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Concepts about Sedimentology and Stratigraphy in Undergraduate Geoscience Courses

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By

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CONCEPTS ABOUT SEDIMENTOLOGY AND STRATIGRAPHY IN UNDERGRADUATE GEOSCIENCE COURSES

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This two-part study examines sedimentologic and stratigraphic concepts in undergraduate geoscience courses. The first part seeks to identify the various types of interactive engagement strategies used in undergraduate science courses, how they are used and in what fields. It also looks at areas in which the geosciences have excelled in interactive engagement strategies. Published studies describing interactive engagement strategies in college-level courses were collected and coded, which identified six emergent types of interactive engagement strategies: (1) Polling, (2) Full-Class Discussion and Activities, (3) In-Class Group Work, (4) Out-Of-Class Group Work, (5) Online Work, and (6) Other types. Interactive engagement strategies within each type are used across all science fields and there is room for adaptation of interactive engagement strategies, popular in one subject, to be utilized efficiently and effectively in other subjets. The second part to this study seeks to understand undergraduate student misconceptions related to sedimentologic and stratigraphic concepts in order to construct a set of effective Lecture Tutorials. Lecture Tutorials were created using data from a faculty survey, faculty feedback and student "think-aloud" interviews and tested in three focus group settings. Three of the five Lecture Tutorials showed statistically significant learning gains for the same students between their post-lecture and post-lecture and

Lecture Tutorial responses to a questionnaire. Student alternative conceptions are present in the student open-ended responses. These alternate conceptions relate to unconformities, sea level, and depositional and erosional processes. The alternate conceptions relating to depositional and erosional processes are unique to this study.

DEDICATION

I dedicate my Masters Thesis in memory of Dr. Fred Voner, professor and advisor at Marietta College. Dr. Voner was a true inspiration to me and sparked my love for geology. As well, he saw my potential for teaching and pushed me to pursue geoscience education. I hope to someday to inspire and impact students' lives the same way he has impacted mine and so many others in his 34 years of teaching.

ACKNOWLEDGMENT

I would like to acknowledge the people who have help me through this process. My Advisor Dr. Leilani Arthurs for all of the time and hard work she has done in helping me complete my thesis research. Dr. David Harwood and Dr. R.M. Joeckel for serving on my committee, The University of Nebraska-Lincoln, Earth and Atmospheric Sciences for the opportunity and funding to complete my thesis work. Finally, I would like to acknowledge my friends and family who have helped me and supported me

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CHAPTER 1: LITERATURE REVIEW OF ACTIVE LEARNING STRATEGIES

1.1. Introduction

After over 900 years of teaching, despite urges for change, traditional lecture is still the predominant teaching style in college courses (Freeman et al., 2014). Traditional lecture can lack the ability to promote intellectual engagement (Allen and Tanner, 2005). During traditional lecture, students typically take notes without any interaction with other students or the instructor (Barr, 2014), leading to the instructors being the most benefited in the classroom (Allen and Tanner, 2005). In creating a traditional lecture, instructors utilize steps to create conditions for learning such as: finding new information, organizing the new information, and then explaining it to others (Allen, 2005). Traditional lecture can be thought of as a “teaching by telling” style of teaching, contradicting theories of learning that claim that students’ need to construct their own knowledge in order to learn (Freeman et al., 2014).

Due to these identified limitations of traditional lecture styles in motivating student learning and intellectually engaging them, interactive engagement strategies (IES) can be an important tool in fostering learning (Allen and Tanner, 2005). IESs attempt to build critical thinking skills (Allen and Tanner, 2005), allowing the student to perform the actions required to overcome changing problems in the learning process (Prince, 2004) while interacting with other students or the instructor. A study of over 6000 students in physics courses shows that IE in a classroom can be more then twice as effective as traditional lecture in building knowledge on basic concepts (Hake, 1997). Increased learning was also seen by Freeman et al.’s 2014 study of 225 published reports, showing that IE in classrooms can increase student test scores by 6%. Student retention rates also increase with IE, but students in traditional lecture courses are 1.5 times more likely to fail (Freeman et al., 2014). IESs typically are in class activities (Prince, 2004) and the learning gains for, and success of, IE in the classrooms is well documented, but IESs have been implemented successfully in online courses (Brown, 2014), lab, field, and other out-of-class settings.

This chapter, from here out, addresses the use of interactive engagement strategies (IES) in undergraduate science courses. To examine the extent to which IES have been adopted in undergraduate college science courses over the past ~20 years, this literature review seeks to answer three questions: (1) what types of interactive engagement strategies are used to teach college science courses? (2) when and how are they used in different disciplines? (3) how does the use of interactive engagement strategies in the geosciences compare to their use in other disciplines?

2. Methods

Articles published in the period 1994-2014 that discuss the implementation of IESs in undergraduate college science are the focus of this literature review. These articles were found by searching the Educational Recourses Information Center (ERIC) database (https://eric.ed.gov/). Search terms were used in a variety of combinations, searching the title, abstract, and keyword (Table 1). Figure 1. Shows the specific steps and number of articles collected at each step for this process.

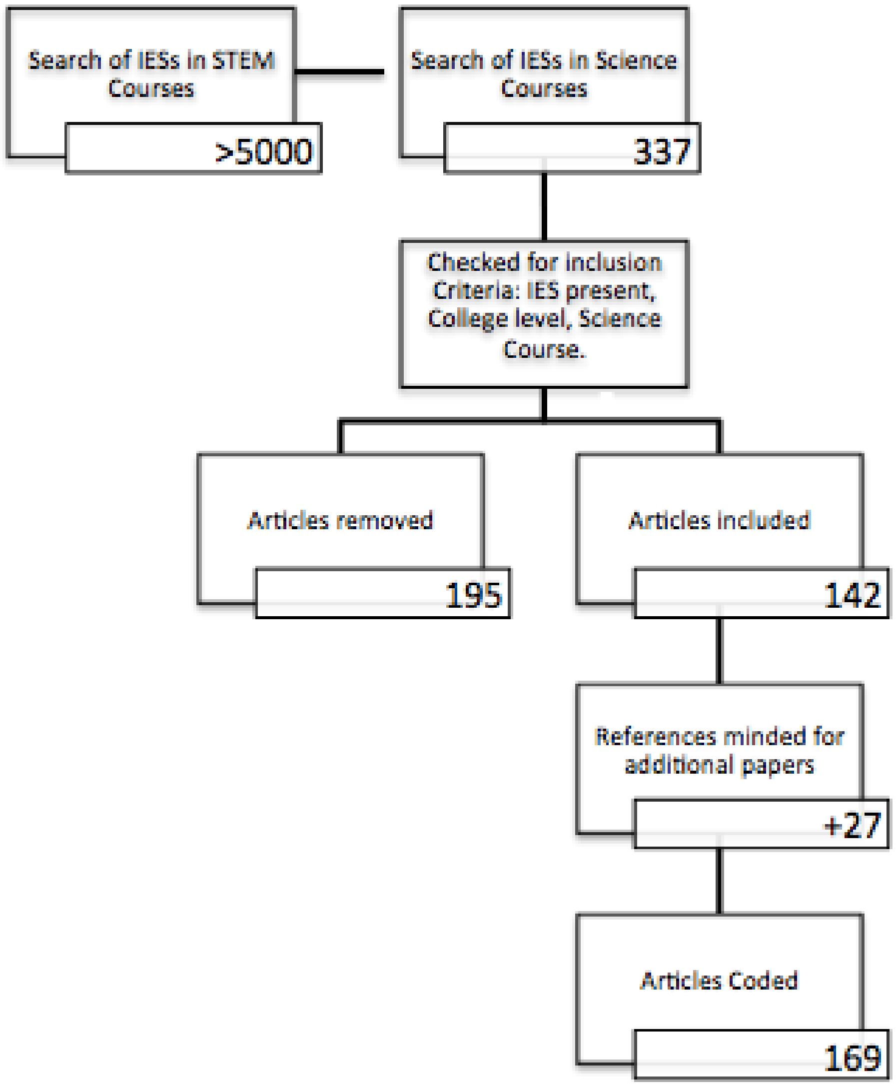

Figure 1: Steps taken to collect articles used in literature review and the number of articles at each step.

Search Area	Search Terms
Title	active learning, geology, clickers, peer instruction, class discussion, POGIL, tutorials, group work, constructivist
Abstract	chemistry, biology, geography, physics, earth sciences, science
Key Words	science, physics, biology, undergraduate, chemistry, active learning, earth sciences, geography, meteorology

Table 1. Terms used to search for articles in the ERIC database, organized by where the term is used in the article.

A coding rubric is used to analyze the articles by creating a comprehensive list of IESs. The IESs were then grouped by implementation and six IES types and several subtypes emerged. The IES types and subtypes were used to create the rubric that was used to analyze each IES mentioned in each article. A total of 203 IES from the 169 articles were analyzed for IES type, sub-type, and specific implementation. These articles were then coded by discipline: biology, physics, chemistry, geoscience, and a small subset of other science disciplines.

3. Results

3.1. Upward trend in IES implementation

Articles included in this literature review were graphed by year to see if any trends in publication can be seen (Figure. 2), then grouped by subject (biology, chemistry, physics, geosciences, and other sciences and graphed by year again (Figure 3). Figure. 1 illustrates an upward trend leading between 10 and 15 articles published each year in recent years.

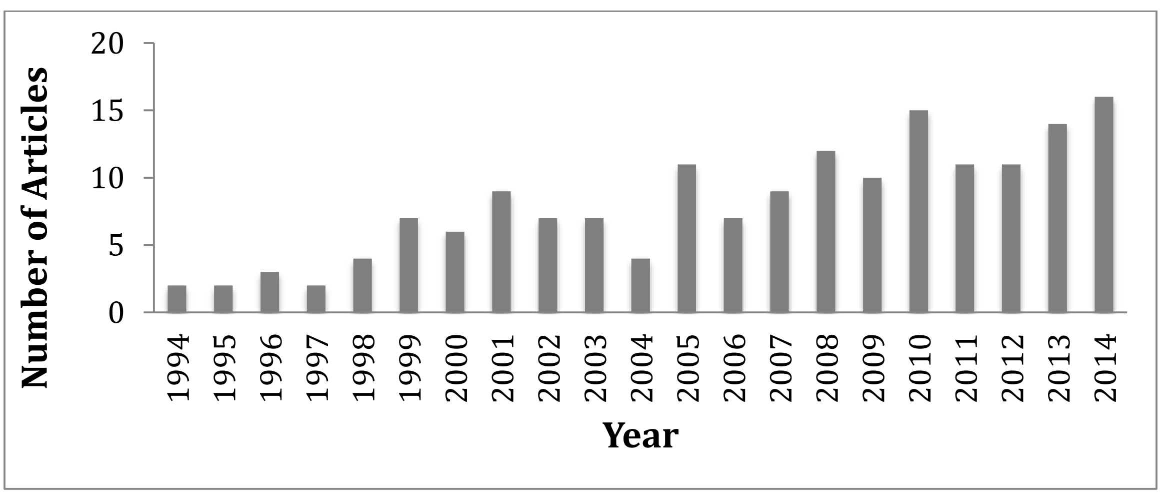

Figure 2: Number of article per year of publication. The past 20 years has seen a positive increase in articles about IESs used in college science courses.

Figure 3 shows a comparison of IESs publications by discipline (Biology, Geology, Physics, and Chemistry). The field of biology shows the most constant publication record, with an overall increasing trend over time. Given that Chemical Education Research (CER) and Physics Education Research (PER) faculty have been better established in university departments than Geoscience Education Research (GER) faculty, the low number of chemistry and physics articles is surprising. A plausible reason for this low number of chemistry and physics articles is that education-related articles in these fields were published in journals not included in the ERIC database.

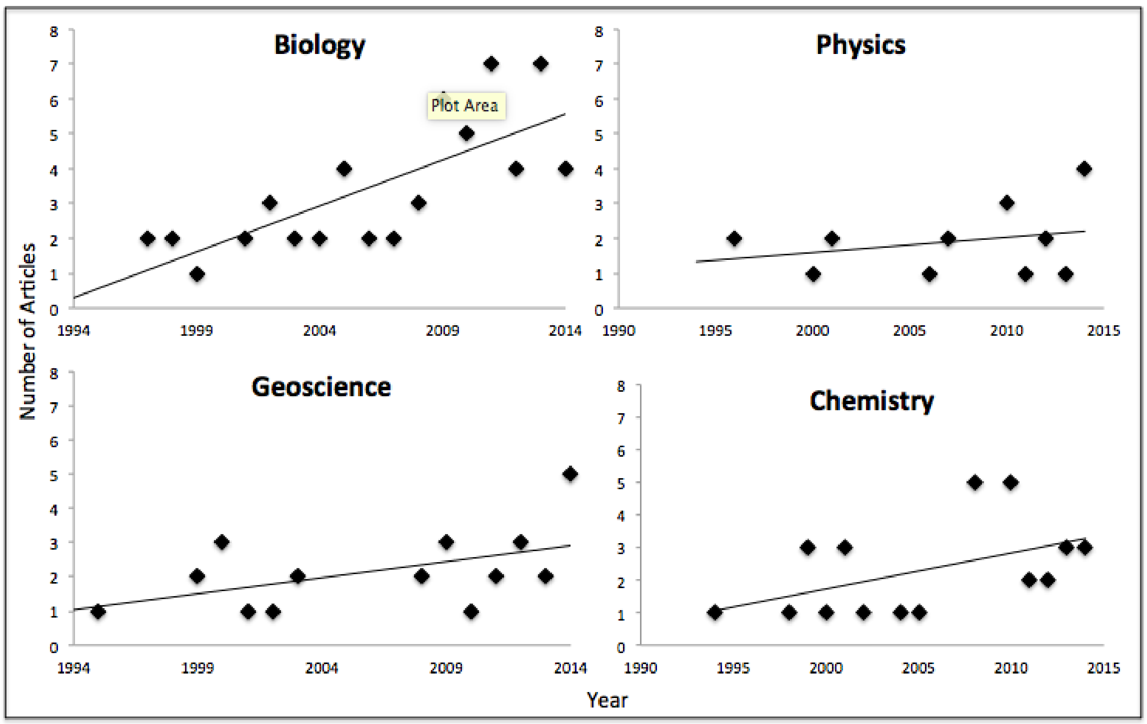

Figure 3: Trend of articles per year by subject.

3.2. Types of Interactive Engagement Strategies (IESs)

Six different types of IESs emerged from articles reviewed: (1) polling, (2) full class discussion or activities, (3) in-class group work, (4) out-of-class group work, (5) online work, and (6) other. These types of IESs are described below for the articles found, noting how frequently they appear in the literature by science disciplines. Four of the five IES types had emergent sub-types (Figure 4): (1) Polling – Peer Instruction, Non-Peer Instruction; (2) full class discussion or activities – discussion, activities; (3) In-class group work – process oriented guided inquiry learning (POGIL), problem based learning, and group assignments; (4) out-of-class group work – group projects, take-home exams and assignments, and peer-led activities; (5) Other strategies – individual, lab, and field.

Of the articles reviewed, 122 articles revealed IES done in the classroom. The sizes of classes range from six students in a class (Christiansen, 2014) to 523 students in a class (Flynn, 2011). Figure 5 separates the articles into class size groups. Twelve articles are included with two data points because these articles had multiple classes in different class sizes was. If multiple classes were included, but class size stayed within the same class range, only one data point was used for that article. Three groups with the largest number of articles, <25 students (27 articles) or 26-50 students (32 articles) and over 150 students (28 articles). Tormey and Henchy (2008) suggest that there is little ability to create student interaction in large classes over 100 students where students are only able to raise hands to agree or disagree, and it is virtually impossible for students to question, comment to, or provide feedback for the instructor. The class size ranges observed in this literature review, suggest that IESs can be implemented into a wide range of class sizes from very small to very large courses.

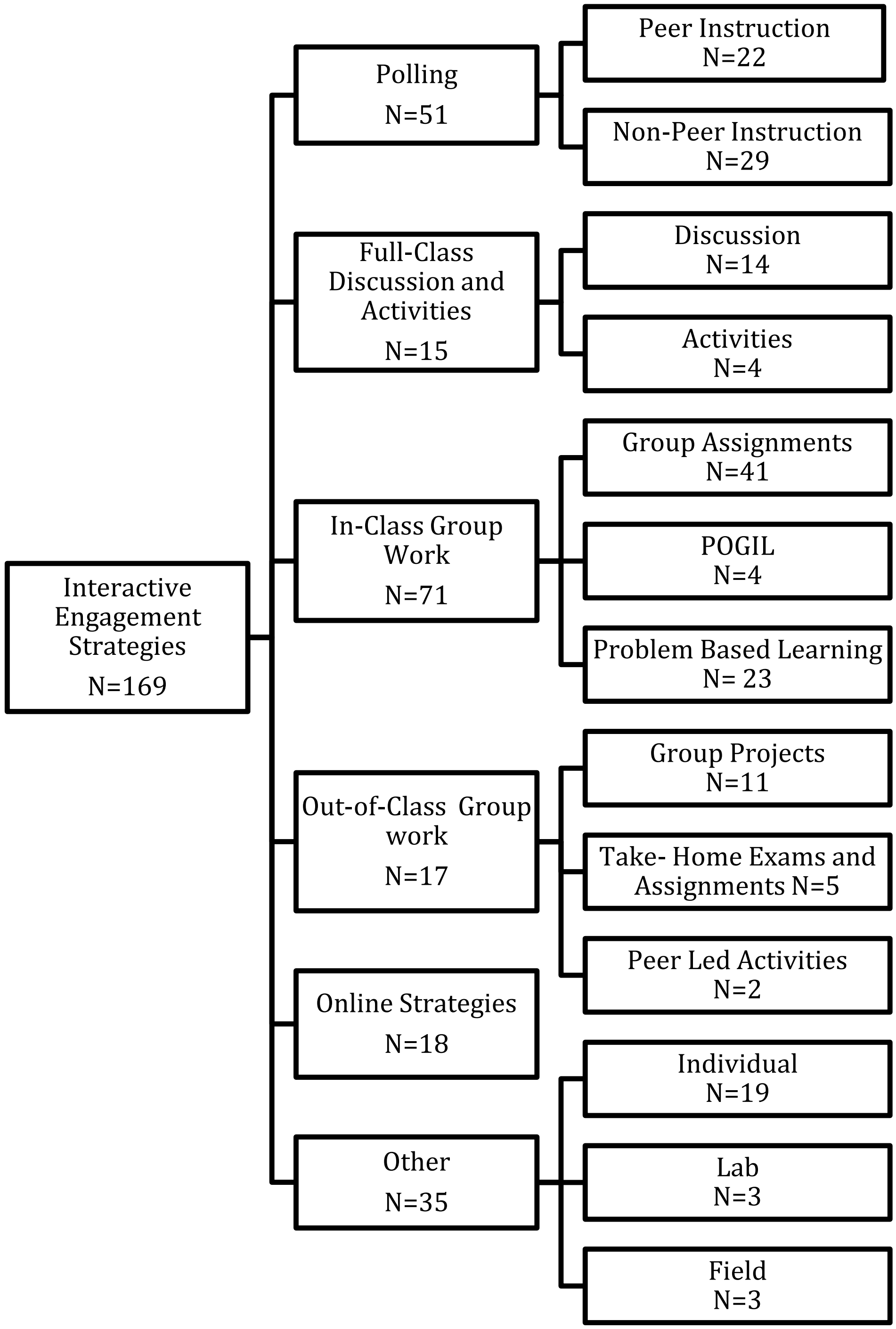

Figure. 4. Organizational chart of Interactive Engagement Strategy Types and Sub-Types.

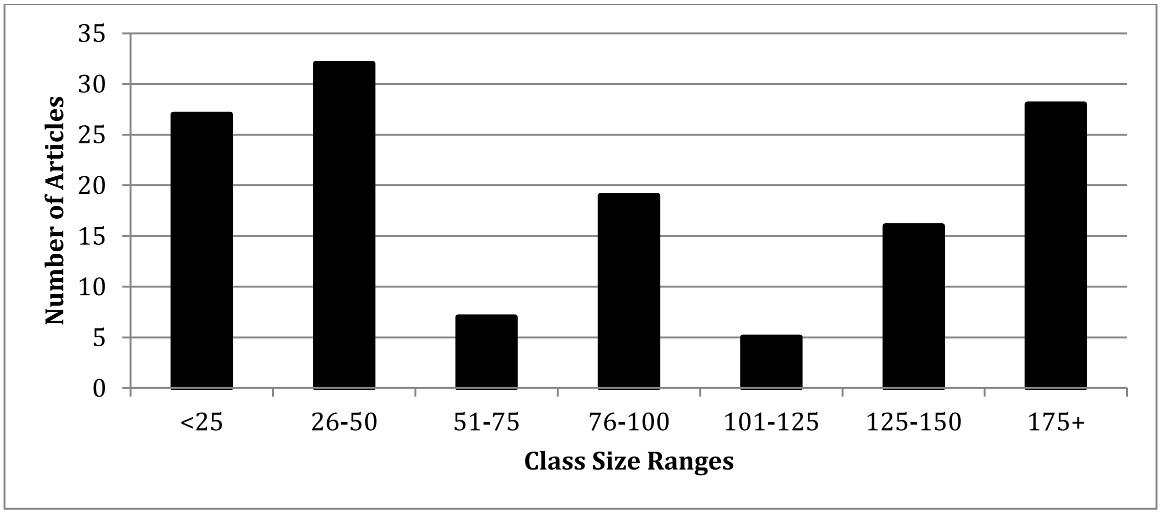

Figure 5. Class size gaps in which IESs have been implemented ranging from <25 to >175.

3.2.1 Poll1ing

Polling is the IEs strategy where information is obtained from students during class using a variety of strategies. As previously stated polling is done in the classroom and can involve individual work, group work or a combination.

Peer instruction (PI), a research-based strategy, comprising well-defined steps for implementation, is the second most cited strategy in the articles analyzed (30% of the articles). The strategy is typically implimented using clickers or some form of audience response systems (Nicol et al., 2003; Allen and Turner, 2005; Duncan, 2006; Freeman et al., 2007; Crossgrove and Curran, 2008; Addison et al., 2009; Armbruster et al., 2009; Coca and Slisko, 2013; Milleret al., 2014;), though other non-electronic sources such as hand raising (Kovac, 2003) or using cards (Freeman et al. 2007) can be used to poll the class. Using either the graphic software package PowerPoint (Armbruster et al., 2009) or a transparency (Kovac, 2003) the professor prompts a conceptual question to the students. Conceptual questions, typically corresponding to the comprehension level of Bloom's taxonomy, are not content-based multiple-choice questions, rather, they are designed to assess student knowledge or understanding of concepts underlying the material (McConnell, 2003). PI is implemented at any point during a lecture: beginning of the class (Freeman et al., 2007; Crossgrove and Curran, 2008) or intermixed during the lecture (Crouch and Mazure, 2001; Freeman et al., 2007;Addison et al., 2009; Smith et al. 2011; Gok, 2012). Once the question if posed to the students, the studnets individually reflect about the problem or question and then vote on the answer they feel is correct. The instructor will consider the results and decide what to do next. If a large majority of students answer correctly the instructor can choose to review the question and move on. For the instructor to review the question and continue with lecture, the articles in this literature review indicated between 60-70% of the students would respond correctly (Freeman et al., 2007; Crossgrove and Curran, 2008; Lasry, 2008; Gok, 2012).

