USGS

- a. Original horizontality
 - b. Cross-cutting relationships
 - c. Superposition
15. Imagine that all minerals found in igneous rocks were the same color. What information would you no longer be able to infer from observing a rock sample?
- a. magma cooling rate
 - b. composition
 - c. texture

16. Liquid hazardous waste is disposed of by pumping it down injection wells. Which well location would be the most suitable to use for an injection well?

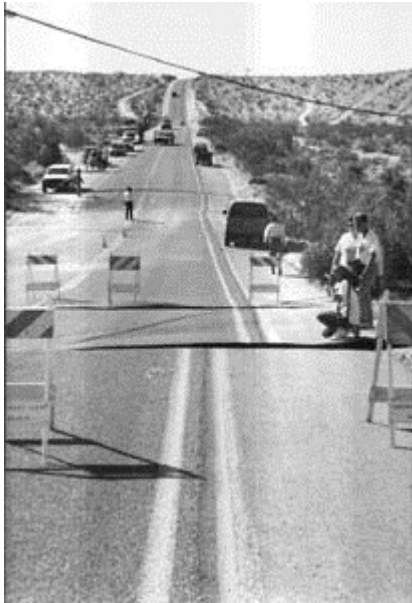


- a.)
b.)
c.)
17. The diagram below shows rock units with their age in millions of years. When did crustal deformation (uplift or mountain building) occur?

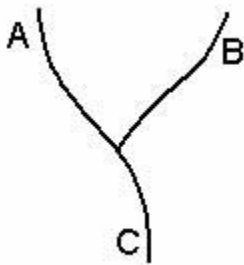


- a. less than 60 million years ago
b. more than 200 million years ago
c. between 60—200 million years ago
d. between 200 - 230 million years ago.

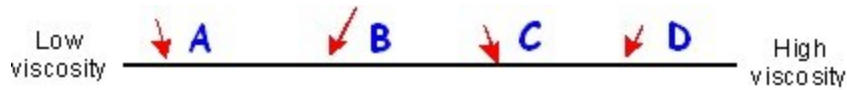
18. What is the relative displacement of the fault that offsets the road in the photo?



- a. left lateral
 - b. right lateral
 - c. normal
 - d. reverse
19. The diagram depicts the confluence of two perennial streams (A and B) forming C. Which of the following statements regarding stream C must be true?
- a. Stream flow velocity is greater than in A or B.
 - b. Stream discharge is greater than in A or B.
 - c. Stream gradient is less than in A or B.

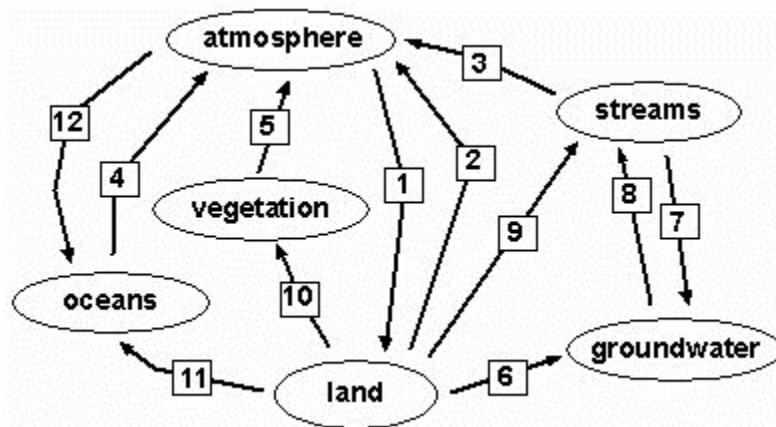


20. Place these materials (maple syrup, milk, peanut butter, frozen yogurt) in the correct position for their relative viscosity. What is at position #B?



- a. frozen yogurt
- b. milk
- c. peanut butter
- d. maple syrup

21. The following diagram illustrates the Hydrologic Cycle. Match the letters below to the arrow on the diagram (note: some letters may be used for more than one arrow).

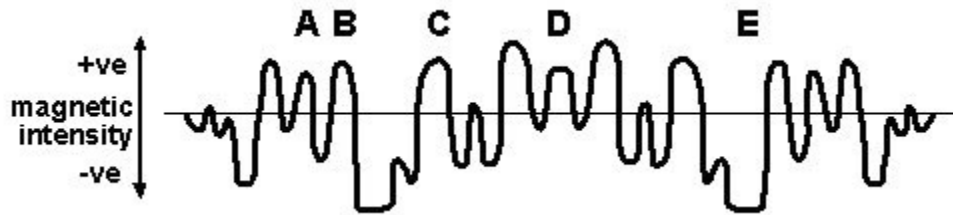


Which process best represents Arrow 1?