If less than 60-70% of the students answer the question correctly the instructor directs students discuss the question in pairs (Crouch, 1998; Mazur, 2001; Kovak, 2003; Allen and Tanner, 2005; Duncan, 2006; Freeman et al., 2007; Crossgrove and Curran, 2008; Lasry, 2008; Addison et al., 2009; Armbruster et al., 2009; Noel, 2010; Perez et al., 2010; Turpen and Finkelstein, 2010; Smith et al., 2011; Crouch and Gok, 2012; Miller et al., 2014). Some instructors choose for students to pair or group by answer choices to ensure pairings with someone who answered differently (Coca and Slisko, 2013). After discussion with their peers, the class will revote. Ideally, more students will answer the question correctly after peer interaction and the instructor can move on with lecture. This scenario may result in the highest growth of knowledge for the students, compared to a large majority of students correctly answering or incorrectly answering the question (Crouch, 1998).

An instructor might find that a majority of students answer the question incorrectly, typically only about 30% of student having the correct answer. The instructor may choose to revisit the topic in lecture and come back to the question (Lasry, 2008; Gok, 2012).

Non-Peer Instruction Polling involves polling that does not follow the previously set out steps for PI. Some instructors use the appropriate PI steps but add their own twist, like multiple questions at a time (Meltzer and Manivanna, 2002Coca and Slisko, 2013;) or have the questions answered online prior to lecture and then revisit it during lecture as a PI question (Crossgrove and Curran, 2008). Some instructors omit a step such as voting after discussion (Hoeskstra, 2008). Others implement an activity or problem set to be done in groups rather than in paired discussion (Reay et al., 2005; Shaver, 2010; Levesqu, 2011; Irons, 2012; Llintonet al., 2014). Students may be asked to do problem sets or activities such as reading an article, or writing about their answer after the questions have been polled (Flynn, 2011; Bandypadhyay, 2012; Linton et al., 2014).

Polling implementations, from the article analyzed, become more distinct individually from this point on. Some instructors present a question to the class and have either no reported follow up (King, 2011; Sevian and Robinson, 2011; Smith et al., 2011) or have students share their answers after individual voting (Obenland et al., 2013; Cotes and Cotua, 2014). Polling can help students confront contradictory information to better understand topics (Lin et al., 2011). Polling can also be used to help students think critically about the next topic, or make predictions (Noel, 2010). One way to do this is the three-question sequence where one question is easy and gets them on the topic, followed by two difficult questions posed to the students to answer individually or in groups (Reay et al., 2005; Reay et al., 2008). Finally, polling can be used in groups for review games (Crossgrove and Curran, 2008), quizzes and competitions (Slish, 2005; Donohue, 2014). If polling in groups, it is important that groups are no larger than four to six students (Caldwell, 2007).

Although polling has been broken down into the two sub-types, PI and non- PI implementation; use of this strategy can vary greatly, leaving room for adaptation and incorporation into any classroom style. Chemistry, biology, and physics are represented evenly in the polling articles that were analyzed, as illustrated in Figure 6.

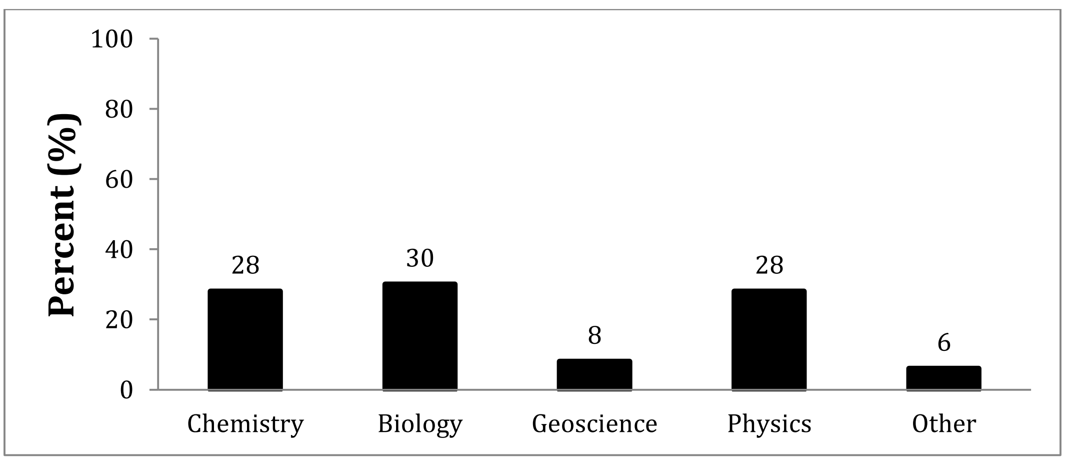

Figure 6: Percent of polling occurrences by subject. N= 51

3.2.2 Full-class discussion or activities

This group of articles reported full-class discussion or activities that described a facilitator leading a discussion or an activity that involves the entire class as a whole.

This IES type is broken up into two sub-types: discussion based (n=12) or activity based (n=4). These occurrences fall predominately in the biology and chemistry and the distribution can be seen in Figure 7.

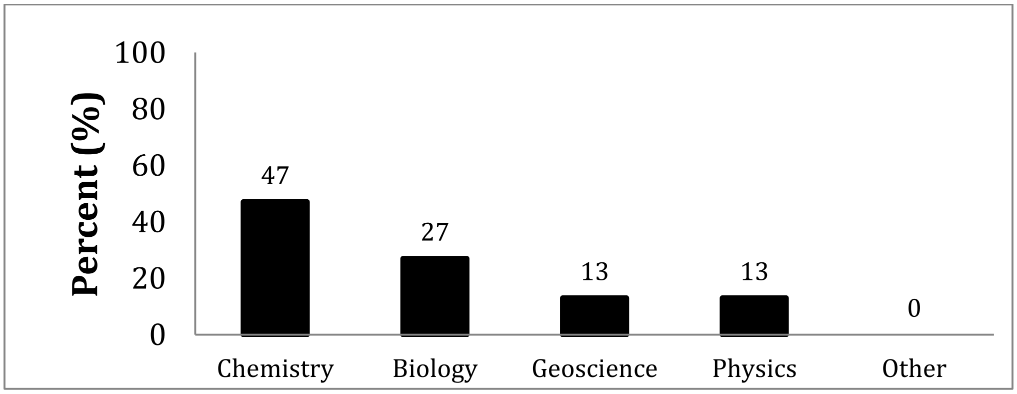

Figure 7: Percent of Full Class Discussion or Activity occurrences by subject: N= 15

Full-class discussions are led either by an instructor (Ross and Fulton, 1994; Marbach-Ad et al., 2001; McClanahan and McClanahan, 2002; Krauss et al., 2010; Gonzalaez-Sancho et al., 2013) or by a student or group of students (Anthony et al., 1998; Hodges, 1999). Instructor-led discussions are typically prompted by a variety of different activities including questions sets (Marbach-Ad et al., 2001; Gonzalez-Sancho et al., 2013), photographs used as case studies (Krauss et al., 2010), or lectures and activities (Ross and Fulton, 1994;McClanahan and McClanahan, 2002). Student-led discussions typically happen in two ways according to the analyzed articles. Individuals initially lead discussions that are prompted by readings done by the whole class prior to class time (Hodges, 1999). The student leader prepares discussion questions for the class in advance and leads the class discussion (Hodges, 1999). Student-led discussions also originate from group projects, where groups prepare discussion around a project (Anthony et al., 1998). Although full-class discussion can vary, the majority of implementations follow the same steps: students' complete assignment, someone leads discussion in class, where the class discusses the question(s).

Full-class activity-based strategies are distinct as a sub-type. All occurrences of these strategies' implementation are in chemistry courses. The activities are either facilitated by the instructor (Orvis and Orvis, 2005; Farrer et al., 2010) or student (Middlecamp et al., 2000). If the activity requires jobs or rolls, the facilitator may assign them or students may choose or volunteer to fill them. At this point, the activities become increasingly distinct from each other. Farrer et al. (2010) break this activity into two parts. Students are initially asked reflection questions about the chemical element assigned, wrapping up with what the student learned about their element. Students then role-play as their assignment element using colored ping-pong balls to distinguish between those who have an extra electron and those needing an electron. Once they have performed as their element they then create the periodic table where each person represents a box on the periodic table. Another example uses paper wads that represent reactants and products where students that represent the driving forces of a chemical reaction (Orvis and Orvis, 2005). Students then work through different experiments with the paper wads to demonstrate the process of a chemical reaction (Orvis and Orvis, 2005). In one last example the class creates a get-to-know you questionnaire (Middlecamp et al., 2000); and agrees on the questions and multiple choice answers for each question. Once the questionnaire is finished, students then go to the board and answer it by checking their individual answers. The activity leads to students doing an analytical activity (Middlecamp et al., 2000), which concludes with an instructor led discussion or debrief to summarize what students should have learned during the activity (Farrer et al., 2010; Orvis and Orvis, 2005; Middlecamp et al., 2000).

3.2.3. In-class group work

In-class group work activities include a large variety of group work completed in a traditional classroom setting with instructor supervision. Articles analyzed discussing group IESs done in a lab, field, or other non-classroom settings are not included in this section, only lecture setting group work has been included. This category was broken down into three sub-types: (1) problem-based learning (PBL), (2) group assignments and quizzes, and (3) process oriented guided inquiry learning (POGIL). In-class group work is the most commonly mentioned IES type (42% of analyzed articles). The majority of the occurrences of these activities are from biology, with geoscience and chemistry holding the next largest percentile as in Figure 8.

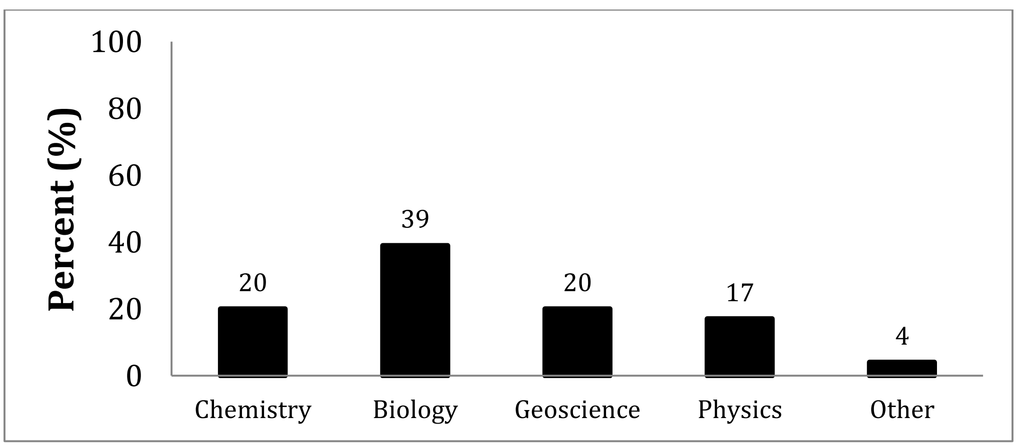

Figure 8: Percent of In-Class Group work occurrences by subject. N=71

PBL is one of the most discussed IESs (32% of in-class group work articles and 14% of all articles analyzed) and has a wide variety of observed implementations. All implementations have the same central goal, to have students work in groups through a difficult, real-world or numeric problem to increase individual learning. Groups for PBL activities can be set up permanently for the duration of the semester (Armbruster et al., 2009; Keller, 2002), assigned each class session (Kovac, 1999; Ramsier, 2000; Christiansen, 2014; Enghag et al., 2007), or selected by the students themselves (Fardilha et al., 2010; Slish, 2005). Assigned groups can either be chosen by the instructor or determined at random by students picking up tokens and arranging themselves accordingly (Ramsier, 2000). PBL activities typically are stand-alone activities; but may be prompted with short videos or movies (Fardilha et al., 2010). Assignments are completed and submitted in different ways; by providing a sheet to work through the problems, or on another paper to hand-in a hard copy at the end of the class (Slish, 2005; Enghag et al., 2007; Eberlein et al., 2008; Hein, 2012; Christainsen, 2014). In some classes, groups are given a dry erase board to collect and share answers as they go (Ramsier, 2001). Others use technology (i.e. computers) to submit answers electronically (Kovac, 1999; Robinson, 2001; Nogaj, 2013). In other implementations of PBL, students share answers in class once they are finished (Armbruster et al., 2009; Nogaj, 2013). These activities can intermix with other activities or assignments such as quizzes (Slish, 2005), or a writing project (Keller, 2002). Instructors implementing PBL may choose to wander the room assisting and/or monitoring the group discussion and providing mini-lectures or additional information as needed (Armbruster et al., 2009; Venville, 2009; Hein, 2012; Christiansen, 2014).

Problems take a variety of forms, with some designed by the instructor (Keller, 2002) that can range from conceptual, real world problems (Robinson, 2001; Enghag et al., 2007; Armbruster et al.; 2009 Christiansen, 2014) to numerical and calculated ones

(Armbruster et al., 2009; Gonzalez-Sancho et al., 2013; Ramsier, 2000; Robinson, 2001). In solving problems, students may be given case studies (Gardner and Belland, 2011; Gonzalez-Sancho et al., 2013), primary literature (Eberlein et al., 2007), and/or textbooks (Enghag et al., 2007).

Group assignments and quizzes are the largest (56% of in-class group work and 24% of all analyzed articles) and most diverse of the subcategories. Assignments focus on creating group cooperation and interaction within the classroom, with implementation and subject matter varying greatly. The Following discussion will review the variety of potential implementations for in-class group assignments as ALS, as well as present the implementations of group quizzes.

The first sub-type, group assignments, are less structured and have more room for variance than other assignment types. These activities may be prompted with a lecture (Walker et al., 2008; Phipps, 2013), a homework assignment (Ross and Fulton, 1994; Barreto et al., 2014), or a video (Anthony et al., 1998). Within groups, students use previous information to create opposing arguments (Anthony et al., 1998), to find the important concepts (Ross and Fulton, 1994), or to do work on the board as rotating groups to finesse the questions until complete (Barreto et al., 2014). In some assignments groups make critiques (Scheyvens et al., 2008), develop hypotheses, explore fundamental principles, or adress guided questions (Walker et al., 2008). Other assignments are less descriptive and are more likely to be influenced by the instructor and class topic, but involve groups working through instructor-assigned questions (Dufresne et al., 1996; HInde and Kovac, 2001; Marbach-Ad et al., 2004). These activities may involve role assignments (Hinde and Kovac, 2001) or rolep-laying (Dengler, 2008). They are typically followed by a wrap-up on the activity, such as class discussion (Anthony et al., 1998; Dufresne et al., 1996), a short follow-up lecture (Ross and Fulton, 1994; Phipps, 2013), or a presentation of findings to the class (Scheyvens et al., 2008).

Some assignments are more hands-on requiring students and groups to “create” something in the classroom (Oliver-Hoyo et al., 2004). For some of these activities, groups are provided with a set of samples or equipment and are to work to create something such as a tool or instrument (Algar and Krull, 2010), or a historic finding like the Bagdad Battery (Lu and Anariba, 2014). These activities are typically followed with a discussion or analysis of the creation (Algar and Krull, 2010; Lu and Anariba, 2014). Other articles describe students working with data and creating maps, animations, or presentations using those data (Lunsford, and Herzog, 1997; Klein, 2003; Bolton et al., 2008), or using GIS data to create images (Livingston, 2000).

Other in-class group activities tended to be unique individually to the other activities, such as: (1) think-pair-share activities (Armbruster et al., 2009), (2) lecture tutorials (LoPresro and Murrell, 2009; Gray and Steer, 2012), (3) and jigsaw method of notes or assignments (Slish, 2005), (4) or data tracking, in this case for weather balloons (Coleman, 2014). Think–pair-share activities give students a topic or question to think about individually, then they are asked to pair up and discuss the topic or questionto eventually share what they discussed with the class (Armbruster et al., 2009).

Lecture Tutorials are worksheet activities specifically designed for the topic to be implemented during lecture, and meant to be short paired or group activities (LoPresro and Murrell, 2009; Gray and Steer, 2012). Lecture Tutorials are designed to target specific topics and misconceptions using student language, avoiding subject jargon (Brogt, 2007). They are short assignments, 10-20 minutes, designed for peer work (; Brogt, 2007; Kortz at al., 2008). Guided questions added by the instructor may aid implementation of Lecture Tutorials (Koenig et al., 2007). Some analyzed articles discuss the importance of debriefing, while others suggest no debrief, providing reasoning for their choice to suggest or not to suggest debriefing. Brogt (2007) suggests to not debriefing a Lecture Tutorial in order to encourage student cooperation to find the right answers, rather than wait for the instructor to reveal them. In contrast, Prather et al. (2004) suggest they should always be followed by a debrief, where students share answers and questions about the Lecture Tutorial, or where the reasoning needed to answer the questions is made clear.

The Jigsaw puzzle method can be used with activities or note taking (Tewksbury, 1995; Slish, 2005), where groups are created and each group is given an activity/chapter/paper to complete, outline or review. Once the task is completed, groups are rearranged where members of different groups mix to form a new group (Tewksbury, 1995; Slish, 2005). At this point, the group with different notes would share their notes with the other groups so that all students were exposed to notes from the original groups (Slish, 2005). In groups where students completed an activity, they are given a new set of activities building upon the prior ones, or alternatively the students then discuss the previous activities as a group, deciding on the most important points and share them with the class (Tewksbury, 1995).

As with almost all in-class group activities, discussion is a major part, it may not be the main focus, but it plays a part in all of the previous activities. Instructors may choose to design activities that will create group discussion. These discussions provide student groups with a proposal, prompt, or question set that they use to promote group discussion (Ebert-May et al., 19997; Paulson, 1999; Bahar, 2003).

Quizzes have a much smaller range of implementation than in-class group activities. Group quizzes can be implemented in two ways. Students either prepare for the quiz, and take the quiz only once in a group (Klappa, 2009; Donohue, 2014) or, alternatively, quizzes can be given via PowerPoint and written down or done using electronic personal response systems (Donohue, 2014). Quizzes can be administered using scratch off Immediate Feedback Assessment Techniques, to the students are grouped individually, discuss the quiz questions and retake the quiz as a group (Lee and Jabot, 2011).

The final sub-type is process oriented guided inquiry learning (POGIL), which are activities that start with a short (~15 minute) lecture, if any lecture at all (Bailey et al., 2012; Simonson and Shadle, 2013). POGIL is designed to replace lecture during a class period (Eberlein et al., 2008). For instructors who choose to present a short lecture at the start of class, POGIL activities continue for the remainder of the class (Bailey et al., 2012). Before the activity begins, students are grouped either by self-selection (Eberlein et al., 2008) or by the instructor carefully assigning the groups (Hu and Shepherd, 2013). Groups have three to four members, where each member has an assigned role. Three roles included in all activities are manager, recorder, and spokesperson (Hu and Shepherd, 2013; Simonson and Shadle, 2013; Bailey et al., 2012). Some groups use only these three roles; if a fourth member is present they do not have a role (Bailey et al., 2012), or in some cases have a fourth role as strategy analysist (Simonson and Shadle, 2013), or technician (Hu and Shepard, 2013). Roles may rotate from class session to class session. Table 2 shows a description of roles. The role of the Instructor during these activities becomes a facilitator- monitoring the groups and answering questions to aid the groups (Bailey et al., 2012; Eberlein et al., 2008; Simonson and Shadle, 2013)

Role	Responsibilities
Manager	Keep group on task and be cognizant of time. Monitor group participation and create suggestions to help group work effectively together.
Recorder	Read questions to group and records groups answers. Communicates with spokes person and instructor/facilitator
Spokesperson	Shares and or presents the groups work to other groups, full class or instructor/facilitator
Technician	Runs any programs and does all computer work to be done.
Strategy analyst	Monitors the groups effectiveness and creates suggestions for improvements. Can also be incorporated into the manager position.

Table 2. Roles and Responsibilities for group members, assigned for POGIL activity.

The activities are specifically designed, cycle-based, guided-inquiry materials (Simonson and Shadle, 2013; Hu and Shepherd, 2013). There are three parts to the activities: exploration, concept invention, and application (Eberlein et al., 2008; Hu and Shepherd, 2013; Simonson and Shadle, 2013). In the “exploration” phase students are given a model to explore and find patterns (Eberlein et al., 2008), creating the basis of knowledge for the remainder of the activity (Hu and Shepherd, 2013). Students in the “concept invention” phase of the cycle further develop patterns and create concepts and relationships (Eberlein et al., 2008). In the last phase, students extend and “apply” their gained knowledge to new situations (Eberlein et al., 2008) and problems (Hu and Shepherd, 2013).

In-class group work is represented in all course subjects and can be done in a large variety of ways. These IESs can be very structured as a type as with POGIL and problem based learning activities. In-class group work can take other forms that can be implemented in all types of class styles and topics as the IESs outlines in the group assignments portion.

3.2.4. Out-of-class group work

Articles including out-of-class group work included discussion of group work outside of the classroom, with no supervision by an instructor. This category was broken down into three sub-types of IESs: (1) take-home assignments and exams, (2) group projects, and (3) peer-led activities. These activities were cited mostly in articles regarding studies of biology courses with ~40% of the occurrence in these subject. Chemistry, geosciences, and physics are evenly represented, this is presented in Figure 9.

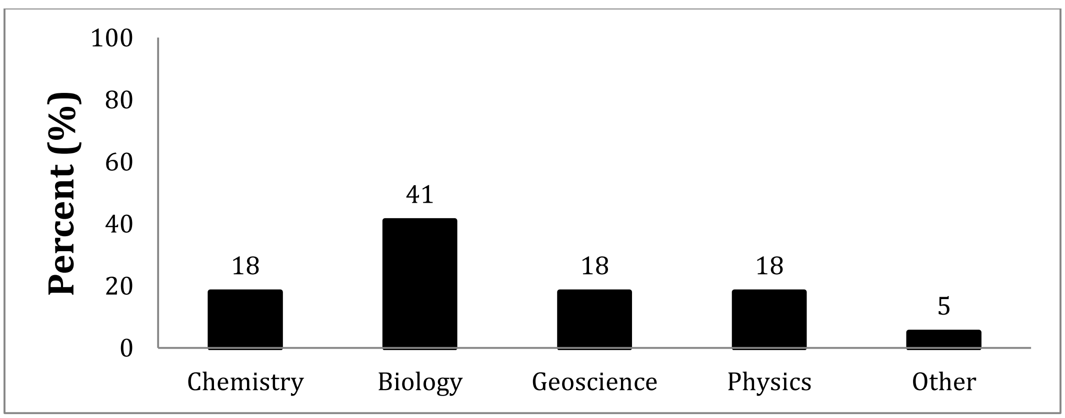

Figure 9: Percent of Out-of-Class Group work occurrences by subject. N= 17

Take-home assignments are typically assigned to students at the beginning of each week (Paulson, 1999; Ramsier, 2000; Mellingseater, 2014) though they can be assigned at each individual class section (Paulson, 1999), whereas take-home exams tend to be assigned to students several weeks in advance of the due date (Kovac, 1999). Take-home assignments consist of difficult problems (Kovac, 1999; Paulson, 1999;

Mellingseater, 2014) and essay questions (Paulson, 1999). These take-home assignments and exams are done outside of the class, either in set lab rooms with technology (Mellingseater, 2014), or at a place of the group's choosing.

Group projects begin with students grouped either by self-selection (Bahar, 2003) or assignment by the instructor (Sutcliffe et al., 1999; Hatcher-Skeers and Aragon, 2002; Bahar, 2003; Mills and Woodall, 2004; Smith at al., 2012). Groups may be assigned a topic (Sutcliffe et al., 1999; Bahar, 2003; Fardilha et al., 2010; Smith et al., 2012) or select a topic of the group's choice (Hatcher-Skeers and Aragon, 2002). Assigned projects vary depending of the course type, but include project assignments such as: (1) creation of a chemistry demonstration (Ramsier, 2000; Hatcher-Skeers and Aragon, 2002) (2) an environmental management report (Smith et al., 2012). Research projects involving literature searches or assigned articles are also included (Fardilha et al., 2010; Mills and Woodall, 2004; Bahar, 2003). Other group projects can involve real-life situations to recreate or adapt (Oliveira et al., 2007). For length of the project, groups met with the instructor about the topic choices and/or the progress of the project (Hatcher-Skeers, and Aragon, 2002; Mills and Woodall, 2004). Group projects should be relevant to the classroom topics with either weekly tasks or the overall goal of the project (Oliveira et al., 2007). At the completion of the project, groups submit or present their work through PowerPoint or similar presentations (e.g. posters, videos, etc.) (Sutcliffe et al., 1999; Bahar, 2003; Mills and Woodall, 2004; Fardilha et al., 2010; Smith et al., 2012), written assignments (Smith et al., 2012), demonstrations (Ramsier, 2000; Fardilh et al., 2010), or through a debate with other group (Sutcliffe et al., 1999). These group projects can be adapted easily depending of the subject, course level, and desired course outcomes.

Peer-led activities are held outside of the classroom and led or supervised by a previous student (Eberlein et al., 2008) or a teaching or graduate assistant (Marbach-Ad and Sokolove, 2002; Dori et al., 2003). Randomly assigned groups met weekly, for additional group discussion (Marbach-Ad and Sokolove, 2002; Laws, 1997), or complete on assigned problem sets and work sheets (Eberlein et al., 2008; Laws, 1997). In some cases, these exercises can be led by a current student who is excelling in the course and will be able to aid students in the group, rather then a TA or previous student (Butcher et al., 2004).

3.2.5. Online Strategies

This IES type occurred in 11% of the analyzed articles; highest occurrence was in biology, with physics and the geosciences close behind and if presented in Figure 10. Online strategies included all online work that students may due in class, out of class, individually, or in groups.

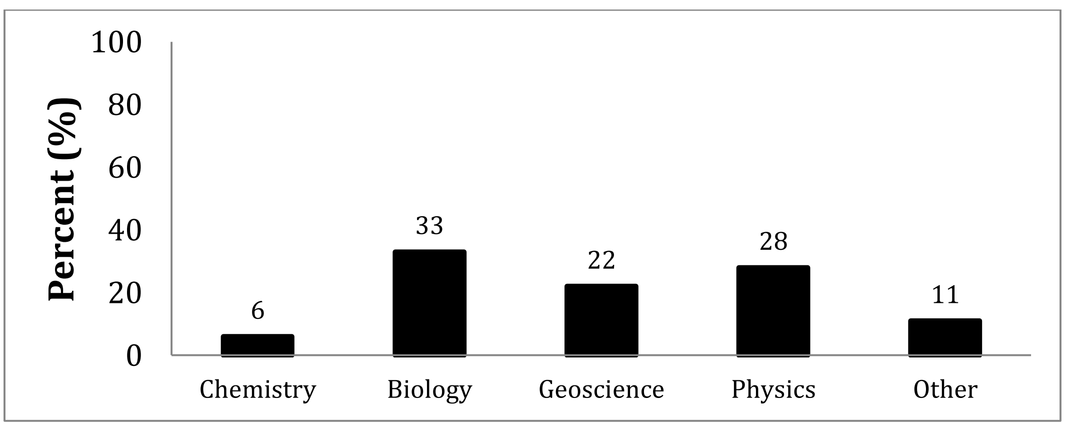

Figure 10. Percent of Online work occurrences by subject. N= 18

Online assignments and activities can be done individually (Pek, 1996; Daeid, 2001; Bromham and Oprandi, 2006; Hill and Nelson, 2011; Gonzalez-Sancho et al., 2013), in groups (Carnegie, 2012) or a combination (Conover and Miller, 2014). The simplest of individual online activities assigned were faculty-made podcasts to be listened to or watched prior to class (Hill and Nelson, 2011). This may also include completion of an immediate feedback online quiz that provides students with immediate feedback on correct answers (Gonzalez-Sancho et al., 2013). Online strategies may involve tutorials or walk-through assignments, where students access using websites such as Moodle (Bromham and Oprandi, 2006; Gonzales-Sancho et al., 2013; Daeid, 2001). These tutorials and walk-through assignments allow students to work through problems and activities' related to classroom topics (Bromham and Oprandi, 2006). Computer aided instructional packages (Pek, 1996) are designed for students to complete different modules to create interaction and involvement on behalf of the students.

Online group activities may also involve workshops where students work through guided-inquiry activities online, perhaps in rooms with computers where groups are able to access the individual assignments (Hinde and Kovac, 2001). Group activities also include the creation of limericks (Carnegie, 2012); where students use online sites such as Blackboard to work together to create limericks on the basis of classroom topics. Combining individual and group activities can be beneficial, for example students post articles to an online forum where other students then read the articles and work together to communicate changes and improvements to the individually created articles (Conover and Miller, 2014).

Other online strategies are available to be downloaded as commercial products that were discussed as group (Frear and Hirschbuhl, 1999; Baser, 2006; Nogaj et al., 2013) or individual activities (Dewy and Meyer, 2000; Bockholt et al., 2003; Cattle et al., 2003; Bodemer et al., 2005) in the analyzed articles. Individual activities involve students working through interactive and/or virtual environment modules where student can change variables in models, answer questions, interpret and analyze data (Cattle et al., 1995; Bodemer et al., 2005; Dewy and Meyer, 2000; Bockholt et al., 2003). These activities can be paired with take-home activities and/or quizzes that are only available in the module or program if the student completed the assignment (Catle et al., 1995). Other activities can utilize free open-source software so students can gain a better knowledge of the topic or tangential topics to enhance their learning (Catalogu, 2006).

Group programs may be used to replace or enhance lecture content (Frear and Hirschbuhl, 1999; Baser, 2006), where students work through models that create different situations that can be compared and contrasted (Baser, 2006; Nogaj et al., 2013), and used in class (Nogaj et al., 2013; Clause et all., 2001). These programs can also be used for virtual fieldwork (Frear and Hirschbuhl, 1999), where real-world simulations help promote interaction and problem solving skills (Frear and Hirschbuhl, 1999). Between individual and group implementations these programs currently cover topics including: environmental geology field topics, soil stacks, climate, electricity, proteins and different medical topics.

3.2.6. Other strategies

The final IES type is an “other” category. This category incorporates the remaining strategies discusses in the analyzed articles that did not fall under the umbrella of the previous five. This includes IESs that were implemented individually in the classrooms, lab settings, or field settings. These IESs occurrence is primarily from biology and the geosciences and can be seen in Figure. 11.

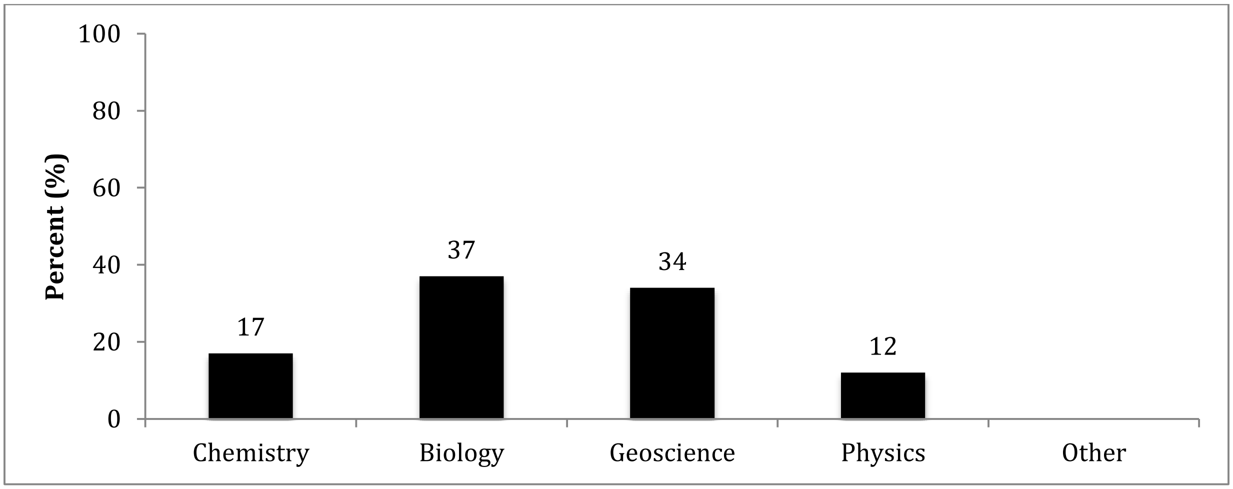

Figure 11. Percent of Other occurrences by subject. N=35

Individual IES have several subcategories of activities: writing activities, problem solving, concept mapping, models, and other individual IES. The most common individual writing activities is the ‘minute paper’ where students are given an open-ended or reflection question and given one minute to write and answer the question (Armbruster et al., 2009; McConnell et al., 2003). In-class metacognitive writing is also used, where students are given increasingly difficult writing prompts (Dengler, 2008) or “letters” to respond to (Lunsford and Herzog, 1997). Students are provided ample time to complete the writing assignment, and in some cases share a brief explanation of their answers with the class (Dengler, 2008). Writing IES can also include activities such as reading journals that help students think critically about what they read (Scheyvens et al., 2008).

Individual problem solving IESs can involve student-given conceptual and numeric problems to students to work out individually in class (Gutwill-Wise, 2001; Kleain, 2003). These problem sets may involve student exploration of maps or atlases

(Klein, 2003). Concept maps typically require students to utilize material, data, or notes to create maps and diagrams that logically organize and interpret the information at hand (Klein, 2003; McConnell et al., 2003; Armbruster et al., 2009).

Individual model creation is done either during the class session or prior to class session, using items such as Play-Doh (Marbach-Ad et al., 2001) or with kits that students purchase (Hageman, 2010). Kits are used for molecule creation in chemistry courses, being made outside of the classroom then brought to the classroom (Hageman, 2010). Similar to creating models, students can create concept maps. One implementation for concept maps utilizes “Cmap” tools (a computerized program for creating concept maps) where students learn how to make a concept map. Students create a concept map in groups on a topic not directly related to the course, then individually create concept maps for the course subject matter (Rebich and Gautier, 2005). Various other strategies have been implemented with students individually: (1) replacing traditional writing assignments with the creation of films and/or documentaries (Anderson, 2013), (2) students creating the most useful “tool” for different situations from supplies given included analysis and applications for their “tools: (Algar, 2010), (3) or guided discovery activities (Schults, 1997), where chemistry students counted different chemical reactions, categorized them, and gave definition to pathways and structures of pathways.

Lab work is inherently active but there are ways to engage students mentally more within the labs. One way to do this is to add discussion and prediction into the labs, where students share predictions prior to the experiment, then discuss results and evaluate how well students’ predictions align can be easily implemented adding a second layer to the experiment (Model et al., 2004). Similarly, students can complete a lab without knowing exactly the lab content, then, afterwards creating a hypothesis of why they received the results they did. Sharing with the class reveals many resulting hypotheses and a demonstration of the correct hypothesis is shown followed by more full class discussion on the results (Johnson, 1998).

The addition of technology into labs is a second way to add more active learning. The use of these tools can be implemented in a variety of ways that will be discussed below. Each tool focus on one of the following: to allow students to look at large scale items that they normally wouldn’t be able to within a lab (Miller et al., 2004, Ramasundaram et al., 2005), or to observe things that time constraints would not normally allow them to see in the lab (McNeal et al., 2008) or to help students visualize what is, or could be, happening (Miller et al., 2004, Ramasundaram et al., 2005). In virtual labs students work on a computer, starting with one item, such as an animation, that then triggers the rest of the lab and guides them through an exploration of 3-D models and simulations (Ramasundaram et al., 2005). Video can allow students to watch others perform tasks that they could not, due to either skill level or in using this technology students can observe and predict and look at large-scale events to see how things happened in nature (McNeal et al. 2008).

Other approaches incorporate interactive engagement into labs by use of groups, in either question driven labs (Teixeira et al., 2010), or through hands-on experiments. To maximize the use of groups in labs, individuals can be given roles to abide by in each lab and to hold each other accountable for their portion of the lab work (Penwell et al., 2004). In Teixxeira et al. (2010) students worked in groups through a set of 33 guiding questions that led them through the appropriate measurements and actions to complete the lab. Having groups dissect animals measure the animal is another way groups were used in a biology lab (Head and Arber, 2013). A final way to get students engaged actively in lab work is to have them recreate situations; for example, physics students are given a light bulb and equipment make voltage measurements. After making calculations they are given their own tungsten piece to recreate the effect of the light bulb on the material (Clause et al., 2008).

Creating interactive engagement labs has been successful, with use of a set of RealTime Physics labs in colleges today (Sokoloff et al., 2007); each lab activity provides students with opportunities to observe and physically create (Sokoloff et al., 2007). The labs utilize groups of 2-4 students, allowing them to address their person conceptions and discuss their ideas and findings with the group or class (Sokoloff et al., 2007).

Fieldwork, though the smallest in number was distinct from other groups. Fieldwork, in all cases, included students outside of the classroom exploring a topic. Many labs are traditionally done using a descriptive-explanatory approach in which the instructor shows students what they are looking at, or looking for, and provides explanations for what they see (Fuller et al., 2000). To create a truly active learning situation an analytical-predictive approach is needed (Fuller et al., 2000), where students are able to complete semi-independent labs, yet some guidance is provided on what they should be measuring or tracking. Students then get to do the fieldwork (i.e. measurements or exploration) and analyze what they found (Hankins and Yarbrough, 2009; Fuller et al., 2000). If students explore multiple things they should also include a comparison portion to their analysis (Hankins and Yarbrough, 2009).

4. Discussion

This literature review seeks to provide a broad understanding of when, where, and how IESs have been used in college-level science courses. It is important because there is no comprehensive analysis of this type. Faculty use a large breadth of different activities to engage students. Some activity sub-types were observed only in the literature from a single science subject, or all but one subject.

Creating a comprehensive list of what is used can allow for a broadening of subject uses for some of the IESs. This literature review categorizes IESs by type and sub-type. The organization map (Figure 2) provides an easy classification scheme for IESs mentioned in the article set. This classification scheme, allows faculty to easily find IESs that fit the type of course they are teaching (lecture, lab, or field), or the snature of the activity wanted.

The low occurrence of physics and chemistry articles found in the ERIC database is a limitation of the study. This low occurrence of these subjects articles is possibly due to journals for these subjects are not included into this database. A similar analysis of subject-specific journals, such as Journal of Geoscience Education, Journal of Chemical Education, etc., could be used to create a larger subset of articles. Implementing this rubric and categorization scheme for these journals could help fill in or strengthen smaller IES types, or sub types, such as online activities.

5. Conclusions

A large variety of IESs from across the different science fields were categorizes into six IES types: polling, full-call discussion or activities, in-class group work, out-of-class group work, online strategies, and others. Individual IES types were then broken down into subtypes based off article-cited implementation. Polling, the use of hand/finger signals, cards or clickers to survey the class, was split into peer instruction or non-peer instruction activities. Full-class discussion or activities was split by discussion or activity. Full-class activities only occured in chemistry articles. In-class group work was the largest of the IES types, 71 articles mention at least one strategy. In-class group work was broken down into three sub-types: (1) problem-based learning (solving real world problems in class in groups), (2) POGIL (a specifically structured class that encompasses the entire class period), and (3) group assignments (all IESs done in groups in the classroom were not problem-based/ and typically did not take the full class period). Out-of-class group work was splint into there sub-types: (1)group projects (long-term assignments done in groups outside of class), (2)Take-home exams and homework's (short assignments that are encouraged or required to be done in groups and count as an exam, quiz, or homework grade), and (3)peer-led activities (activities done supervised by someone other than the instructor outside of class time) made up th. Online strategies did not include any sub-types; all online activities were included into this IES type. The Final IES type was Other. This IES type included Individual (activities done individually and completed primarily in the classroom), lab activities (these are done in a lab setting), and field (activities done in a field setting).

The overall number of articles being published was observed to be increasing from 1994 to 2014. A stead increase in articles was also observed in the set of articles from biology, but not as obvious in physics, chemistry and the geosciences. The number of geoscience articles published in the last 20 years is comparable to physics and chemistry. Geoscience articles were highly represented in the other strategies categories with all fieldwork articles coming from these articles. This could be that the geosciences are more prone to going to the field then others simply due to subject matter.

It was also observed that IESs can be implemented in any variety of class sizes. The smallest class size observed was 6 students, with the largest being 523. It is sometimes thought that IESs only work in small classes, these articles show that they can be successfully implemented in very large ones as well.

There is more room for research in several of these categories. First, the online strategies, a recent push to add technology to the classes or the adaptation of hybrid (in-class and online courses) could provide a nice area of research to help strengthen these . As well, there is room for creation of programs for specific topics. There is a number of chemistry, climate and soil programs but there are few covering others. Second, the others group. Lab work is typically required for all of these subjects. Incorporating more active learning into he lab process can add additional learning gains in the classroom. Research into how effect these active learning strategies are within the lab setting is incredibly important. Finally, research into full class activities and discussion has plenty of room to grow. Utilizing the full class allows for a variety of opportunities but little research is out there and much of the research is very segregated and filling in the gaps on these activities and more research on how effective they are would add a new breadth of research to this subject.

Crosspollination is also available for many of these active learning strategies. Both Polling and POGIL have been cross-pollinated successfully between many of these science fields though, has not been to the geosciences according to this literal search. Full class discussion and activities were highly concentrated in chemistry. Though, none of these activities seemed mutually exclusive and crosspollination of full class discussion and analytical activities would be a small transition with little conversion effort.

In conclusion, there are many ways active learning strategies can be implemented in and outside of classroom. Knowing how effect these strategies can be and knowing appropriate implementation are important when trying to utilize them in a classroom setting.

CHAPTER 2: Sedimentology and Stratigraphy Concepts

2.1. Introduction

Since the introduction of science into the general education curriculum in the 19th century, there have been continuous efforts to improve how science is taught. A shift in focus from how science benefits and connects one to society to a more concept-centered focus of teaching science occurred post-World War II, with a larger emphasis on national security and competition against other countries in areas such as space exploration (DeBoer, 2000). This change may have been responsible for the loss of making instructional connections between science application and the students' experiences (DeBoer, 2000). In 1996, the National Science Education Standards (NSES) were created to help build scientific literacy in the U.S. The NSES used the term 'scientific literacy' as a broad encompassment of science education objectives such as: utilizing science to understand and answer questions in day-to-day experiences, reading scientific articles with a general understanding, and identifing local and national issues related to science (DeBoer, 2000).

More recent efforts to transform higher education science courses was, in part, due to the decreasing number of college freshmen pursuing and or staying in science, technology, engineering, or mathematics (STEM) majors. According to the National Center for Education Statistics, natural sciences and mathematics have seen a decrease in percentage of college students enrolled in these majors from 9.8% of all college students in 1970 to 7.9% in 2012, an almost 20% decrease. This decrease is even more dramatic in graduate level attendance.

Ninety percent of STEM majors, who switch to a different major, indicate that their main reason for leaving is poor pedagogy, curricular structure, and overall instruction (Daempfle, 2003). Deampfle (2003), specifically found students leaving STEM criticized the lack of discussion and overwhelming focus of one-way instruction. Reinforcing this idea, Felder (2002) identified four reasons driving STEM majors to leave STEM, two of the four reasons relate to the classroom being too passive and centered on competitive versus cooperative learning (Felder, 1993). There is a general lack of focus on the students and their learning needs.

One other possible reason for declining STEM majors, as frequently quoted by faculty, is the inability to perform cognitively or cope with difficult coursework and subject matter (Daempfle, 2003). A study by Strenta et al. (1994) found that low grades were the number one reason why students leave their STEM major. One possible reason students perform poorly is in the expectation of college instructors and the reality of what high school teachers teach (Daempfle, 2003), college faculty focus on interdisciplinary integration of the subject where high school teachers often do not (Daempfle, 2003). A study by Schwartz et al. (2008) looks at the possibility of high schools' focus on breadth versus depth, and its effect on first year college students' success in college classes. In-depth learning of a single topic is argued to provide a better understanding resulting in better cognitive growth which requires time to achieve (Schwartz et al., 2008). Schwartz et al.'s (2008) study of over 10,000 students showed that students with a high school education that go in-depth on concepts are more likely to perform better in college level science courses. A student's high school education does not mean that student will perform poorly in a college level course, but it can be a factor. Decreasing students with poor grades may be able to help in lowering the number of students leaving STEM majors each year.

To combat students' dissatisfaction with pedagogy and students' struggle to achieve academic success in STEM majors, the addition of interactive engagement into the classroom could help. Education research in STEM fields shows that a transition to interactive, student-centered instruction can improve student learning (Henderson et al., 2010). Research on education reform and increasing science literacy suggest the addition of inquiry, active learning and interactive engagement, and a social aspect to a class can increase scientific literacy and retention (Lave, 1996; Anderson, 2002; Henderson, 2010; Felder, 1993).

Interactive engagement is a process that engages students with any type of instructional methods that promotes higher-level learning and thinking processes (Prince, 2004), as well as having students interact with peers or the instructor. Over the past 20 years, hundreds of studies tested the implications of various interactive engagement strategies on college learning in STEM courses. A comprehensive analysis of high school and college courses with or without the use of interactive engagement shows that courses that utilized interactive engagement typically had higher gains than those who did not (Hake, 1998). Hake (1998) also saw a large decrease in the number of students who dropped, failed, and withdrew from courses that used interactive engagement. Peer Instruction (PI) is one of the most commonly used and highly studied IES. PI has been studied since the early 1990's with studies following courses utilizing PI for as long as 10 years (Crouch and Mazur, 2001). PI utilizes classroom or personal response systems, "clickers", to have students answer Concept Tests (conceptually based multiple-choice questions). Students individually answer the question, and then based upon responses, are typically asked to have paired discussion, after which they will revote (Miller et al., 2014). Crouch and Mazur (2001) found significant learning gain differences in students on pre- and post-instruction scores on the Force Concept Inventory from traditional lecture in 1990 to the use of PI in the course in 1991. The results of this study are shown in Figure 1. PI is a commonly used IES, but it is not the only approach shown to improve student learning

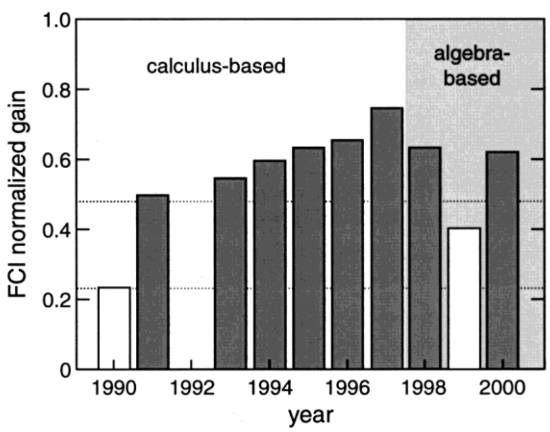

Figure 1. Comparison of results of Force Concept Inventory in Physics courses with using Peer Instruction (1991,1993-1998, 2000) and Traditional Lecture Courses (1990 and 1999). (Crouch and Mazur, 2001)

Lecture Tutorials (LT) are a second common and well-researched IES. LTs have been created for Physics (*Tutorials in Introductory Physics)* by McDermott and Shaffer (2002), Astronomy (*Lecture-Tutorials for Introductory Astronomy)* by Prather et al. (2004), and Geology (*Lecture Tutorials in Introductory Geoscience)* by Kortz and Smay (2009). LTs are short in-class worksheets, designed to be easily implemented into a traditional lecture with little work on behalf of the instructor. The LT should be implemented into the appropriate content context and scaffolding sequence of instruction during a standard lecture period. The individual LTs are designed to have conceptual questions that address student misconceptions and facilitate conceptual change. The questions are scaffolded to build on each other. LTs are typically one to two pages (front and back) and take 10-20 minutes for students to complete (Prather et al., 2004). Kortz at al. (2008) found that learning gains on questions taken from the GCI showed a decrease in learning gains in students with an extended lecture over the topics of the LT, while students who had used the LT showed a 19% learning gain. Learning gains such as this have also been seen in studies where LTs are utilized in lecture and non-traditional settings (Prather et al., 2004; LoPresto, 2009; Wallace et al., 2012; Kryjevskaia, 2014).