- a. evaporation
 - b. precipitation
 - c. transpiration
 - d. infiltration/percolation
 - e. run-off
22. If you pull on a rubber band it will change shape. Pulling on the band is an example of _____.

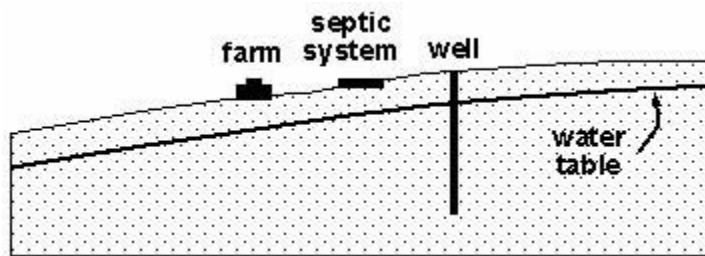
- a) stress
 - b) viscosity
 - c) strain
 - d) brittleness
23. This is part of a magnetic profile across an oceanic ridge system. The profile shows both positive and negative anomalies. Based on the symmetry of the patterns, where is the axis of the ridge located?
- a. A
 - b. B

- c. C
- d. D
- e. E



24. Three similar containers were filled with flour, rice or Cheerios. If you were to pour water into each container, how would they rank in terms of permeability (from highest to lowest)?
- a. Flour, Rice, Cheerios
 - b. Rice, Cheerios, Flour
 - c. Cheerios, Rice, Flour
 - d. Rice, Flour, Cheerios
25. One million years ago ice sheets covered much of the Earth's land surface during an ice age. How did this affect the salinity of the oceans?
- a. Oceans were saltier than today.
 - b. Oceans were less salty than today.
 - c. Ocean salinity was the same as today.
26. A stream channel is narrowed by bridge construction. How will the velocity of flow change if the depth and discharge of the stream remain constant?
- a. velocity will increase
 - b. velocity will decrease
 - c. velocity will not change
27. A rapidly growing city within a humid climate zone experiences a land use change from predominantly crop land to mostly urban/suburban. A likely natural response would be:
- a. Increased infiltration—reduced flooding
 - b. Reduced infiltration—increased flooding
 - c. Increased infiltration—increased flooding
 - d. Reduced infiltration—reduced flooding
28. A farmer drilled a well into an open aquifer composed of sand and gravel. He installed a septic system downslope from the drinking well (see diagram). A few years later the septic system started to leak. Water tests showed that the well water was clean and uncontaminated by bacteria present in the septic system. Why did the septic system not

contaminate the drinking water supply?



- a. The bacteria were drowned in the groundwater.
- b. The groundwater flow carried water away from the well.
- c. Gravel has a low permeability that makes it difficult for bacteria to travel from the septic system to the well.
- d. The septic system is not located in the aquifer's recharge zone.

APPENDIX C: GRADING RUBRICS AND OBSERVATION PROTOCOL

ORAL PRESENTATION COMPREHENSIVE RUBRIC FOR INSTRUCTION AND EVALUATION

Developed by the AAC&U VALUE Project Oral Communication Metarubric Team: Jo Beld, St. Olaf College; Marc Braun, Augustana College; Mary Gill, Buena Vista University; Brad Mello, National Communication Association; Laura Palucki-Blake, Agnes Scott College, July 2008

Clarity of organization

	(4) Exemplary	(3) Proficient	(2) Developing	(1) Beginning
<i>Introduction:</i> The introduction previewed the topic and organization of the presentation.				
<i>Main point:</i> The central claim of the presentation was easy to identify.				
<i>Grouping of ideas:</i> The presentation was organized into clearly-identifiable sections with an explicit organizational pattern (e.g., chronological, problem-solution, analysis of parts, etc.).				
<i>Conclusion:</i> The conclusion reinforced the central claim of the presentation.				