In addition, studies have compared PI and LTs to see if one active learning strategy provided higher learning gains than the other. Results from Mora's (2010) study compared class scores on the GCI for four classes, two of which used PI, the other using LTs, show that both class styles resulted in significant learning gains, but neither statistically significant compared to the other. This study then compared the results of the PI and LT GCI scores to scores from studies that used GCI in traditional lecture courses and found both courses significantly improved learning, in some cases almost twice as much. These results are shown below in Table 1. Gray and Steer (2012) implemented LTs into two classes and, in one, added PI also, resulting in no significant difference between the two class instructional approaches. Another result of these studies was that students in the bottom half of the class on the initial GCI showed greater learning gains than students in the top half (Mora, 2010). Increasing the lowest student scores could help reduce the numbers of students that land in the D-F grade range, as seen in the results stated previously in the Hake (1998) study.

Style	N	GCI-Pre	GCI- Post	GCIpost-GCIpre	G
PI	45	38.2 (SD=13)	49.4 (SD=12.3)	11.2	0.18
LT	37	36.4 (SD=12.1)	46.9 (SD=13.8)	10.5	0.16
Libarkin and Andersen	2493	41.5 (SD=12)	45.8 (SD=13)	4.3	0.07
Kortz at al.	86	39.3 (SD=13)	48 (SD=14)	8.7	0.14

Table 1: Comparison of PI, LT and tradition Lecture courses results on the Geoscience Concept Inventory (Mora,2010).

Gray and Steer (2012) also looked at student attitudes towards instructional approaches; the course using only LT was rated higher than average. Classroom activities were rated highly overall with no significant difference between the two courses. However, both LTs and PI improved learning and had high satisfaction by students, but the implementation of both in a single course does not increase student learning more than the use of a single intervention.

For LT and other IESs to be most effective it is important to address student misconceptions. Misconceptions in the geosciences primarily focused on children and/or K-12 students, though some studies focused on undergraduates.

Students in the geosciences do not understand Earth’s interior and processes, such as plate tectonics. One study found that when simply drawing the interior of the Earth, many descriptions of what they drew where based off analogies, “Like a dart board”, “Like a jawbreaker” etc. (Libarkin et al., 2005). Libarkin et al. (2005) found that students would use many technical terms, but were unsure what they actually meant. Many times students were confused on how terms went together, mixing chemical boundary terminology and physical state terminology for the interior of the Earth. Students hold many misconceptions about plate tectonics including where plate tectonics take place in the Earth, and how plate tectonics affect Earth’s physical appearances (Libarkin et al., 2005). Sibley (2005) states the two most prominent misconceptions are: (1) that mountains form from two ridged plates colliding with no roots or effect on the lithosphere and (2) that mountains come from one plastic plate overlying a ridged plate with no roots or changes to the lithosphere. Relating to students misconception of how plates move, Libarkin et al. (2005) found that students understand how plates moved to create the Earth we currently live on, but when probed about the future of the Earth they do not see the Earth’s surface changing is.

This final misconception about plate tectonics relates to Kusnick’s (2002) idea that student’s think of the Earth as stable. Students believe Earth’s features are static and mountains do not change, rivers run where they always have, and rocks form where they are found. Nonetheless, Kusnick (2002) found that students believe that when Earth does change or move it is due to catastrophic events.

One of the largest and most fundamental misconceptions or learning difficulties students have stem from the understanding of geologic time. To start, many students do not believe the Earth is 4-5 billion years old (Libarkin et al., 2005). Of the three institutions participating in this study, 38% of students from one school and 16% from a second thought the Earth was less than one billion years old (Libarkin et al., 2005). Not grasping how old the Earth is hinders students from being able to understand geologic concepts on this time scale. Libarkin et al. (2005) found that students believed life was present at the formation of the Earth with three dominating types appearing: (1) simple single celled organisms, (2) water creatures, and (3) all life observed today. This shows that students have a hard time thinking past the human time scale. This is reflected in Kusnick's (2002) students ideas about the formation of sedimentary rocks, finding that 29% of students used general terms when talking about the time it takes to create a sedimentary rock, and another 29% specifically stated timescales of a year or less. Under 20% of students felt rock formation took significant amounts of time.

Other misconceptions have been found in the geosciences relating to rock formation, volcanoes, and terminology. Many students do not understand how rocks form, expressing the idea that all rocks in rivers are sedimentary, and that sedimentary rocks form through accretion of more sediment (Kusnick, 2002). Relating to terminology, geologists and faculty alike tend to think about rocks in technical terms, though many students think of rocks as something they can hold in their hands (Kusnick, 2002). Prompting the idea that faculty and intervention must be explicit in how they discuss and address words with multiple meanings.

The goal of this study is to identify student misconceptions and learning difficulties in sedimentologic and stratigraphic concepts and to create a set of Lecture Tutorials on sedimentology and stratigraphy concepts. The questions to be addressed are: (1) what have faculty observed to be the most difficult concepts for students to learn? (2) what misconceptions have faculty observed that make these concepts difficult for students? (3) how effective are LTs at helping overcome learning difficulties and misconceptions?

2.1.1 Theoretical Frameworks

It is well known that students do not come to a classroom as a blank slate, or with no prior knowledge of the material that a course may cover, though many of these concepts are not consistent with what the scientific community thinks. Students have these misconceptions because they have placed the concepts in inappropriate ontological categories or are unaware of major parts of the concept (Chi et al., 1994). These misconceptions have been acquired through an individual's everyday actions and lay culture (Vosniadou, 2007). For this study, LTs are designed to confront student-held misconceptions and about sedimentology and stratigraphy concepts, and facilitate conceptual change. Conceptual change happens gradually through the modification of the individual's ideas of the physical world by enriching or revising their current understanding (Vosniadou, 1994).

These LTs are designed to scaffold concepts such that one builds on the other in in each subsequent LT question. Scaffolding is the process in which a novice is able to complete a task or reach a goal they otherwise would not be able to (Holton and Clarke, 2006). Scaffolding was traditionally thought of as an "adult controlling those elements of the task that are essentially beyond the learner's capacity" (Holton and Clark, 2006; Puntambekar and Hubscher, 2005). These LTs use reciprocal scaffolding, where at least two people come together to achieve a common task or goal and at any given time can be the expert or the novice (Holton and Clarke, 2006). This is done by having students pair up to complete the LTs; different students bring in different ideas and knowledge to help complete the tasks together (Holton and Clarke, 2006).

2.2. Methods

A survey to elicit faculty observed misconceptions about sedimentology and stratigraphy concepts was administered using Qualtrics survey software. The survey was sent to faculty emails mined from geology department websites from six Carnegie rankings: RU/VH: Research University (very high research activity), RU/H: Research University (high research activity), Assoc/Pub4: Associate's—Public 4-year Primarily Associates, Bac/Diverse: Baccalaureate Colleges—Diverse Fields, Bsc/A&S: Baccalaureate Colleges—Arts and Science, and Bac/Assoc: Baccalaureate/Associate's Colleges. Faculty had one month to complete the survey. The survey was designed to take no more than 30 minutes to complete. A reminder/thank you email was sent out two weeks after the original email had been sent. One month following the initial invitation, the survey was closed and the collected data were analyzed. Demographics for instructor participants in shown in Table 2.

Instructor participants	Different institutions	Type of Institution					
		RU/VH	RU/H	Assoc/Pub	Bac/Diverse	Bac/A&S	Bac/Assoc
n=39	N=31	14	15	1	3	4	1

Male	Female	Other	Caucasian	Indigenous	African	Asian	Hispanic/ Latino	Other
46%	48%	6%	90%	2%	2%	2%	0%	8%

Table 2: Demographics of instructors participating in survey.

Once analysis of misconceptions and learning difficulties were finished, the LTs were edited. The initial four LTs' foci were in line with identified misconceptions and learning difficulties observed by the faculty. Specification of individual questions and question types were edited so that each question directly addresses one or more identified misconceptions or learning difficulties.

After LTs were edited, they were sent to 8 instructors to provided feedback on the LTs. Each instructor was given one to four LTs to provide feedback, based on what they noted previously. Each instructor was asked to use the ‘track changes’ function in Word to provide feedback on the LTs. They were also given a feedback form to solicit insight into how useful the individual LT. or parts of the LT. would be to them in their own instructional efforts. The instructors were given two weeks to provide feedback on the LT.

To elicit student feedback on the LTs, individual think-aloud interviews were conducted with 8 students. These students were recruited from upper-level courses in the geosciences. To recruit the 34 students for Focus group interviews, emails were sent to faculty that teach introductory courses inside and outside of the geosciences, requesting permission to speak with their classes. Class visits happened within the first month of the spring 2016 semester. A member of the research team visited each class to solicit student participation. Within the week after the class visit, a second email was sent to the faculty asking them to send an email to the class as a reminder for students who were in the class the day of the visit, as well as a way to recruit the students that were not.

Think-aloud interviews were the first interviews completed; they lasted ~60 minutes each. Third- and Fourth-year geology students were recruited for these interviews. Students met with one of the research team members in the lab room. Participants signed a consent form. They were then given a copy of the LT to complete.

For this interview they were asked to read the questions out loud and speak their thoughts of what they would do as they worked through the LT. Each interview was recorded and transcribed for data analysis.

Based on faculty feedback and the think-aloud interviews, the LT set was edited and then used for focus group interviews with first-year or non-major geology students. A pre- and post-instruction questionnaire was created for each individual LT. The pre- and post- instruction questionnaires were then reviewed by four geoscience experts for readability, and to assure that the questions were interpreted as intended.

Thirty-Four students participated in the focus group interviews. Fourteen of which had taken a geology course, and only four were college-level introductory geology courses. The students comprised 14 males and 20 females, with 27 students identifying as white, 3 American Indian or Alaskan Native, and 2 Asian. Students represented 12 freshman, 7 sophomore, 5 juniors, and 10 seniors or 5th year seniors. Groups of no more than six students participated in focus group interviews at a time. Groups worked through one of three different focus group protocols. All focus group protocols had the focus group participants meet with a member of the research team in the lab. Participants were then given a consent form to read and sign, giving consent to continue the study. Once consent forms were signed, students individually took a short questionnaire over the concepts to be addressed in the LT. There were three different focus groups: Focus Group 1, Focus Group 2, and Focus Group 3. Students in Focus group 1, were given a < 5-minute lecture over each LT topic. They then retook the initial questionnaire. Focus Group 1 interviews lasted roughly 40 minutes each. The final questionnaire completed by students in Focus Group 1 will be referred to as “post-instruction questionnaire”, because the only learning gains from the lecture are being reflected in student results of the questionnaire.

Students in Focus Group 2, completed the same questionnaire as Focus Group 1 and were given the same corresponding lecture. After the lecture, students were grouped and worked through the LT corresponding to the questionnaire and lecture. After completing the LT, students retook the questionnaire. Each focus Group 2 style interview lasted roughly 60 minutes, and each group completed three to five LT topics. The final questionnaire completed by students in Focus Group 2 will be referred to as "post-instruction and LT questionnaire", because student responses reflect information gained from both the short lecture and completion of the LTs.

Students in Focus Group 3 completed the questionnaire, listened to the corresponding lecture, then retook the questionnaire as in Focus Group 1. These students worked through the corresponding LT in pairs or groups of 3, and then retook the questionnaire for a third time. Focus Group 3 style interviews lasted roughly 75 minutes and two to three LT topics were completed in each interview. Questionnaires completed by students will be referred to as "post-instruction questionnaire" for the questionnaire completed immediately after the short lecture (as with Focus Group 1) and the final questionnaire will be referred to as "post-instruction and LT questionnaire" (as with Focus Group 2). At the end of all focus group interviews, students were thanked and compensated $15 each for their time.

Focus group data were then coded and scored. All student answers were transferred to an electronic version via an Excel document. A rubric for scoring responses on a scale of 0-3 was created to score each question. The scoring rubric was used by one rater to score the articles. The rubric was then revised by a second rater and then implemented by both raters (the rubric is attached as appendix J). Scoring responses to each LT was done independently, by both raters, with an 84% initial agreement. Raters then met and discussed mismatched codes until 100% agreement was attained. An initial agreement by focus group and LT is in Table 2.

Focus Group 1	Deposition	79% agreement
	Diagenisis	97% agreement
	Stratigraphic Facies	64% agreement
	Sequence Stratigraphy	91% agreement
	Unconformities	90% agreement
Focus Group 2	Deposition	81% agreement
	Diagenisis	89% agreement
	Stratigraphic Facies	84% agreement
	Sequence Stratigraphy	92% agreement
	Unconformities	84% agreement
Focus Group 3	Deposition	90% agreement
	Diagenisis	92% agreement
	Stratigraphic Facies	81% agreement
	Sequence Stratigraphy	95% agreement
	Unconformities	90% agreement

Table 3. Initial dual coder agreement by focus group and LT.

3. Results

3.1 Instructor Survey Results

Six key concepts were identified by instructors as being taught in over 50% of the courses they teach: Sea level rise and fall (85%), diagenetic processes (59%), stratigraphic columns (77%), facies association (77%), unconformities (92%), and stratigraphic units and relationships (77%). Fifteen instructors identifed other key concepts relating to tectonics, identification of rocks and minerals, depositional environments, and interpreting or identifying geologic features.

Instructors provided feedback on what, in their experience teaching, they observe to be the most difficult topics for students, as well as the most common misconceptions and ten grouping topics emerged and are presented in Table 3. These results were used to create four LTs that focus on the topics of: sequence stratigraphy, deposition and diagenesis, stratigraphic units and relationships, and sedimentary facies. LTs designed are one-page worksheets that should take roughly 10 minutes in class.

Grouping topic	% occurrence	Type of responses and examples

Deposition	38%	**Depositional environments**: "Students think that sedimentary rocks are deposited in deep ocean basins, and represent the vast span of geologic time" and "Sedimentary depositional environments (e.g. large scale basins) that are on the scale observed in the rock record have been difficult concepts for students to grasp" **Depositional processes and features:** "Eolian and aqueous bedforms, bedform migration and climb and hot they deposit sediment strata"
Sequence stratigraphy	30%	**Direct mention of Sequence Stratigraphy:** "Walthers Law and sequence stratigraphy immediately come to mind" **Focus on changes in sea level:** "Sea level rise and fall indicators in the geologic record".
Time and Dimensional thought	38%	**Mention of time alone:** "Deep time" "Deep time of geology is too long- they can't switch to millions and billions of years: **Mention of 4-D thinking or time and space:** "Complex 4-D problems" "relationship between time and space is difficult." "A sedimentary system is static in space and time" **All other Dimensional thinking**: "Everything is 2-dimrnsional. Rock layers are stripes instead of tabular" "The idea that something can take a long time. For instance, The limestone that underlies the campus was created under ocean and now it is dry land"
Processes and resulting features	15%	"Putting together the processes with the characteristics for the rocks, either in hand sample or in thin section" "I do think they have a hard time going backwards from sediment to process of formation"
Unconformities	13%	**Mention unconformities**: "recognizing unconformities" "They have difficulty dealing with what it means if there is a period of non-deposition or erosion" **Mention "missing time" or "gaps"**: "Gaps in the geologic rock record" "Students are not cognizant that sedimentation cannot tale place in the absence of water, and thus gaps in the sedimentary record may be erosional or simply lack of deposition"
Facies	13%	"Lateral facies changes" "facies association…particularly architectural elements and bounding surface"
Rock Reading	4%	"Students are rarely competent in identifying rocks and minerals"

Diagenetic Processes	18%	"fluid flow in porous sediment and realted phenomena which are hard to see" "Rates of diagenisis" "Diagenetic processes"
Data collection processes	8%	"That we can provide accurate imagery of stratigraphy at depth, leading to them questioning why we have such "poor seismic and why they have to interpret it" "3-D modeling" "radiometric dating"
Other	28%	**About the study**: "sedimentology and stratigraphy are easy" "weak understanding of linkages and differneses between academic and professional worlds" "interpretations can be made without support of sound observational framework" **Other:** "results of the great flood" "any sedimentary rock that has a pink hue must possess a lot of potassium feldspar"

Table. 4- Instructor identified learning difficulties and observed misconceptions.

3.2 Instructor Feedback Results

Instructors responses were used to create the LTs that were created, and revised by nine instructors. After revision, five LTs were created. Copies of original and final LT are provided in appendix H and appendix I.

The original "Sequence Stratigraphy" LT received very positive instructor feedback, requiring only minor modification. Question 1 was reworded to focus on the location of the shoreline over time rather than the look of the beach over time, for clarity. Question 2, 2a, and 2b were unchanged. There was concern that these topics may require more background knowledge for the students, but was also cited as potentially the most useful questions by others, so that there was not enough concern to change or remove the questions. The figure in question 3 was most often cited at the most useful part. A modification of the figure was suggested: to increase the slope of land to make changes in sea level more obvious. The original and post figures are shown below as Figure B and Figure C.

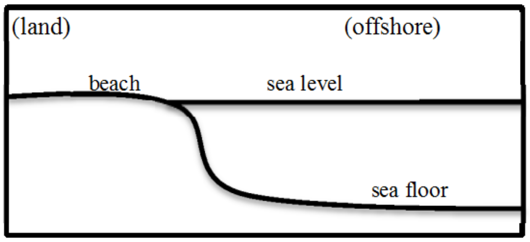

Figure 2. Initial Lecture Tutorial Image

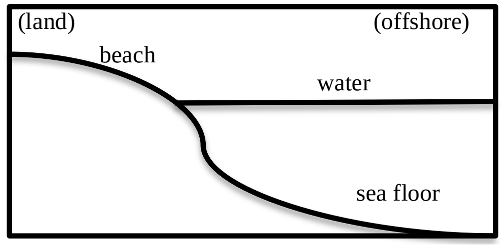

Figure 3. Modified Lecture Tutorial Image

"Deposition and Diagenesis" was converted to "Diagenesis" only. Questions 1 and 2 were kept with minimal changes to the wording. Faculty reviews were 75% favorable to this LT, with the largest concern being the amount of time it would take during class. Question 3 was removed from this LT to be used in a later LT.

The LT about "Stratigraphic Units and Relationships" received favorable revoews from faculty for the questions, with 67% saying they could see using some if not all of the LT. Instructors stated that the focus of the title was not reflected in the questions. As a consequence, this LT was renamed to "Unconformities". Instructors requested that more types of unconformities be shown, and that showing geologic cross-sections along with real rock examples would be helpful. Question 1 was revised to reflect those suggestions; previously asked students to identify an unconformity on a photo, and was revised to show two real photos along with corresponding geologic cross sections for students to identify the location of the unconformity. No changes were made to question 2. The addition of a 5th sub-question was added to question 3. This question asked students "What happened during formation of the unconformities?" This addition was in response to instruction feedback that it was important not only to ask about the history leading up to the unconformities, but also addressing what causes an unconformity.

The LT about "Sedimentary Facies" received the least favorable reviews, and feedback was useful for editing the LT. The largest concern was that the first question related directly to facies, whereas the others where focused more on deposition. To address this, Question 1 was retained as the sole item for the "Sedimentary Facies" LT. Questions 2 and 3 were removed for this LT and were combined with question 3 from "Deposition and Diagenesis" were combined to create a 5th LT, entitled "Deposition".

3.3 Think aloud Interview Results

Eight upper-level geology undergraduate and first-year geology graduate students participated in think-aloud interviews, that lasted roughly 60 minutes. Think-aloud interviews revealed that most LT questions were interpreted as intended, though several changes were made. First, question 2b of the original Deposition and Diagenisis LT was edited because it asked students to think about to 2ai and seemed to confuse and delay students from answering the question. This phrasing was revised to 2a(i) in order to make it more clear for the reader and direct their thinking. Second, figures in question 2b of Sequence Stratigraphy were changed. Twenty-Five of participants drew inside the figure, as shown in figure 4, rather than drawing additional layers on top. The middle of the figure was filled-in help prevent this confusion.

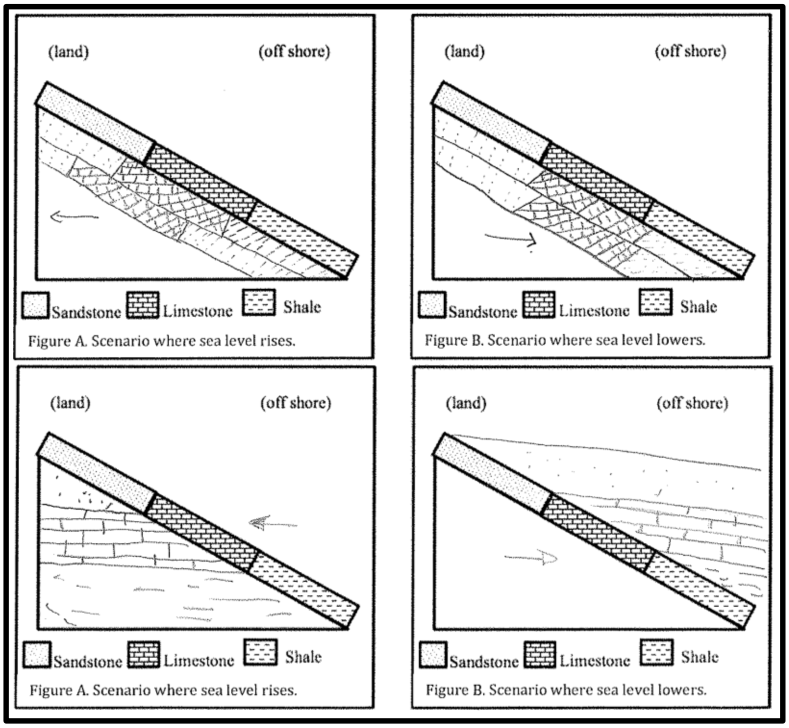

Figure 4. Examples of misinterpretation of Sequence Stratigraphy Question 2B from Think-aloud- Interviews

3.4 Focus Group Learning Gains

Learning Gains were calculated for each student's scores on the pre- and post-instruction questionnaire using the following equation:

$$<g>= (postscore\%-prescore\%)/(100-prescore\%)$$

Each LT's corresponding pre

- and post-instruction questionnaire was then averaged by focus group style. Focus Group 1 shows learning gains for students who listened to lecture only. Focus group 2 results show learning gains for students who listened to a lecture and completed the corresponding LT in groups of two or three people. Focus Group 3 results show student learning gains for both listening to a lecture and completing the corresponding LT in groups of two or three. A t-test analysis determined that significant differences in learning gains were associated with the Focus Groups that utilized LTs, compared to those that did not (Table 4).

The LT about Deposition associated with positive learning gains for all focus groups. Focus Group 3 showed an increase of 0.31. This learning gain is significant (p= 0.008). When comparing all students' scores for post-lecture to post-lecture and LT, the latter shows a learning gain increase of 0.16 compared to the post- lecture scores, but is not statistically significant at .05.

FG1 <g>	FG2 <g>	Difference in <g>	FG3-LO <g>	FG3-L/LT <g>	Difference in <g>	All-LO <g>	All-L/LT <g>	Difference in <g>
0.20	0.17	-0.03	0.26	0.58	0.31	0.24	0.40	0.16
P=0.78			P=.0076			P=.0885		

Table 5: Learning gains for the Deposition LT. FG stands for FG, LO stands for lecture only, L/LT stands for lecture and LT.

The Diagenesis LT shows similar results to the Deposition LT, as can be seen in Table 5. Focus Group 3 shows a learning gain of 0.23 from students post-lecture scores to post-lecture and LT scores. This was shown to be statistically significant (p= 0.0055). An overall learning gain between all students post-lecture scores and all students post-lecture and LT scores shows a learning gain difference of 0.13, but was not significantly different.

FG1 <g>	FG2 <g>	Difference in <g>	FG3-LO <g>	FG3-L/LT <g>	Difference in <g>	All-LO <g>	All-L/LT <g>	Difference in <g>
0.69	0.66	-0.02	0.54	0.77	0.23	0.59	0.71	0.13
P=0.81			P=0.0055			P=.0753		

Table 6: Learning gains for the Diagenisis LT. FG stands for FG, LO stands for lecture only, L/LT stands for lecture and LT.

The Facies LT showed less favorable results with no statistically significant changes between students' post-lecture score and post-lecture and LT scores as can be seen in Table 6.

FG1 <g>	FG2 <g>	Difference in <g>	FG3-LO <g>	FG3-L/LT <g>	Difference in <g>	All-LO <g>	All-L/LT <g>	Difference in <g>
0.72	0.51	-0.21	0.62	0.67	0.05	0.67	0.58	-0.09
p=0.78			p=.6779			p=.1438		

Table 7: Learning gains for the Facies LT. FG stands for FG, LO stands for lecture only, L/LT stands for lecture and LT.

The Sequence Stratigraphy LT shows a learning gain increase in all three situations that were compared, as can be seen in Table 7. Focus Group 3 shows an increase of 0.35 from the post- lecture to post-lecture and LTs (p=0.0077). The overall gain for students post- lecture to post- lecture and LT is 0.28 and is statistically significant (p=0.028).

FG1 <g>	FG2 <g>	Difference in <g>	FG3-LO <g>	FG3-L/LT <g>	Difference in <g>	All-LO <g>	All-L/LT <g>	Difference in <g>
0.57	0.68	0.11	0.51	0.85	.35	0.54	0.82	0.28
P=0.536			P=.008			P=.028		

Table 8: Learning gains for the Sequence Stratigraphy LT. FG stands for FG, LO stands for lecture only, L/LT stands for lecture and LT.

The Unconformities LT shows a very slight learning gain increase in all three situations. No situations showed statistically significant results.

FG1 <g>	FG2 <g>	Difference in <g>	FG3-LO <g>	FG3-L/LT <g>	Difference in <g>	All-LO <g>	All-L/LT <g>	Difference in <g>
0.42	0.47	0.05	0.43	0.45	0.02	0.42	0.46	0.04
P=0.552			P=.85			P=.461		

Table 9: Learning gains for the Unconforities LT. FG stands for FG, LO stands for lecture only, L/LT stands for lecture and LT.

3.5 Deposition alternate conceptions

Three of the five pre- and post-instruction questionnaire questions about deposition revealed students have alternative conceptions about deposition. Initially, 27% of students think that only water environments were able to create sedimentary rock, or have sediment deposited in that environment. This idea was reflected through student responses where they explicitly stated that they are formed in areas with water such as “wet environments”, compared to responses where students listed specific environments such as “ rivers, streams, [and] deltas”. This specific question also recorded a small number of students (18%) who thought that volcanoes or tectonic forces create sediment and sedimentary rocks, showing that a small number of students are unaware of what a sedimentary rock is and how it is formed.

Student responses for question 3 showed that 32% of students felt that rock can be moved around as a whole and re-deposited as the same rock. For example, one student stated:

“Some rocks could have been moved earlier by wind or water”

This idea was, intermixed with idea that rocks below the surface can be eroded and moved above other rocks with little to no damage or erosion of the overlying younger rock. In the words of one student, for example:

“wind/water could have moved older rock above younger rock”

Even after the focus group lecture and completion of LTs, some students retain such misconceptions, illustrating how deeply held ideas are among students.

Question 5 showed a similar result with 18% of students stating, in at least one response to the question, that the lower layer of rock was eroded, leaving the higher layer but at a lower elevation, such as in Figure 5.

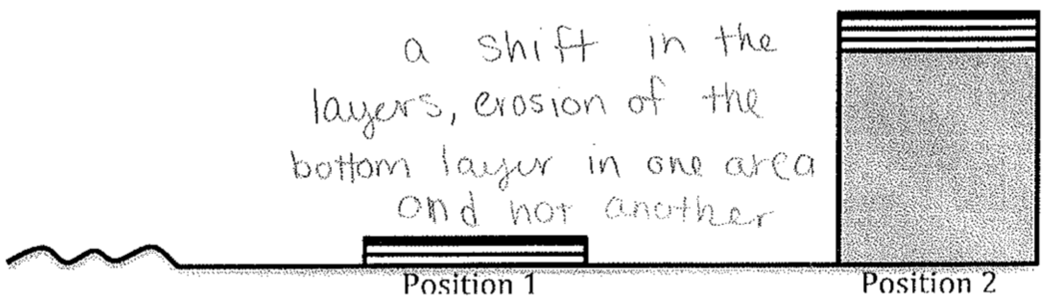

Figure 5. Student alternate perception of erosion of lower rocks.

It is clear that this student feels that the rocks below the layer present at position 2 use to exist at position 1, but was eroded away leaving the layer at the lower elevation seen at position 1.

Thirty-Two percent of student responses in at least one pre- post-questionnaire shows that students think that rock from a higher elevation can be eroded and re-deposited as the same rock formation in a different location at a lower elevation as seen in Figure 6.

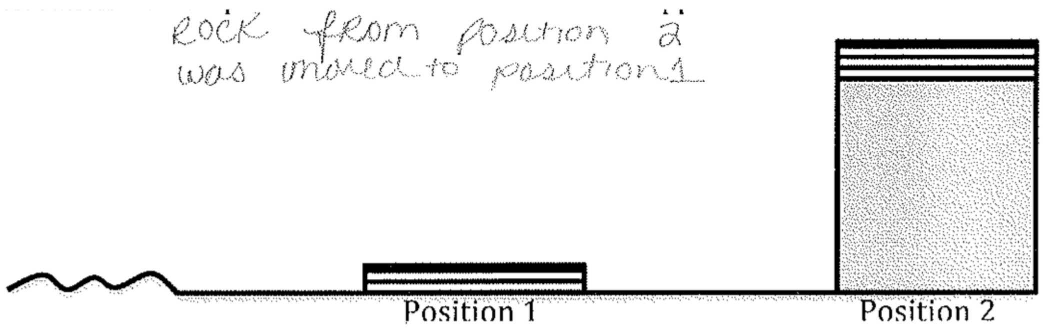

Figure 6. Student alternate perception erosion and re-depostion of rocks at different elevations.

The final observed alternate conception, seen in this LT, was that students thought water or sea level caused formations to be deposited at different elevations. Some students were vague on their reasoning, offering answers such as “the elevation of water”. Others were more specific about how they felt water did this, attributing the change in elevation due to a transgression and/or regression. The idea of water playing a role in this situation occurred in at least one of the individual students responses for 68% of students.

3.6 Diagenesis alternate conceptions

Students’ prior knowledge responses to the open ended questions for the LT about Diagenesis reflect a lack of prior knowledge of this topic. Many students initial responses either directly stated a lack of understanding, “I don’t know” or “ I guessed”. For answers that did not directly identify as a guess, they show a lack of any understanding by referencing erosion or tectonics as a cause.

3.7 Sedimentary Facies alternate conceptions

Similar to the results for the LT about Diagenesis, students’ prior knowledge responses to open-ended questions in the LT about Sedimentary Facies reflects a lack of any prior knowledge. Similar responses such as “just a guess” or “I don’t know” are common among students’ initial responses to the question. Some students chose to attempt an answer. These answers reflected a lack of understanding with responses such as “the phase of the life/age of the formation of the rock” or more lighthearted responses such as “the plural of face”.

3.8 **Sequence Stratigraphy alternate conceptions**

Questions probing students’ prior knowledge of sequence stratigraphy produced repetitive alternate conceptions about sea level and sedimentation. Student open-ended responses to Question 2 showed that 32% of students think that it is possible to see changes in sea level because sea level leaves an observable physical mark on the rock where sea level once was. Specific examples of student responses are provided below:

“because it would erode the rock wherever sea level is”;

“the sea probably deposits salt on the rocks”;

“I feel that is very evident as it leaves marks.”;

It was apparent that some students felt physical marking could be observed on rock layers as they are deposited where sea level once was, and are visible today. It is possible for some geomorphic features, marine terraces or strandlines, to leave marks on the rock due to sea level. Due to the participants having little to know geologic background, answers were interpreted that the participants would not have an understanding of these geomorphic features.

Question 2 solicits students’ ideas about what causes changes sea level. Students provided a total of 12 unique categories. Table 9 shows the percentage of students in each category for prior knowledge, post-lecture and post-lecture and LT student responses.

Students show a general trend from totally incorrect ideas, such as “what life forms are present. Flora, fauna, food chains and access to resources”, to more correct answers relating to climate change and tectonic events such as uplift and subsidence.

Student idea of what changes sea level	% of student response from Prior knowledge questionnaire	% of student response from post-lecture questionnaire	% of student response from post-lecture and lecture tutorial questionnaire
Moon/tides	27	9	9
Volcanoes	9	9	18
Topography of ocean floor	9	0	0
Global warming/ Climate change	27	27	55
Glaciers melting/freezing	18	36	18
Weather- drought, excessive rain, storms	32	27	0
Natural Causes- no more explanation	5	9	9
Tilt of the earth	5	9	0
Tectonic plate movement- uplift, subsidence	5	64	73
Sedimentation	0	36	73
Other	18	0	0
Life- humans or animals	9	0	0

Table 10: Percentages of student ideas of what changes sea level.

3.9 Unconformities alternate conceptions

Question 1 on the Unconformities LT asks students if they think the rock record shows a continuous history of time, and why. Twenty-seven percent of students think, in at least one of the responses, that it does because if we understand what past life existed and what the environments used to be like, then we have to have a full history in the rock record. Students even used past life and evolution as a way of accommodating gaps in the rock record, giving responses such as "as unconformities happen, evolution happens over time and this shows history". This question also revealed that about 23% of students think, in at least one response, that rocks created at the creation of Earth are all still around today:

"Layers can show how long ago the earth existed".

Other students rationalized this idea with putting in ideas about the strength of the rock or its ability to be "altered":

"rocks have been around since the beginning of time and are hard to alter by man (impossible)."

Another alternate conception that was observed via students' answers on the Unconformities pre- and post-instruction questionnaire is that tectonic forces and events cause gaps in the rock record. Most responses showed little reasoning, with tectonic forces or specific types of tectonic events, such as earthquakes, as the answers.

Question 5 showed potential to be misinterpreted, 45% of students showed answers that did not seem to be appropriate for the question. Typically, student answers focused on how to find out what happened during the unconformity, rather than if you can explain the history after an unconformity. Only one student showed a consistent misinterpretation, all other students showed correct interpretation of the question in other pre- and post- instruction renditions of the question.

4. Discussion

4.1 Learning Gains

This study examined learning gains of lecture and LTs in a non-traditional classroom setting. It is different from many prior studies, which typically implement LTs in college lecture-based courses (LoPresto et al., 2009; Wallace et al., 2012; Prather et al. 2005; Finkelstein and Pollock, 2005; Gray and Steer, 2012; Prather et al., 2009; Mora, 2010; Kortz et al., 2008; Kryjevskaia et al., 2014) or recitation settings (Brogt, 2007; Koenig et al., 2007). Yet, none have done them in a focus group setting. The use of focus groups in this study led to a smaller sample size than if the study were conducted in a course. However, it allowed for more direct comparison of how much information each student gained from the lecture and the LT.

Greater leaning gains were observed for students' responses on the post- lecture and LT scores than the post-lecture scores of the pre- post questionnaire for four of the five LTs. Comparing Focus Group 1 to Focus Group 2 showed consistently the smallest learning gain comparisons, and at times even negative learning gains, neither of which are statistically significant.

The LTs were designed to help aid student learning. Similar to the results of Kortz et al. (2007), some of the LTs were more useful than others in this setting. Neither the LT on Sedimentary Facies, nor the one on Unconformities, showed statistically significant results comparing post-instruction scores to post-instruction and LT scores for any set of students. The Sedimentary Facies LT was evaluated for its effectiveness with single question with a maximum score of three for that LTs; as such, this is not a full-fledged

LT but it provided the basis for continued development. All other LTs were evaluated with four or five questions, with an overall score of 12 or 15 .

Student learning gains for the lecture only portion are consistent with, but still slightly higher in some cases, with the learning gains from Wallace et al. (2012) and Prather et al. (2005) for lecture. Average student learning gains for each lecture topic fell between a learning gain of 0.2 to 0.72 from their prior knowledge questionnaire to their post-lecture. Wallace et al. (2012) saw learning gains from as low as 0.04 to 0.37. The learning gains from lecture observed by Prather et al. (2005) showing a 0.2 gain from lecturer. The scores of both studies being generally higher than those of similar studies such as a 0.5 gain observed by Kortz et al. (2008).

Three LTs did show significant learning gains: Deposition, Diagenesis, and Sequence Stratigraphy. These LTs show an increase of 0.31, 0.23, and 0.35 learning gain over the students' post-lecture scores for Focus Group 3. These results reflect similarly to Prather et al.'s (2005) results where students had an average increase of 0.2. The results of the students' post-instruction to post-instruction and LT gains put student responses for Deposition and Sequence Stratigraphy in the medium learning gains (<g>) (0.30≤ <g> <0.70) according to Hake (1998). Diagenisis falls in to the low learning gains region (<g> <0.30) (Hake, 1998).

4.2 Alternative Conceptions

In this study students' alternate conceptions were analyzed for correctness and for repeated patters. It was apparent that students had very little to no prior knowledge about the topics of Diagenesis and Unconformities. This lack of prior knowledge was not surprising given that students participating in the study typically had not taken any geology, or had not taken a geology course since high school.

Several of the alternate conceptions observed in these interviews are reflected in existing literature. It is observed that students have a wide range of initial ideas of what can change sea level, from fully correct ideas, such as climate change and glaciers melting, to alternate conceptions, such as the amount of life in the ocean or day-to-day weather. One alternate conception observed in this study was that the tides and the moon's motion change the sea level. This idea was supported by a study by Herrera and Riggs (2013) in which they found that students felt tides changed relative sea level. This item was scored as a partially-correct answer because students said that they see the tide move sea level up the beach and back down the beach during the course of the day. So that on a short time scale, relative sea level can change due to the tides, which was different from Herra and Riggs (2013).

The alternate conception students had about rocks on Earth existing from the "beginning of time" are still around today, could reflect the idea of a stable Earth that was observed in Kusnic (2002). This is the idea that students think Earth does not change except due to catastrophic events (Kusnic, 2002). For students to believe that rocks from the creation of earth are present today would support Kusnic's (2002) idea that the Earth doesn't change. Kusnic's (2002) idea is also supported by students views that an unconformity is the result of a one-time tectonic event, such as an earthquake. This idea reflects the view that for an event of no deposition or erosion of a layer, something big must have happened.

Four alternate conceptions are observed as being unique to this study. Three of the unique alternate conceptions come from Deposition. The first unique alternate conception from Deposition was students thinking that a rock formation could be eroded, transported, and deposited as the same formation. The second is the idea that lower layers in a rock sequence can be eroded away to lower the elevation of the upper rock layers. The third unique alternate conception is the notion that sediment is only deposited in water environments. The final alternate conception that was unique to this study was that students thought there was an observable physical marks on rocks to indicate sea level once was.

5. Conclusions

The focus of this study was to create a set of Lecture Tutorials that could be used in a variety of college-level geology courses. The LTs are created on the basis of previous studies reported in the literature and faculty observed learning difficulties and misconceptions that were reflected through a survey. Five Lecture Tutorials were created: Sequence Stratigraphy, Deposition, Diagenesis, Unconformities, and Sedimentary Facies. These LTs are meant to be used in the classroom during lecture and should take roughly eight to twelve minutes to complete. These LTs were tested in three different focus group settings with a maximum of 11 students participating in each focus group. This small sample size gives the opportunity to look at each student’s responses for conceptual understanding and to identify alternate conceptions.

Three of the five LT did show a statistically significant increase in student learning gains, while two did not. This does not mean they were not useful to students;

they just did not produce statistical results. The LT on sedimentary facies should be revised to have multiple questions so that it scaffolds information in a similar way to the other LTs.

An Instructor’s Guide should be created for LT. The Instructor’s Guide would give information on what a LT is and suggested implementation for the LTs. Potential student answers, from the focus group responses, and discussion topics for each LT question will included to give instructors an idea of what to expect.

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APPENDIX

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Appendix B: Coding for Literature Review

- **College:** must be implemented in a college level course or discussion about how it could be implemented in a college course must be present.
- **IES present:** that there is recognition of at least 1 interactive engagement strategy in the article.
- **Subject:** The field of study that the IES is being used in.
    - **1=Chemistry**
    - **2= Biology (anatomy, physiology)**
    - **3=Geology (geography, meteorology, earth science, environmental science, climatology, astronomy)**
    - **4=Physics**
    - **5= Other Sciences (research science, general science)**
- **Year:** the year of that article
- **Class Type:** What type of class it is. Drop down: lecture, lab, field, or online.
    - **1=lecture**
    - **2=lab**
    - **3=field**
    - **4= other**
- **# of IES's Mentioned:** how many IESs are mentioned in the individual article.
- **IES: polling**: The IES is polling meaning that the students are asked questions as a whole and answered are received in a variety of possible ways
    - **IES: polling/ Peer-Instruction-** the polling is done through appropriate peer instruction: individual thinking-individual voting- paired discussion-paired voting
    - **IES: Polling/ Non-peer instruction**- the implementation of polling is done in any form that is not peer instruction.
- **IES: web program/ online work-** The IES has students using online programs or activities or the use of pre-designed programs in or outside of the classroom.
    - **IES: Online work- type**- online activities such as homework, tutorials, and quizzes that are completed online.
    - **IES: web program**- pre-designed programs utilized by students.
- **IES: Full Class Discussion/ Activities**- any discussion or activity that utilizes the full class
    - **IES: Full Class Discussion-** discussion using the full class
    - **IES: Full Class Activities:** activities using the full class
- **IES: In-class Group work**-any work done in the class room in group supervised by a faculty member
    - **IES: In-class Group work/ problem based learning**- in class work utilizing problem solving as the main part of the activity
    - **IES: In-class Group work/ assignments-** all in class group work that is assigned to group that is not problem based- including readings, videos, discussions, quizzes, lecture tutorials, think-pair-share and others.

- **IES: In-class Group work- POGIL**- the use of the traditional POGIL style and referring to it as POGIL.
- **IES: Out of Class Group Work**- Any group work done outside of the class room not monitored by a faculty member.
    - **IES: Out of Class Group Work- projects-** long term projects that student's work on in groups outside of the classroom.
    - **IES: Out of Class Group Work- exams and homework's**- all take home exams or homework's done in groups
    - **IES: Out of Class Group Work peer led activities-** out of class group work supervised or led by a TA or a previous student.
- **IES: Individual**- interactive engagement strategies used individually.
- **IES: Field**- any thing done in a field setting.
- **IES: Lab**- anything done in lab settings.

Appendix C: Interview Protocol for Think-Aloud Interviews

Part 1: Welcome & Getting Started

Hello, are you [name of scheduled participant]? I am [investigator's name]. Thank you for volunteering to participate in this research. Before we get started, I'll ask you to complete two forms (i.e. *consent form*, and *participant intake form*).

> Here are the forms. They are a *consent form* and a *participant intake form*. This is the *consent form*. Signing it indicates that you voluntarily participate in this research, acknowledge that there is little to no risk to you in participating, and that you agree to the data collection procedures outlined in the form. Please take a moment to read the consent form and ask any questions that you might have about it before signing. [Give participant time to read, ask questions, and sign the consent form.] This is the *participant intake form*. It asks for background information of each participant that will help us to interpret the data that is collected. As you fill it out, please let me know if anything is unclear or if you have questions about it. [Give participant time to complete the form.]

Part 2: Introduction to Session

As you already know, this study is aimed at (i) documenting the public's ideas about geologic sediments and strata and (ii) developing and refining instructional worksheets that can be used to help students learn about sedimentology and stratigraphy. During this interview session, I will provide you with one or more worksheets to read, work through, and comment on.

I would like you to read each question in the worksheets out loud. After you read the question out loud, I would like you to paraphrase the question or restate the question in your own words. This will help me to see whether the question is being interpreted in the way that we would like it to be interpreted. After you paraphrase or restate the question, then I would like you to answer the question as well as you can given what you might already know about the topics. After talking out your answer, please write down your answer in the space below the question.

While you are responding to each question, I will be taking notes on your input.

If you have questions about the answers to the survey questions, then I can answer them for you ***after*** the interview. The reasons for this are (i) to maintain consistency in how everyone is interviewed and (ii) so that I don't bias any of your own answers.

Before we begin, do you have any questions?

Part 3: Worksheet script (use for each worksheet)

Step 1
Let's begin with Question 1. Please read the question out loud. [Allow interviewee time to read the question.]
Now, please paraphrase or restate the question using your own words. [Allow interviewee time to restate question.]

Step 2
If the interviewee paraphrases the question in a way that indicates the question was interpreted as intended, then go to Step 3.

If the interviewee paraphrases the question in a way that suggests the question was NOT interpreted as intended, then do the following:
(i) Ask the question: Could you explain what it is about the question that leads you to think …?
(ii) Explain to the interviewee what the question meant and then ask the following question?

(iii) Ask the question: If you were to edit the question, what would you do to make it clearer?

Step 3
Now that I know the question is being interpreted in the manner intended, please answer the question out loud and then write down your answer in the space provided. [Allow time.]

Step 4
If the answer is clear and no follow-up questions are needed, then go on to the next question. If you are on the last survey question, then go on to Part 4 of the interview script:
If the answer is either unclear or needs elaboration, then do the following:
(i) Ask clarifying questions such as:
(a) I'm not sure what you mean by …. Could you please explain or elaborate on what you mean?
(b) In your sketch, what is this? Could you label it for me? Can you explain what you're thinking is here?

Part 4: Debriefing and Payment

Okay, that concludes our interview session. At this time, do you have any questions that you'd like to ask me about the interview session or the study? [Discuss participant's questions.]

At any time, you are welcome to contact the researchers of this study at [write down contact information for them] to inquire about the progress of this study and about any presentations or publications that come out of this study.

Thank you again for your participation in this study. To wrap things up, here is the agreed monetary compensation of $15.00 for your participation in this study.

Thank you for your time and thoughtful participation.

Appendix D: Interview protocol for Focus Group interviews

Part 1: Welcome & Getting Started

Hello, are you [names of scheduled participants]? I am [investigator's name]. Thank you for volunteering to participate in this research. Before we get started, I'll ask you to complete two forms (i.e. *consent form*, and *participant intake form*).