Effectiveness of substantive content

	(4) Exemplary	(3) Proficient	(2) Developing	(1) Beginning
<i>Main point:</i> The central claim of the presentation was clear, concise, and compelling.				
<i>Supporting points:</i> Each section of the presentation conveyed a supporting claim that advanced the central claim.				
<i>Evidence:</i> The amount and variety of supporting material (e.g., examples, statistics, quotes from authorities, analogies) made the supporting claims compelling.				
<i>Sources:</i> The sources cited in the presentation were reliable and appropriate to the subject.				
<i>Language:</i> The language characterizing the presentation was grammatical, vivid, appropriate to the subject and occasion, and free from bias.				
<i>Visual aids:</i> Visual aids (e.g., PowerPoint slides, handouts, charts, graphs) were introduced when needed, were easy to understand, and augmented the content of the presentation without overwhelming the oral component.				

<i>Topical significance:</i> The presentation addressed a substantive topic worthy of the attention of the listeners.				
<i>Overall effectiveness of content:</i> In general, the presentation was informative and/or persuasive.				

Connection to the audience

	(4) Exemplary	(3) Proficient	(2) Developing	(1) Beginning
<i>Relevance of topic:</i> The presentation was explicitly related to the interests and/or experiences of the listeners.				
<i>Credibility of supporting material:</i> The presentation included evidence and sources that the audience would find credible.				
<i>Responsiveness:</i> The speaker restated or clarified audience questions and provided concise, relevant, and knowledgeable responses.				

OBSERVATION PROTOCOL

The purpose of having several instructors observe the class is to gather as much information about the process of the lesson as possible. Your primary task is to observe *how the students respond to the lesson and make some conclusions about how well the LESSON worked.* In other words, please note behaviors of the students and the benefits/difficulties of the lesson, NOT the behaviors of the instructor 😊!

Please do not engage with the students in any way, even if you see them struggling or going in a wrong direction.

Please do not engage with the instructor in any way, and please be discrete in your movement in class.

You will be observing two groups of approximately 5 students.

Given the goal of helping students understand the problematizing of the task at hand, develop the correct questioning strategy and construct validity, please look for evidence/examples that students are using conceptual understanding to discuss and develop appropriate questions in groups. Please do pay particular attention to discussions centering around the theme being discussed.

Please do take notes on your group's behavior. In addition to noting any good and poor examples of their ability to think about the logic of construct validity, please also note such things as

- How the group developed their questions and discussion points. Did they integrate their individual definitions? Did they simply string their individual definitions together? Something else?
- Were the students using the ancillary materials at hand to explore ideas?
- Any evidence that the students seemed interested and/or engaged in the lesson
- Any derailing of the process
- Any problems in the group dynamics (dominating members, quiet members, etc.)
- Any problems understanding the directions
- Anything else you think is substantial!

Observer Reactions to the Lesson

Now that you have observed the lesson, please answer the following questions.

- | | | | | | | |
|---|---|---|---|---|---|---|
| 1. All members participated in the process | 1 | 2 | 3 | 4 | 5 | 6 |
| 2. The group was able to stay on track with the lesson (i.e. did not derail, discussing irrelevant information) | 1 | 2 | 3 | 4 | 5 | 6 |
| 3. The group seemed confused about the technical processes of the lesson | 1 | 2 | 3 | 4 | 5 | 6 |
| 4. The group seemed confused about the concepts the lesson was addressing | 1 | 2 | 3 | 4 | 5 | 6 |
| 5. The group seemed to understand the <i>concept</i> of the geological process | 1 | 2 | 3 | 4 | 5 | 6 |
| 6. The group seemed to understand the development of the problem | 1 | 2 | 3 | 4 | 5 | 6 |
7. Given your observations, what aspects of the lesson need to be changed? How could the lesson be improved?
8. What aspects of the lesson should remain the same? What worked well?

VITA

Sunay was born in Jamshedpur, Bihar to Capt. V.K Palsole and Mrs. Veena V. Palsole. He graduated with a M.Sc. in Applied Geology from the Indian Institute of Technology at Powai, and worked in the oil industry before coming to UTEP for the Geophysics program. He got his masters degree in geophysics in 1996, earning the outstanding student award along the way. Always a user of technology, Sunay got interested in the use of technology to enhance teaching and entered the world of educational technology.

Sunay's interest in the teaching of geology was sparked in a conversation about climate change and science in general while judging a science fair. Sunay is convinced that the teaching of the earth sciences is key to the growth and survival of science and has been interested in the development of new modalities of teaching and learning to increase awareness and interest in the earth sciences.

When not engaged in the pursuit of the earth sciences, Sunay works as an administrator in academia where he has built highly successful educational technology shops with a focus on innovative technology and the use of technology in support of pedagogy.

This thesis/dissertation was typed by Sunay Palsole.