> Here are the forms. They are a *consent form* and a *participant intake form*. This is the *consent form*. Signing it indicates that you voluntarily participate in this research, acknowledge that there is little to no risk to you in participating, and that you agree to the data collection procedures outlined in the form. Please take a moment to read the consent form and ask any questions that you might have about it before signing. [Give participant time to read, ask questions, and sign the consent form.] This is the *participant intake form*. It asks for background information of each participant that will help us to interpret the data that is collected. As you fill it out, please let me know if anything is unclear or if you have questions about it. [Give participant time to complete the form.]

Part 2: Introduction to Session

As you already know, this study is aimed at (i) documenting the public's ideas about geologic sediments and strata and (ii) developing and refining instructional worksheets that can be used to help students learn about sedimentology and stratigraphy. During this group interview session, I will provide you all with some combination of (i) completing a questionnaire, (ii) reading an article, and (iii) working on and discussing a worksheet related to learning about geologic sediments and strata.

I would like you all to participate as if you were part of a class where you are learning about geologic sediments and strata together.

Before we begin, do you have any questions?

Part 3: Focus Group Scripts

Type 1

Before we begin, I would like you all to answer the questions to this pre/post questionnaire. Your responses will help us understand what you already know about geologic sediments and strata prior to any instruction that you receive during this focus group interview.

Once you've finished the questionnaire, please read this article.

After you read this article, please answer the questions to this pre/post questionnaire. Your responses will help us understand how useful the article is in communicating information about geologic sediments and strata.

Type 2

Before we begin, I would like you all to answer the questions to this pre/post questionnaire. Your responses will help us understand what you already know about geologic sediments and strata prior to any instruction that you receive during this focus group interview.

Once you've finished the questionnaire, please read this article.

After you read this article, please pair up and work together to discuss and complete this worksheet.

After they complete the worksheet, the investigator will lead a debriefing discussion about the worksheet.

Now that you've had a chance to read and learn more about geologic sediments and strata, please answer the questions to this pre/post questionnaire. Your responses will help us understand how useful the article is in communicating information about geologic sediments and strata.

Type 3

Before we begin, I would like you all to answer the questions to this pre/post questionnaire. Your responses will help us understand what you already know about geologic sediments and strata prior to any instruction that you receive during this focus group interview.

Once you've finished the questionnaire, please read this article.

After you read this article, please answer the questions to this pre/post questionnaire. Your responses will help us understand how useful the article is in communicating information about geologic sediments and strata.

After you complete the questionnaire (same as the pre/post questionnaire), please pair up and work together to discuss and complete this worksheet.

After they complete the worksheet, the investigator will lead a debriefing discussion about the worksheet.

Now that you've had a chance to read and learn more about geologic sediments and strata, please answer the questions to this pre/post questionnaire. Your responses will help us understand how useful the article is in communicating information about geologic sediments and strata.

Part 4: Debriefing and Payment

Okay, that concludes our interview session. At this time, do you have any questions that you'd like to ask me about the interview session or the study? [Discuss participant's questions.]

At any time, you are welcome to contact the researchers of this study at [write down contact information for them] to inquire about the progress of this study and about any presentations or publications that come out of this study.

Thank you again for your participation in this study. To wrap things up, here is the agreed monetary compensation of $15.00 for your participation in this study.

Thank you for your time and thoughtful participation.

Appendix E: Intake Form for Think-Aloud and Focus Group Interviews

Sedimentology and Stratigraphy Concepts
Intake Form

<u>Purpose & Instructions</u>: So that we may have some basic background information about the students who participate in our study, please answer the following questions before we begin the interview:

1. Please indicate the names of any geology courses that you have taken and when you took them. Include any geology courses that you are currently enrolled in.

Name of Geology Course	What grade in school (e.g. 8th grade) or year in college did you take the course (e.g. freshman)?

2. Currently, what year in college are you? Check one:
 □ Freshman □ Sophomore □ Junior □ Senior □ 5th year senior □ Other

3. What gender are you? Check one:
 □ Female □ Male □ Other: ________________

4. What race/ethnicity are you? Check one:

□ American Indian or Alaska Native: A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.

□ Asian: A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

□ Black or African American: A person having origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black or African American".

□ Native Hawaiian or Other Pacific Islander: A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

□ White: A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

□ Other: ________________

Appendix F: Think-Aloud Interview Consent form

Sedimentology and Stratigraphy Concepts: Student Input

Sedimentology and Stratigraphy Concepts
Individual Interview

UNL undergraduate students are invited to participate in a research project to reveal and characterize the public's understanding of geologic sediments and strata. The findings of this research will help inform science educators about the public's understanding of these geological concepts which, in turn, will assist them in formulating more effective educational and communication strategies around these concepts and related issues. This project is conducted under the direction of the Dr. Leilani Arthurs, Assistant Professor, 330 Bessey Hall, University of Nebraska-Lincoln, Lincoln, NE 68588 (402-472-6353).

The purpose of this project is two-fold: (i) document the public's ideas about geologic sediments and strata and (ii) develop and refine instructional worksheets that can be used to help students learn about sedimentology and stratigraphy. We would like to obtain your input and feedback on the worksheets being developed. Participation in this study is entirely your choice.

You may ask the researchers questions at any time by contacting us at bkreager2@huskers.unl.edu. If you have any questions regarding your rights as a research subject or wish to express any concerns, please contact Research Compliance Services at 402-472-6965 or irb@unl.edu.

You are being asked to participate in an individual think-aloud interview. The interview will take place at a mutually agreed upon time and place. During this interview, you will be asked for input and feedback on one or more worksheets. You will be asked to think-aloud while working through the questions. The information from this interview will be used strictly for scholarly purposes (e.g. to improve our understanding of what makes science presentations effective instructional tools and learning tools). The interviews will be audio recorded and used to fill in the interviewer's notes. After the interviewer's notes are complete, the audio recording will be deleted. We would also like to take a picture of you being interviewed by the interviewer; the photo might be used in scholarly presentations such as professional conferences.

Check one: ☐ I agree OR ☐ I do not agree to be audio recorded.

Check one: ☐ I agree OR ☐ I do not agree to be photographed.

Interviews will be conducted by Dr. Leilani Arthurs or Bailey Kreager. Participant identifiers (i.e. your name) are not essential for the study and will not appear in any of the scholarly presentations of this research but must be collected for financial and auditing purposes. The interview will take approximately 1 hour. You will be paid $15.00 for your participation, unless you have volunteered to do the interview without pay.

Participant Initials: ______ (this goes at the bottom of the page)

The potential risks of participating in this study are minimal. Your participation in this project is strictly voluntary.

It has no impact on your course grades or jobs, and you have the right to refuse to answer any question(s) for any reason as well as to withdraw at any time. Your individual privacy will be maintained in all published and written data resulting from this study. Talks, based on this study, will be given to various professional audiences. Audio recordings will be kept in a secure computer and deleted within one year after the start of this project (about July 2016). All handwritten notes will be kept in a locked filing cabinet. Data from these interviews will be kept indefinitely after project completion and the project investigators may share anonymous data with other researchers working on similar studies.

I have read this paper about the consent information for this study or it was read to me. I know the possible risks and benefits. I know that being in this study is voluntary. I choose to be in this study. I have received, on the date signed, a copy of this document containing three pages.

Name of Participant (printed): ___________________________________

Signature of Participant: _______________________________________ _ Date: _______________

□ Check here to indicate that you also initialed all previous pages of the consent form.

Appendix G: Focus Group Consent form

Sedimentology and Stratigraphy Concepts: Student Input

Sedimentology and Stratigraphy Concepts
Group Interview

UNL undergraduate students are invited to participate in a research project to reveal and characterize the public's understanding of geologic sediments and strata. The findings of this research will help inform science educators about the public's understanding of these geological concepts which, in turn, will assist them in formulating more effective educational and communication strategies around these concepts and related issues. This project is conducted under the direction of the Dr. Leilani Arthurs, Assistant Professor, 330 Bessey Hall, University of Nebraska-Lincoln, Lincoln, NE 68588 (402-472-6353).

The purpose of this project is two-fold: (i) document the public's ideas about geologic sediments and strata and (ii) develop and refine instructional worksheets that can be used to help students learn about sedimentology and stratigraphy. We would like to obtain your input and feedback on the worksheets being developed. Participation in this study is entirely your choice.

You may ask the researchers questions at any time by contacting us at bkreager2@huskers.unl.edu. If you have any questions regarding your rights as a research subject or wish to express any concerns, please contact Research Compliance Services at 402-472-6965 or irb@unl.edu.

You are being asked to participate in a group interview, also called a focus group. The interview will take place at a mutually agreed upon time and place. During this interview, you will be asked to complete some combination of the following: complete a pre-/post-instruction questionnaire, listen to a mini lecture about geologic sediments and strata, and provide feedback on a worksheet about sediments and strata. The information from this interview will be used strictly for scholarly purposes (e.g. to improve our understanding of what makes science presentations effective instructional tools and learning tools). Due to the nature of a focus group, researchers cannot guarantee complete confidentiality. The interviews will be audio recorded and used to fill in the interviewer's notes. After the interviewer's notes are complete, the audio recording will be deleted. If any member of the focus group does not consent to being audio recorded, then no audio recording will be made. We would also like to take a picture of you being interviewed by the interviewer; the photo might be used in scholarly presentations such as professional conferences.

Check one: □ I agree OR □ I do not agree to be audio recorded.

Check one: □ I agree OR □ I do not agree to be photographed.

Interviews will be conducted by Dr. Leilani Arthurs or Bailey Kreager. Participant identifiers (i.e. your name) are not essential for the study and will not appear in any of the scholarly presentations of this research but must be collected for financial and auditing purposes. The interview will take approximately 1 hour. You will be paid $15.00 for your participation, unless you have volunteered to do the interview without pay.

Participant Initials: ______ (this goes at the bottom of the page)

The potential risks of participating in this study are minimal. Your participation in this project is strictly voluntary.

It has no impact on your course grades or jobs, and you have the right to refuse to answer any question(s) for any reason as well as to withdraw at any time. Your individual privacy will be maintained in all published and written data resulting from this study. Talks, based on this study, will be given to various professional audiences. Audio recordings will be kept in a secure computer and deleted within one year after the start of this project (about July 2016). All handwritten notes will be kept in a locked filing cabinet. Data from these interviews will be kept indefinitely after project completion and the project investigators may share anonymous data with other researchers working on similar studies.

I have read this paper about the consent information for this study or it was read to me. I know the possible risks and benefits. I know that being in this study is voluntary. I choose to be in this study. I have received, on the date signed, a copy of this document containing three pages.

Name of Participant (printed): ___________________________________

Signature of Participant: _______________________________________ _ Date: _______________

□ Check here to indicate that you also initialed all previous pages of the consent form.

Appendix H: LT for faculty review/TAI

Deposition and Diagenisis

<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concepts of deposition and *diagenesis*. The questions are designed to give you the opportunity to *begin thinking* about these and related concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>: Diagenesis can be caused by compaction of overlying sediment.
Key misconceptions and/or learning difficulties:

- Students are not cognizant that sedimentation cannot take place in the absence of water
- Students think sedimentary rocks are deposited in in deep ocean basins, and represent the vast span of geologic time.
- Students tend to not understand that limestones/carbonates share the same sedimentary structures with sand and silt.

1) Figure A below represents an enlarged (zoomed in) side view of sand grains that were deposited as a layer and that are not compacted. The top of the figure represents the top of the sedimentary layer, and the bottom of the figure represents the bottom of the sedimentary layer. Each gray circle represents an individual sand grain and the white space in between the gray circles represent open spaces in between the sand grains.
Figure B represents the total original space taken by the sand grains shown in figure C. In Figure B, draw a sketch of what you think the layer in Figure A should look like after enough additional sediment has been evenly deposited on top of it in order to compact the layer. In your sketch, be sure to consider the size, shape, and position of the grains and the amount of space around each of the sand grains.

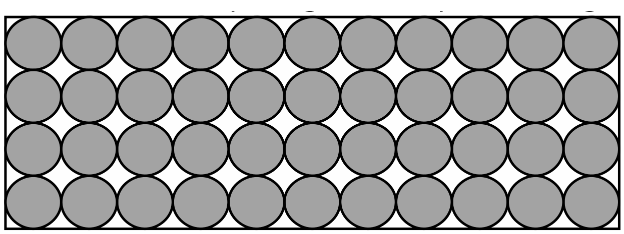


Figure A. Before sand grains in layer are compacted.

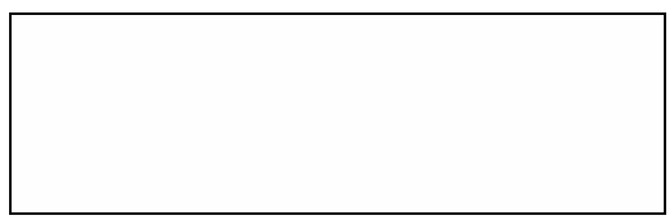


Figure B. After sand grains in layer are compacted.

1a) Compare Figures A and B: How does the amount of pore space change after compaction occurs?

Circle one: Increases Decreases Stays the same

1b) Refer to your sketch in Figure B and elaborate on your idea: (i) Are the sand grains still <u>loose</u> individual grains or are they now somehow <u>attached</u> to one another? (ii) Describe the reason(s) why you think the sand grains are loose/attached.

1c) Imagine that the white spaces in Figure A were filled with water before the sedimentary layer was compacted to form Figure B. (i) What do you think would happen to the water in between the sand grains in the sedimentary layer shown in Figure A as the layer is compacted? (ii) Describe the reason(s) why you think the sand grains are loose/attached.

1d) Imagine you collect a brick-sized amount of sediment from Figure A and from Figure B. (i) Would the density of the brick-sized amount from Figure A be greater/lesser/same as that from Figure B? (ii) Why?

2) Figure C shows a sedimentary layer of mud with a wedge of sandstone protruding into it on the left-hand side. The mud holds more water than the sand does. The top of the figure represents the top of the sedimentary layer, and the bottom of the figure represents the bottom of the sedimentary layer.

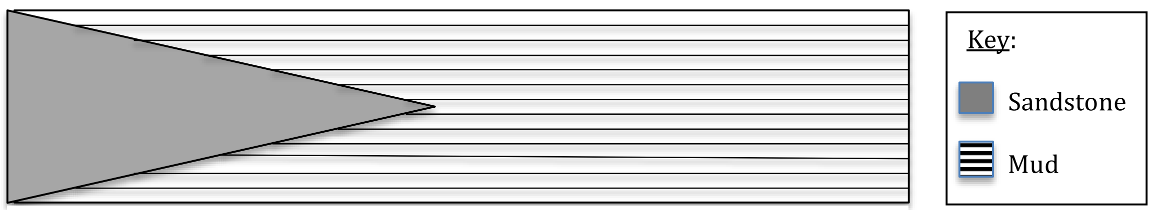


Figure C. Before layer is compacted.

2a) Imagine that enough additional sediment is deposited evenly over the top of the entire layer represented in Figure C to compact it.
(i) Will the sandstone and the mud be affected by the compaction in the same way? Circle one: YES/NO (ii) Describe the reason(s) why you selected Yes/No.

2b) Figure D represents the total original space taken by the sandstone protrusion and mud layer shown in figure C. Based off of your prediction in question 2ai, draw a sketch of what you think the sandstone protrusion and mud layer would look like after the compaction described in question 2a occurs.

Figure D. After layer is compacted.

3) Three students are discussing where sedimentary rocks can be deposited.

Student A: Sediment is only created in the deep oceans. The ocean's sediments are fine-grained and have a continuous record of deposition over time.

Student B: There is no input of sediment into the deep ocean so it can't create sediment. Sedimentary rocks are created in rivers and shallow waters. Quartz sand from the land is pushed or brought into the shallow waters being deposited and then turned into rock

Student C: No, almost all sedimentation happens in the desert where there is large build up of sand and sediment and no water to wash it away.

3a) (i) Which student(s) do you agree with the most? (ii) Why do you agree with the student(s) to the extent that you do?

3b) Drawing on your existing knowledge, where can sedimentary rocks be formed?

Sedimentary Facies

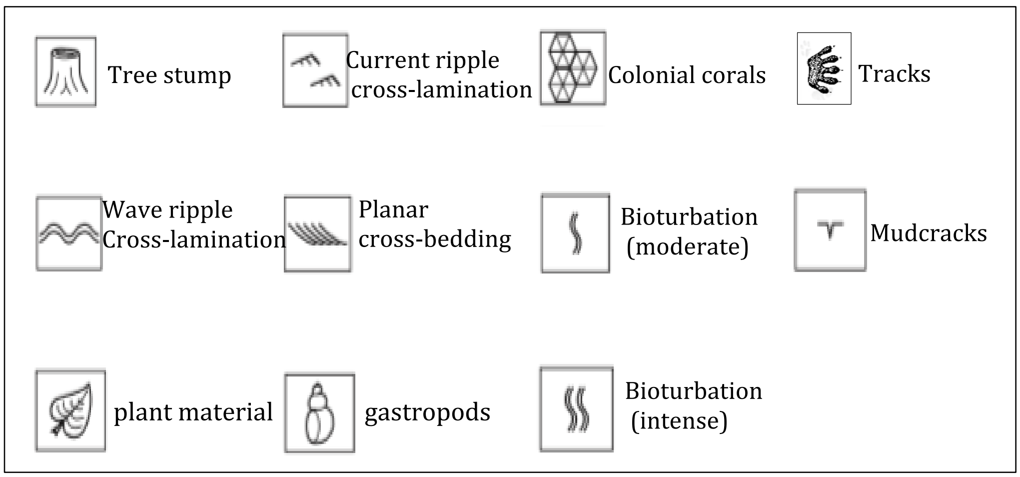
<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concept of *sedimentary facies* and related concepts. The questions are designed to give you the opportunity to *begin thinking* about these concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>: Sedimentary facies are layers of rock distinguished by features that separate it from layers above and below.

Key misconceptions and/or learning difficulties:

- If a rock is at the same elevation it must be the same age.
- Certain depositional sedimentary structures are thrown at students without an explanation of process, and bedforms that deposit them.

1) Below are different features that can define a facies. Group the different features in to three categories and explain why you chose those categories.



1a) Group 1 is based on

____

______________________________ and it contains the following features: ____________________

____

________.

1b) Group 2 is based on

____

______________________________ and it contains the following features: ____________________

____

________.

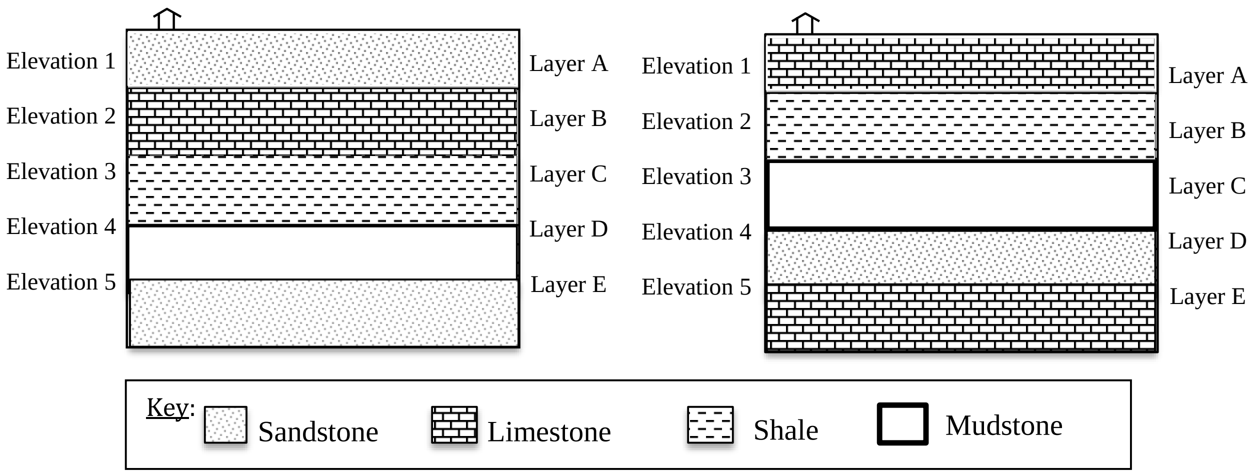
1c) Group 3 is based on

____

_________________________________ and it contains the following features:

____

2) Figures A and B below show rock layers in the subsurface. A small house indicates where the surface is. (i) For each figure, which layer is the oldest, and which layer is the youngest layer? (ii) Why?



3) Figure B represents the same sedimentary layers as Figure A but after a period of uplift. The number of each ELEVATION means that it is at the same elevation as another layer with the same ELEVATION number.

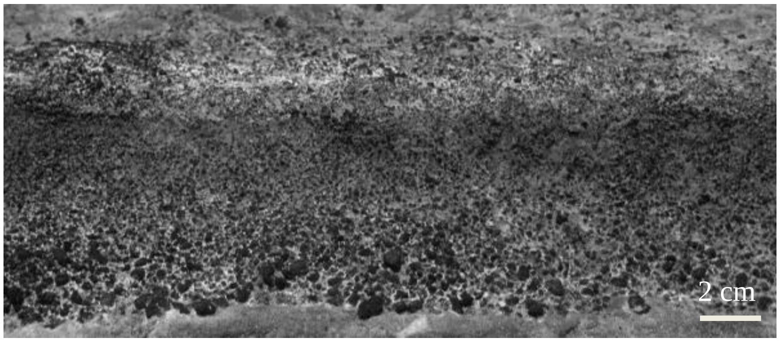
3a) In the table provided below, write the pairs of layers in Figure A and Figure B that correspond to or match one another.

Figure A Layers	Figure B layers

Table 1. Corresponding pairs of layers from Figure A and Figure B.

3b) How did you decide which layers in Figure A correspond to match which layers in Figure B?

4) Student A and Student B are examining the following figure.



From: http://legacy.belmont.sd62.bc.ca/teacher/geology12/photos/misc/sedimentary/

Student A: The larger sediment grains are at the bottom because they are heavier. The sediment was deposited as one layer. Over time the larger grains put pressure on the smaller ones eventually working their way to the bottom of the layer.

Student B: I think the larger sediment grains are at the bottom because they weigh more so they were deposited earlier then the smaller grains because the smaller grains would stay in the water or air that was moving it longer.

4a) Which student(s) do you agree with the most?
4b) Why do you agree with the student(s) to the extent that you do?

Sequence Stratigraphy

Purpose: This lecture tutorial provides you, the student, with an introduction to the concept of *sequence stratigraphy*. The questions are designed to give you the opportunity to *begin thinking* about this concept and related concepts in order to prepare you for deeper discussion about them with your instructor.

Introductory statement: Sequence stratigraphy is the study of sea level change and sedimentation.

Key misconceptions and/or learning difficulties:

- Transgressions, regressions, and sequence stratigraphy mentioned specifically as difficult concepts several times.

1) Three students are discussing what the shorelines on their local beach may look like in the future.

Student A: The shoreline will always look the same. As sea level rises more sand is deposited building up the beach so it just stays the same.

Student B: The shoreline will move farther out to sea. As more sand is deposited over time on the beach, the water will reach less and less inland leaving us with a larger beach.

Student C: Even if more sand is deposited as long as sea level is rising the beach will get smaller and the shoreline will move inland.

1a) Which student(s) do you agree with the most?

1b) Why do you agree with the student(s) to the extent that you do?

2) The overall change in sea level due to the addition or subtraction of water is called eustatic-sea level change. Changes in sea level many times are referred to as “relative sea level” change. This is because many things can happen under water that affect where sea level is relative to land.

2a) What are possible situations other than the addition or subtraction of water that could change sea level relative to land at the shoreline?

2b) Figure A and Figure B represent a change in environments from offshore on the right moving to land on the left. (i) In Figure A, draw two layers above the provided layer showing the location of similar sedimentary units as sea level rises and moves inland. (ii) Draw an arrow to show the direction they moved. (iii) Repeat the same two tasks in figure B for a scenario that involves the lowering of sea level.

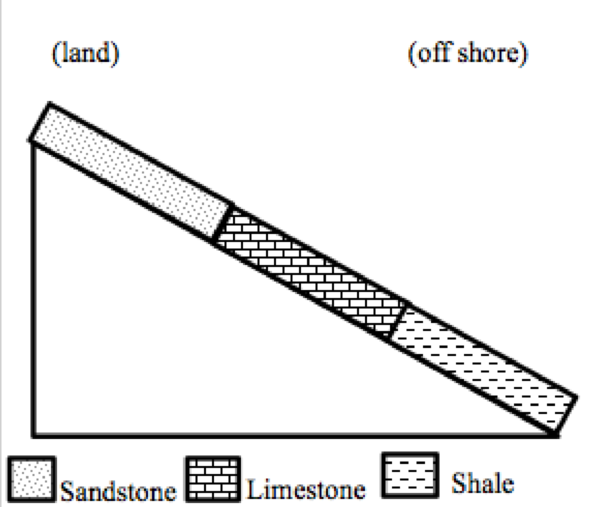


Figure A. Scenario where sea level rises.

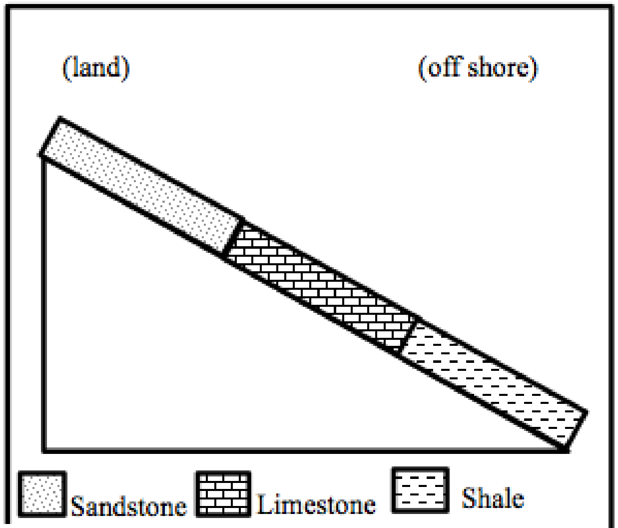


Figure B. Scenario where sea level lowers.

3) Figure C shows a side-view image of a beach from land to offshore. Below Figure C are several descriptions of changes over time to the conditions represented in Figure C.

3a) In the box corresponding to each description, draw a line to show where you think the *new sea level* that corresponds to the description should be relative to the sea level shown in Figure C and in the box.

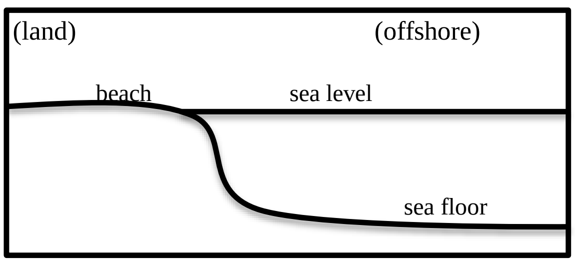
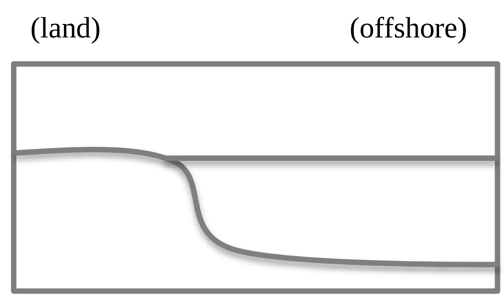


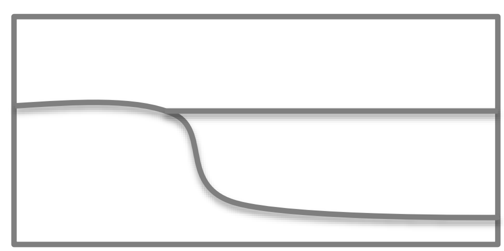
Figure C. Conditions at some starting point in time.

Description A: Draw a line to indicate where the new sea level is when the eustatic-sea levels have not changed, but tectonic forces have pushed up the land relative to Figure C.



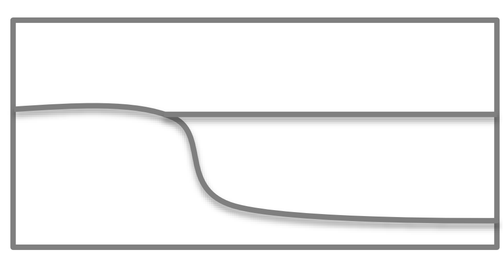
Box A.

Description B: Draw a line to indicate where the new sea level is when the eustatic-sea levels have not changed, but the land surface has lowered relative to Figure C.



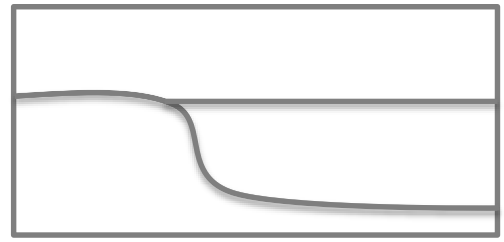
Box B.

Description C: Draw a line to indicate where the new sea level is when there has been a consistent cooling and ocean levels have been reduced as more water is turning to ice at the poles.



Box C.

Description D: Draw a line to indicate where the new sea level is when temperatures are warmer compared to conditions in Figure C, ice melts, and the meltwater flows into the oceans.



Box D.

Stratigraphic Units and Relationships

<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concept of a *stratigraphic unit* and related concepts. The questions are designed to give you the opportunity to *begin thinking* about these concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>: A stratigraphic unit is a distinct volume of rock defined by a major and unique characteristic.

Key misconceptions and/or learning difficulties:

- Gaps in the sedimentary record may be erosional or simply lack of deposition.
- What is missing time
- Have difficulty dealing with what it means if there is a period of non-deposition or erosion- and absence in the rock record.
- Distinction between rock and time

1) Figure A show a gap in time captured in the rock record.
1a) On Figure A draw a line to show where you think the gap in time is.

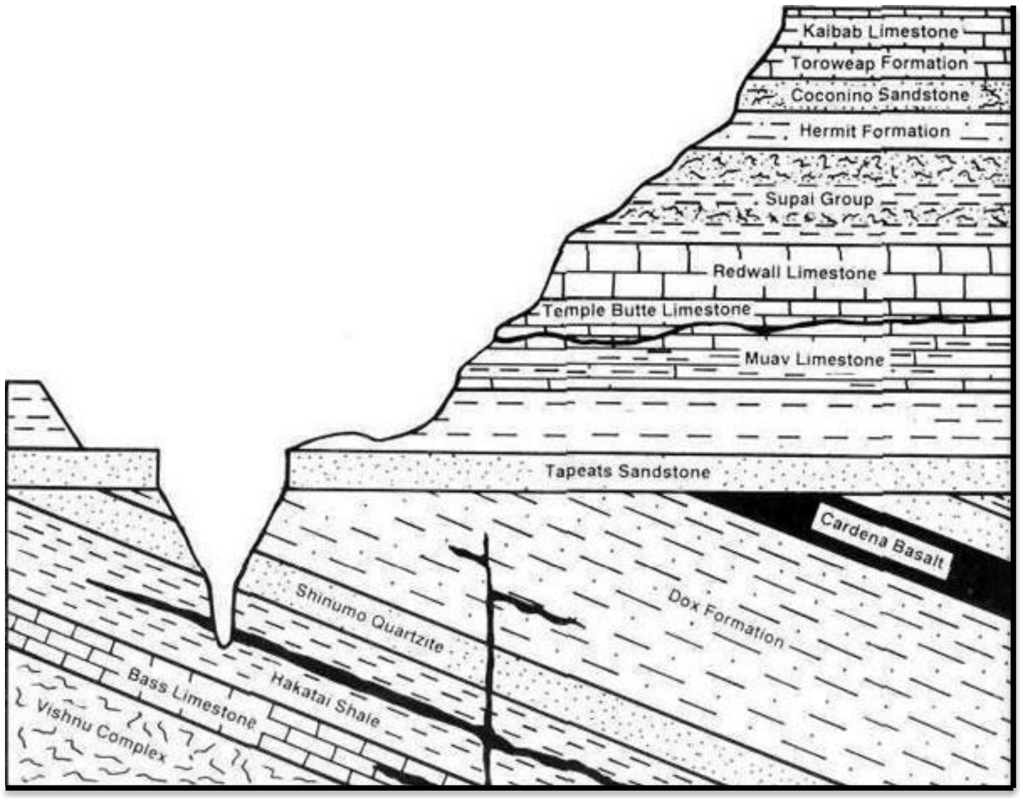
Figure A. From: @Geotripper images

1b) In the space provided to the right of Figure A, (i) describe the reason(s) for why you think the gap in time is where you the drew the line and (ii) provide an explanation for what could have caused the gap in time.

2) Three students are discussing why gaps in time, called *unconformities*, occur in the rock record.

Student A: Unconformities are caused because no sediment was deposited in a certain location at a certain time in the geologic past.
Student B: Unconformities occur because the land was too dry in the geologic past for sediment to become rock not because there was no sediment.
Student C: Unconformities are caused because the rocks were exposed and eroded away in the geologic past faster than the sediment was deposited.
2a) Which student(s) do you agree with the most?
2b) Why do you agree with the student(s) to the extent that you do?

3) A side view, called a geologic *cross section*, of the Grand Canyon is provided below. Analyze the geologic history of the Grand Canyon using the following instructions.



From: http://www.ricksci.com/ear/earp_geo_time_ican.htm

3a) Along the right-side border and the bottom border, number the rock layers (1, 2, 3, etc.) in order from oldest to youngest. Start with "1" for the oldest layer.

3b) Identify the location of any unconformities that you see by circling them.

3c) For each circled unconformity, assign a letter A, B, C, etc.

3d) For each unconformity that you identify with a letter, describe the history that preceded the unconformities formation. In other words, what happened geologically before and up to the formation of the unconformity.

Appendix I: Feedback form for Faculty feedback

1) Which Lecture Tutorial are you reviewing? Circle the one that applies.

    Stratigraphic Units and Relationships   Sequence Stratigraphy

    Deposition and Diagenesis   Sedimentary Facies

2) Do you teach your students about the concept(s) that you checked above in Q1?

3) If you teach about this concept, what is the title of your course and what level is it (intro, upper undergrad).

4) If you teach your students about this concept, what specifically do you want your students to know or be able to do with knowledge of the concept(s)? In other words, what learning goals do you have for students that relate to the concept(s)?

5) Does the Lecture Tutorial address aspects of the concept(s) that you want your students to know or be bale to do with knowledge of the concept(s)?

    Yes

    No

    Comment:

6) How likely is it that you would use all or part of this Lecture Tutorial to teach students in your class?

    I could see using all of it.

    I could see using parts of it.

        Comment: Which part(s)

    I can't see using any of it.

        Comment: Why not?

7) What do you think might be the MOST helpful/useful thing about this Lecture Tutorial to your students? Please explain why.

8) What do you think might be the LEAST helpful/useful thing about this Lecture Tutorial to your students? Please explain why.

9) Please include and additional comments or feedback you might have.

Appendix J: Lecture Tutorials for Focus Groups

Deposition

<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concept of *deposition* and related concepts. The questions are designed to give you the opportunity to *begin thinking* about these concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>:

1) Three students are discussing where the sediments that form sedimentary rocks were originally deposited.

Student A: Sediment is only created in the deep oceans. The ocean's sediments are fine-grained and have a continuous record of deposition over time.

Student B: There is no input of sediment into the deep ocean so it can't create sediment. Sedimentary rocks are created in rivers and shallow waters. Quartz sand from the land is pushed or brought into the shallow waters being deposited and then turned into rock

Student C: No, almost all sedimentation happens in the desert where there is large build up of sand and sediment and no water to wash it away.

1a) (i) Which student(s) do you agree with the most? (ii) Why do you agree with the student(s) to the extent that you do?

1b) Drawing on your existing knowledge, where can sedimentary rocks be formed?

2) Figures A and B below show rock layers in the subsurface. A small house indicates where the surface is. (i) For each figure, which layer is the oldest, and which layer is the youngest layer? (ii) Why?

Figure A.

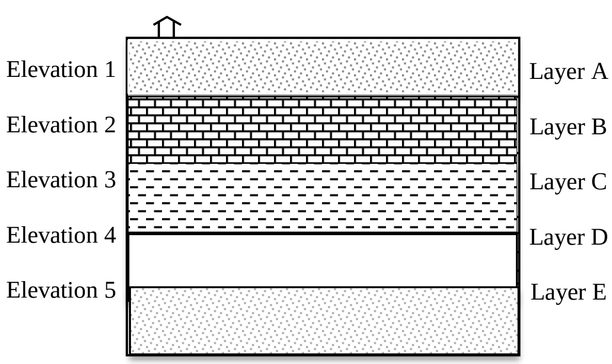
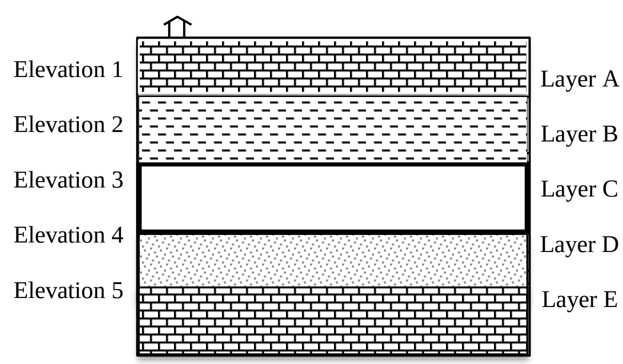


Figure B.



3) Figure B represents the same sedimentary layers as Figure A but after a period of uplift. The number of each ELEVATION means that it is at the same elevation as another layer with the same ELEVATION number.

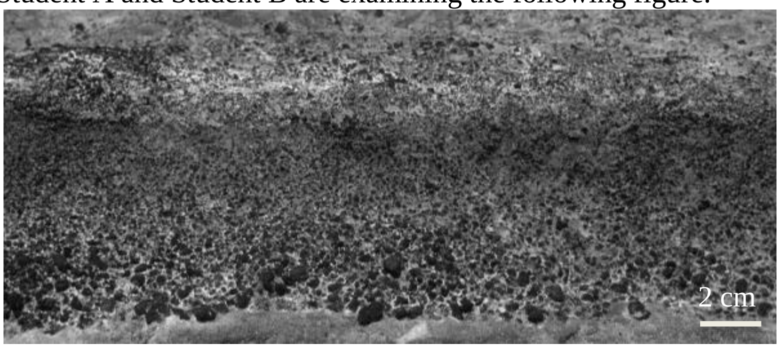
3a) In Table 1. Identify the layers from Figure A and Figure B that represent the same aged rocks.

Figure A Layers	Figure B layers

Table 1. Corresponding pairs of layers from Figure A and Figure B.

3b) How did you decide which layers in Figure A correspond to match which layers in Figure B?

4) Student A and Student B are examining the following figure.



From: http://legacy.belmont.sd62.bc.ca/teacher/geology12/photos/misc/sedimentary/

Student A: The larger sediment grains are at the bottom because they are heavier. The sediment was deposited as one evenly mixed layer. Over time the larger grains put pressure on the smaller ones eventually working their way to the bottom of the layer.

Student B: I think the larger sediment grains are at the bottom because they weigh more so they were deposited earlier then the smaller grains because the smaller grains would stay in the water or air that was moving it longer.

4a) Which student(s) do you agree with the most?

4b) Why do you agree with the student(s) to the extent that you do?

Diagenisis

<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concepts of *diagenesis*. The questions are designed to give you the opportunity to *begin thinking* about these and related concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>: Diagenesis is a low pressure changes within sedimentary rocks and can be caused by compaction of overlying sediment.

1) Figure A below represents an enlarged (zoomed in) side view of sand grains that were deposited as an uncompacted layer. The top of the figure represents the top of the sedimentary layer, and the bottom of the figure represents the bottom of the sedimentary layer. Each gray circle represents an individual sand grain and the white space in between the gray circles represent open spaces in between the sand grains.
Figure B represents the total original space taken by the sand grains shown in Figure A. In Figure B, draw a sketch of what you think the layer in Figure A should look like after enough additional sediment has been evenly deposited on top of it in order to compact the layer. In your sketch, be sure to consider the size, shape, and position of the grains and the amount of space around each of the sand grains.

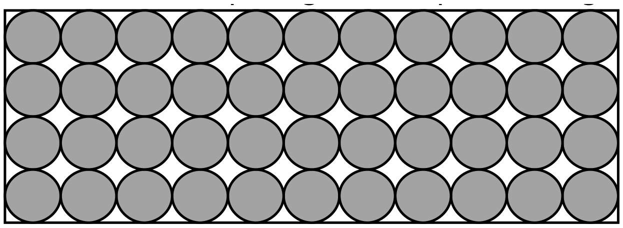


Figure A. Before sand grains in layer are compacted.

Figure B. After sand grains in layer are compacted.

1a) Compare Figures A and B: How does the amount of pore space change after compaction occurs?

Circle one: Increases Decreases Stays the same

1b) Refer to your sketch in Figure B and elaborate on your idea: (i) Are the sand grains still <u>loose</u> individual grains or are they now somehow <u>attached</u> to one another? (ii) Describe the reason(s) why you think the sand grains are loose/attached.

1c) Imagine that the white spaces in Figure A were filled with water before the sedimentary layer was compacted to form Figure B. (i) What do you think would happen to the water in between the sand grains in the sedimentary layer shown in Figure A as the layer is compacted? (ii) Describe the reason(s) why you think the sand grains are loose/attached.

1d) Imagine you collect a brick-sized amount of sediment from Figure A and from Figure B. (i) Would the density of the brick-sized amount from Figure A be greater/lesser/same as that from Figure B? (ii) Why?

2) Figure C shows a sedimentary layer of mud with a wedge of sandstone protruding into it on the left-hand side. The mud holds more water than the sand does. The top of the figure represents the top of the sedimentary layer, and the bottom of the figure represents the bottom of the sedimentary layer.

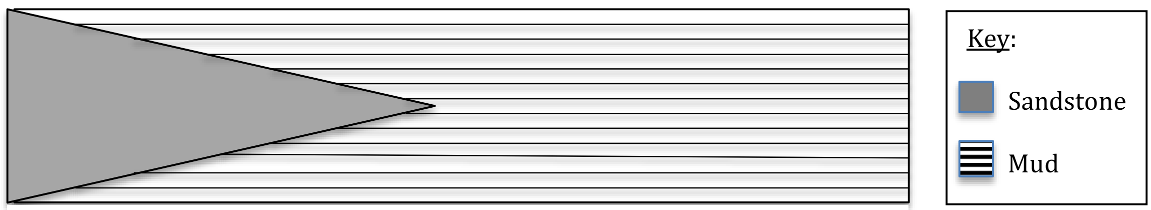


Figure C. Before layer is compacted.

2a) Imagine that enough additional sediment is deposited evenly over the top of the entire layer represented in Figure C to compact it.

(i) Will the sandstone and the mud be affected by the compaction in the same way? Circle one YES/NO

(ii) Describe the reason(s) why you selected Yes/No.

2b) Figure D represents the total original space taken by the sandstone protrusion and mud layer shown in figure C. Based off of your prediction in question 2a(i), draw a sketch of what you think the sandstone protrusion and mud layer would look like after the compaction described in question 2a occurs.

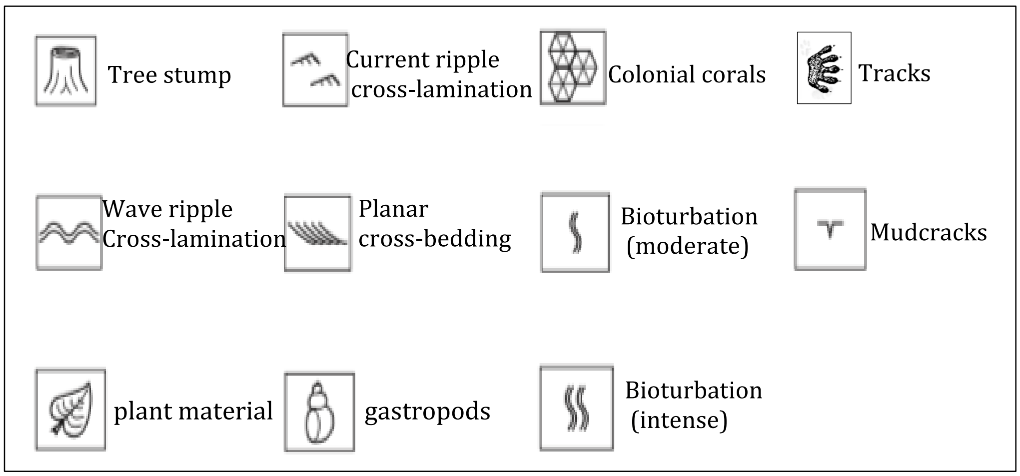
Figure D. After layer is compacted.

Sedimentary Facies

<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concept of *sedimentary facies* and related concepts. The questions are designed to give you the opportunity to *begin thinking* about these concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>: Sedimentary facies are layers or groups of layers of rock distinguished by features that separate it from layers above and below.

1) Below are different features that can define a facies. Group the different features in to three categories and explain why you chose those categories.



1a) Group 1 is based on

____

____________________________ and it contains the following features:

____

1b) Group 2 is based on

____

____________________________ and it contains the following features:

____

1c) Group 3 is based on

____

____________________________ and it contains the following features:

____

Sequence Stratigraphy

Purpose: This lecture tutorial provides you, the student, with an introduction to the concept of *sequence stratigraphy*. The questions are designed to give you the opportunity to *begin thinking* about this concept and related concepts in order to prepare you for deeper discussion about them with your instructor.

Introductory statement: Sequence stratigraphy is the study of sea level change and sedimentation.

1) Three students are discussing what the shorelines on their local beach may look like in the future.

Student A: The shoreline will always be in the same spot. As sea level rises more sand is deposited building up the beach so the shoreline just gets higher but stays in the same place.

Student B: The shoreline will move farther out to sea. As more sand is deposited over time on the beach, the water will reach less and less inland.

Student C: Even if more sand is deposited as long as sea level is rising the shoreline will move father in land

1a) Which student(s) do you agree with the most?
1b) Why do you agree with the student(s) to the extent that you do?

2) The overall change in sea level due to the addition or subtraction of water is called eustatic-sea level change. Changes in sea level many times are referred to as "relative sea level" change. This is because many things can happen under water that affect where sea level is relative to land.
2a) What are possible situations other than the addition or subtraction of water that could change sea level relative to land at the shoreline?

2b) Figure A and Figure B represent a change in environments from offshore on the right moving to land on the left. (i) In Figure A, draw two layers above the provided layer showing the location of similar sedimentary units as sea level rises and moves inland. (ii) Draw an arrow to show the direction they moved. (iii) Repeat the same two tasks in figure B for a scenario that involves the lowering of sea level.

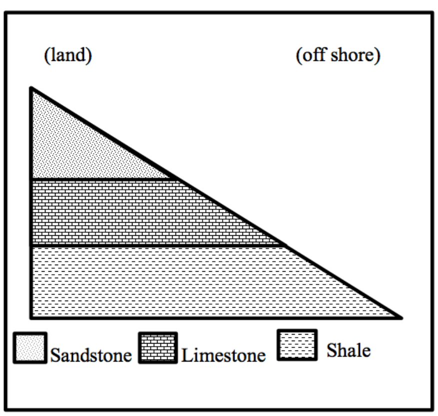


Figure A. Scenario where sea level rises

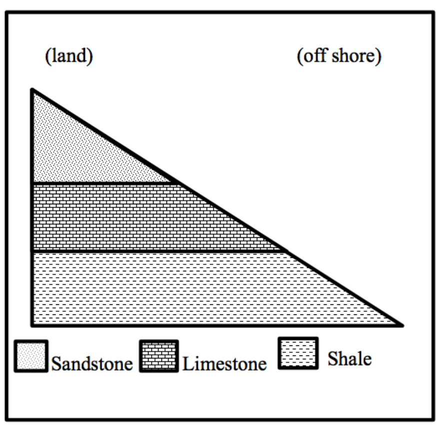


Figure B. Scenario where sea level lowers.

3) Figure C shows a side-view image of a beach from land to offshore. Below Figure C are several descriptions of changes over time to the conditions represented in Figure C.

3a) In the box corresponding to each description, draw a line to show where you think the *new sea level* that corresponds to the description should be relative to the sea level shown in Figure C and in the box.

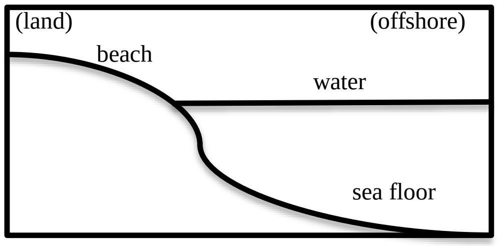
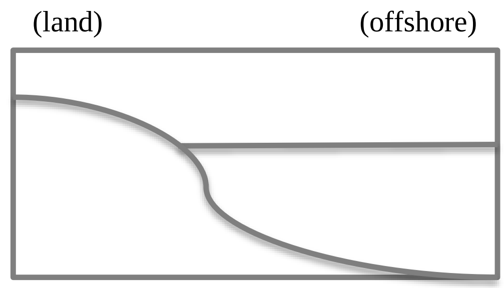


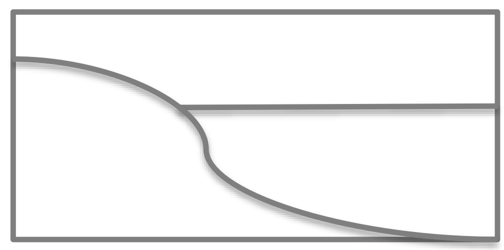
Figure C. Conditions at some starting

Description A: Draw a line to indicate where the new sea level is when the eustatic-sea levels have not changed, but tectonic forces have pushed up the land relative to Figure C.



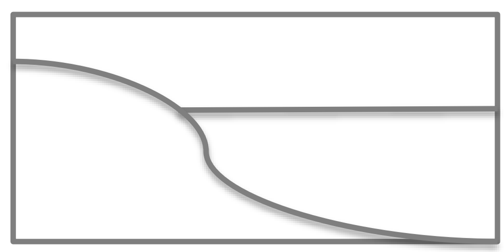
Box A

Description B: Draw a line to indicate where the new sea level is when the eustatic-sea levels have not changed, but the land surface has lowered relative to Figure C.



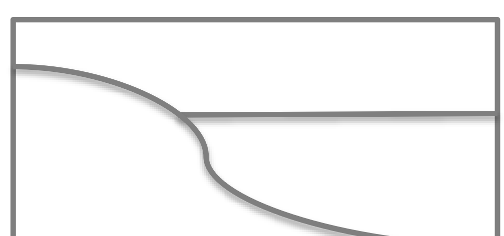
Box B

Description C: Draw a line to indicate where the new sea level is when there has been a consistent cooling and ocean levels have been reduced as more water is turning to ice at the poles.



Box C

Description D: Draw a line to indicate where the new sea level is when temperatures are warmer compared to conditions in Figure C, ice melts, and the meltwater flows into the oceans.



Box D

Unconformities

<u>Purpose</u>: This lecture tutorial provides you, the student, with an introduction to the concept of a *unconformities* and related concepts. The questions are designed to give you the opportunity to *begin thinking* about these concepts in order to prepare you for deeper discussion about them with your instructor.

<u>Introductory statement</u>: Unconformities are gaps in time seen in the rock record.

1) Figure A-D show unconformities captured in the rock record. Figure B is a geologic section of Figure A and Figure D is a geologic section of Figure C
1a) On Figure A and Figure C draw a squiggly to show where you think the gap in time is.

Figure A

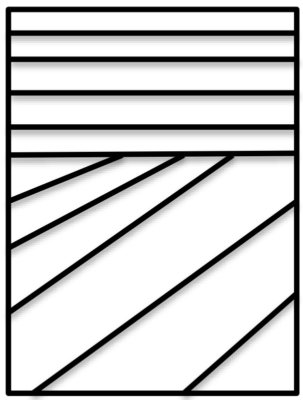


Figure B

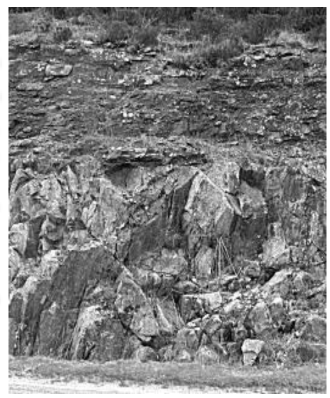


Figure C

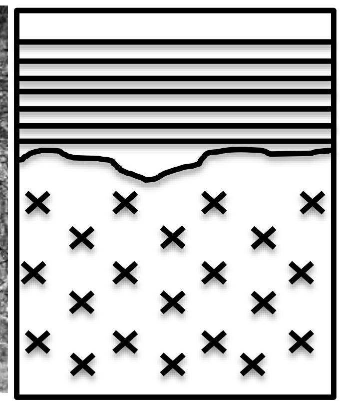


Figure D

From: Geotripper

From: http://www.geograph.org.uk/photo/823453

1b) Figure A, (i) describe the reason(s) for why you think the gap in time is where you drew the line and (ii) provide an explanation for what could have caused the gap in time.

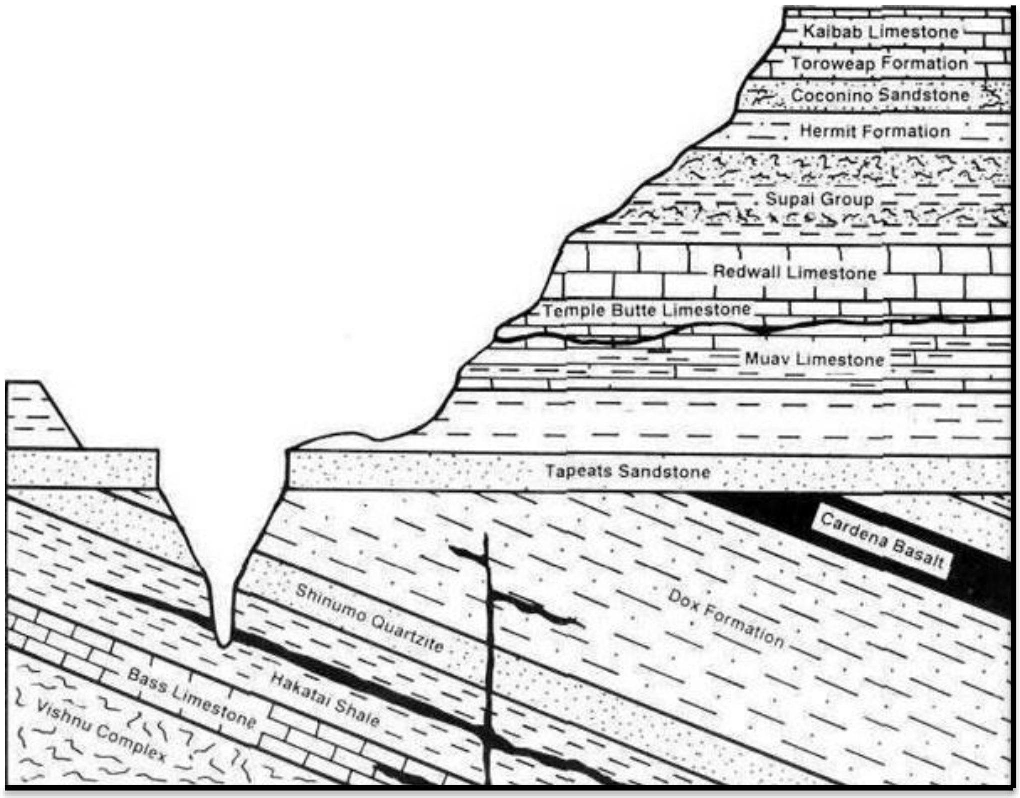
1c) How are the two *unconformities* different from each other?

2) Three students are discussing why *unconformities* occur in the rock record.

Student A: Unconformities are caused because no sediment was deposited in a certain location at a certain time in the geologic past.
Student B: Unconformities occur because the land was too dry in the geologic past for sediment to become rock not because there was no sediment.
Student C: Unconformities are caused because the rocks were exposed and eroded away in the geologic past faster than the sediment was deposited.

2a) Which student(s) do you agree with the most?
2b) Why do you agree with the student(s) to the extent that you do?
3) A side view, called a geologic *cross section*, of the Grand Canyon is provided below. Analyze the geologic history of the Grand Canyon using the following instructions.

From: http://www.ricksci.com/ear/earp_geo_time_ican.htm



3a) Along the right-side border and the bottom border, number the rock layers (1, 2, 3, etc.) in order from oldest to youngest. Start with "1" for the oldest layer.

3b) Identify the location of any unconformities that you see by circling them.

3c) For each circled unconformity, assign a letter A, B, C, etc.

3d) For each unconformity that you identify with a letter, describe the history that preceded the unconformities formation. In other words, what happened geologically before and up to the formation of the unconformity.

3e)What happened during the formation of the unconformities

Appendix K: Scoring Rubric for Focus Group Responses

Diagenisis Q. 1

- 0= NO
- 1= Yes and answer contains incorrect reasoning. (i.e wind, erosion, hit by others).
- 2= Yes and answer contains with partially correct r or mostly incomplete reasoning. They mention a correct diagentic process as well as an incorrect reason similar to those scored as 1.
- 3= Yes and answer with a fully correct answer. Appropriate diagenetic processes mentioned with no additional incorrect reasoning. (i.e compaction, dissolution, water changing them)

Diagenisis Q. 2

- 0= True
- 1= False and contains incorrect reasoning or very general answer showing mostly incomplete conceptual understanding (i.e. cold environments, not just temp/pressure).
- 2= False and answer contains at least one diagenetic processes that can occur.
- 3= False and answer with multiple diagenetic processes.

Diagenisis Q. 3

- 0= Completely incorrect answer- No diagenetic process mentioned or general answer (they changed shape, size and position).
- 1= Diagenetic process mixed with incorrect notion or mostly incomplete reasoning.
- 2= Mention of one possible diagenetic process that could happen.
- 3= Answer showing a fuller understanding of how different diagenetic processes interact in a layer, mentioning at least two possible things that could happen to the layer.

Facies Q.

- 0= No, completely incorrect answer.
- 1= List a factor or feature that can be found in a facies is mostly incomplete and may include ideas that are incorrect.
- 2= Mentions only one of the following: distinctive characteristic, repetitive layer, or exists as more than one layer but only one of the above.
- 3= Mentions at least 2 of the three: characteristic, repetitive layer or exists as more than one layer.

Sequence Stratigraphy Q. 1

- 0=True.
- 1= False and answer contains tottaly incorrect reasoning.
- 2= False and answer mentions facies, is partially correct but incomplete, and may include incorrect reasoning.
- 3= Changes in deposition, shifting of rock formation/facies/depositional environments mentioned with no incorrect reasoning.

Sequence Stratigraphy Q2.

- 0=Totally incorrect.
- 1= Mentions 1 or more of below correct answers, mostly incomplete and may include incorrect reasoning.
- 2= Mentions at least 1 of the below with no additional incorrect reasoning.
- 3= Mentions 2 or more of the following: glaciers (melting/freezing) or climate change, tectonic events (uplift, subsidence) and sedimentation.

Sequence Stratigraphy Q3.

- 0= Chose option A, B or D
- 3= Chose option C.

Sequence Stratigraphy Q4

- 0=Chose option B, C, or D.
- 3=Chose option A.

Unconformities Q1

- 0= True.
- 1= False and answer contains a tottaly incorrect or completely vague answer (i.e. there are gaps)
- 2= False as answer mentions unconformities or “gaps in time”, or erosion/no deposition, partially correct and may include incorrect reasoning.
- 3= False and answer includes both erosion and no deposition.

Unconformities Q2

- 0= Anything but unconformities, nonconformities, disconformities, and angular unconformities.
- 1= Mention of nonconformities, disconformities, angular unconformities, “gaps in time”.
- 3= unconformities

Unconformities Q3

- 0= True.
- 1= False and answer totally incorrect reasoning.
- 2= False and answer mentions igneous and metamorphic rocks go through similar processes
- 3= False and answer includes nonconformities, or that these rocks go through erosion.

Unconformities Q4.

- 0= Totally incorrect answer.
- 1= Answer includes erosion and/or deposition <u>and</u> also incorrect ideas.
- 2=Answer includes either erosion <u>or</u> no deposition (and no incorrect ideas).
- 3= Answer includes both erosion <u>and</u> no deposition (and no incorrect ideas).

Unconformities Q5

- 0=No.
- 1=Yes and answer contains totally incorrect reasoning or is over simplified (e.g. "scientist must have").
- 2=Yes and answer mentions about layering and may include incorrect answer.
- 3=Yes and answer mentions rocks formed after and they show the history.

Deposition Q1.

- 0= No answer
- 1= General answer such as all environments or mention of a specific environment (mountains).
- 2= Mentions any type of environment <u>and</u> mentions driving force (wind/water) <u>or</u> continuous deposition.
- 3= Mentions any type of environment and both driving force (wind/water) <u>and</u> continuous deposition.

Deposition Q2.

- 0= Chose A, B, C.
- 3= Chose D.

Deposition Q3.

- 0=True.
- 1=False and partially incorrect answer (e.g. deposition on side of hill and middle part of hill eroded).
- 2= False and answer mentions tectonic events and incorrect ideas.
- 3=Answer mentions tectonic events and no incorrect ideas.

Deposition Q4.

- 0= 1 answer
- 1= 2 answers
- 2= 3 answers
- 3= 4 answers

Deposition Q5.

- 0=Totally incorrect answer
- 1= partially incorrect answer (e.g. deposition on side of hill and middle part of hill eroded).
- 2= Answer mentions tectonic events and incorrect ideas.
- 3= Answer mentions tectonic events and no incorrect ideas.

Appendix L: Pre- and Post-Instruction Questionnaires for Focus Groups

Sequence Stratigraphy Questions

1. Changes in sea level are virtually impossible to see in the rock record.

True or False

1a. Explain why you picked True or False.

2. What can change sea level?

4.City planners in Florida are discussing future development in the area and want to factor into their plans rising sea level. Which one of the following can they expect as sea level rises.

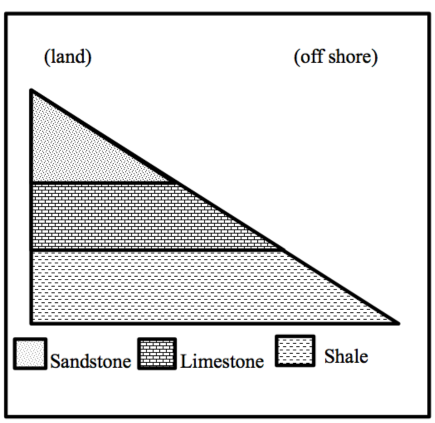
a. The shoreline remains where it is.

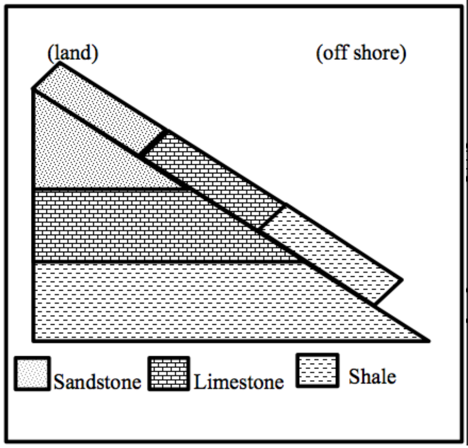
b. The shoreline moves further out to sea.

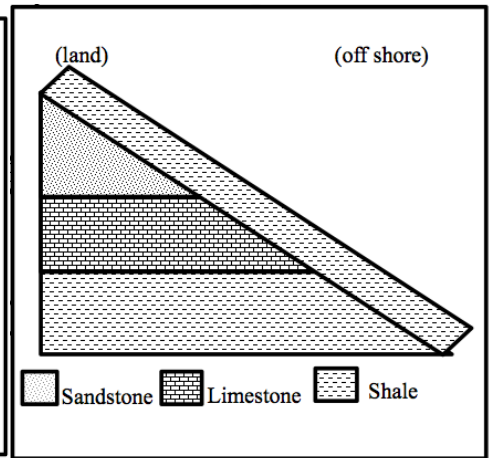
c. The shoreline moves further inland.

d. Position of the shoreline is not based on changes in sea level.

5. Using the diagram below. If sea level were to rise, where would similar sedimentary units be located?

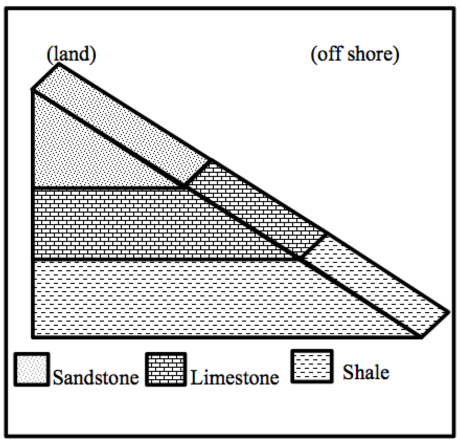


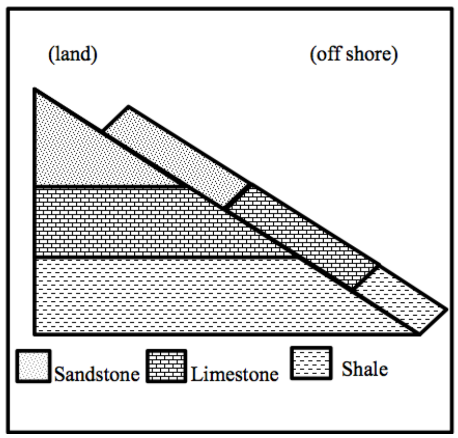




Option A

Option B





Option C

Option D

Diagenisis Questions.

1. Do the grain size, shape or position of the sediments that make up a sedimentary rock change over time? Indicate your answer by filling out the table below.

	Yes, can change	No, can't change	Why?
Grain size			
Grain shape			
Grain position			

2. Diagensis only occurs when there are high temperatures or high pressures.

True or False

2a. Explain why you chose True/False

3. Imagine a layer of sedimentary rock with small sediment particles and lots of space between them. What would happen to the sedimentary particles in that layer of rock if it were compacted?

Unconformities

1. The rock record shows a continuous history of time?

True or False

Explain why you chose true/false

2. Gaps in time in the rock record are called ____________________?

3. Gaps in the rock record are only found in sedimentary rocks?

True or False

3a. Explain why you chose True/False

4. What processes could lead to gaps in the rock record?

5. Is it possible to determine what happens after a gap in the rock record? Yes or No?

5a. Why did you chose YES/NO

Deposition

1. Sedimentary rocks are made up of sediments that were deposited in different types of environments. What types of environments were the sediment deposited in?

2. How, if at all, is the depth of a sedimentary rock layer correlated to the age of the same rock layer? Select the answer below that best matches your idea.

a. The older the sedimentary rock is, the closer to the surface it is.

b. Depth of a sedimentary rock layer is not correlated to it its age.

c. All sedimentary rock layers are the same age.

d. The older the sedimentary rock is, the deeper it is.

3. Rocks at the same elevation above sea level are the same age.

True or False

3a) Explain why you chose: True or false

4. The sedimentary particles that make up a sedimentary rock layer are…. (Circle all that apply)

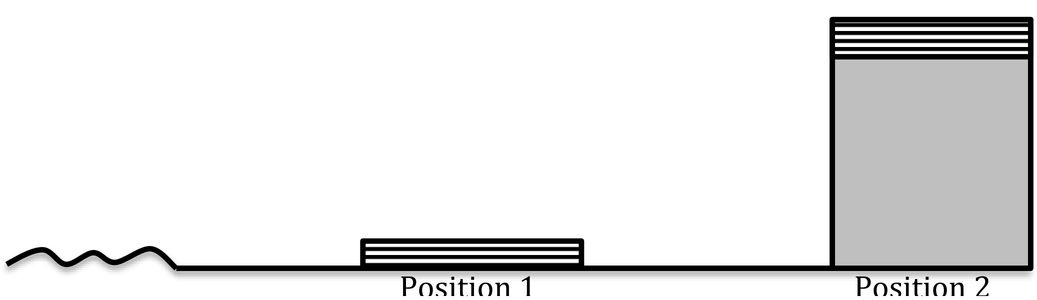
a. the same size.

b. well rounded in shape.

c. different sizes.

d. angular in shape

5. A sedimentary rock layer at one location is also located at a different location with a higher elevation with respect to sea level. How could this happen?



6. What is a sedimentary facies?

Deposition and Sedimentary Facies

1. Sedimentary rocks are made up of sediments that were deposited in different types of environments. What types of environments were the sediment deposited in?

2. How, if at all, is the depth of a sedimentary rock layer correlated to the age of the same rock layer? Select the answer below that best matches your idea.

a. The older the sedimentary rock is, the closer to the surface it is.

b. Depth of a sedimentary rock layer is not correlated to it its age.

c. All sedimentary rock layers are the same age.

d. The older the sedimentary rock is, the deeper it is.

3. Rocks at the same elevation above sea level are the same age.

True or False

3a) Explain why you chose: True or false

4. The sedimentary particles that make up a sedimentary rock layer are…. (Circle all that apply)

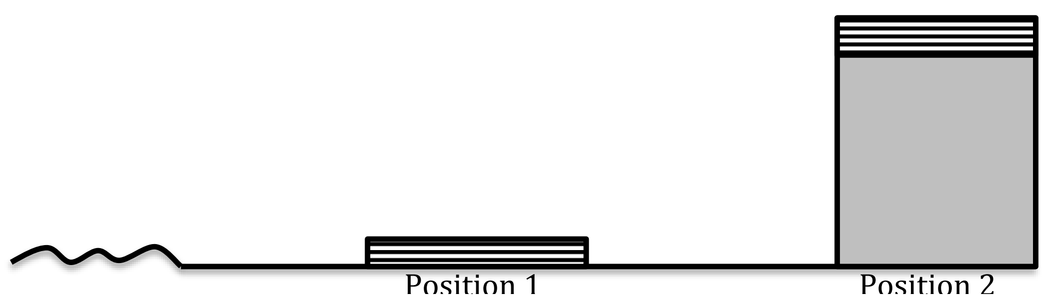
a. the same size.

b. well rounded in shape.

c. different sizes.

d. angular in shape

5. A sedimentary rock layer at one location is also located at a different location with a higher elevation with respect to sea level. How could this happen?



6. What is a sedimentary facies?