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ABSTRACT

This study investigates the effectiveness of traditional and reform approaches in teaching earth science to future elementary school teachers. The research team was interested in whether reform strategies produce more content knowledge and a more positive change in attitude toward earth science among elementary education students when compared to students receiving traditional instruction. Study participants were 49 students at the University of Southwestern Louisiana enrolled in an introductory earth science course for elementary school teachers, half in a traditional section and half in an experimental section taught using reform strategies, including small class size, integrated lecture and laboratory activities, and increased emphasis on group work and problem solving skills. Findings indicated that while there was not a statistically significant difference in actual content learning, students in the experimental section did tend to score slightly higher on the content test. Also, students in the experimental section showed a significant positive change in attitude. Data from student interviews indicated that additional project work outside of class would strengthen the overall course. If it is not possible to use the reform approach exclusively due to financial or other constraints, it is recommended that every effort be made to incorporate as many reform strategies as possible within the traditional organizational pattern. The survey instrument and the earth science content test are appended. (Contains 20 references.) (ND)

An Investigation into the Effectiveness of Science Reform Strategies in Teaching Earth Science at the University Level

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Introduction

Project 2061 of the American Association for the Advancement of Science (AASA) has resulted in a new awareness of the need to reform science teaching and content at all levels. *Science for All Americans* (Rutherford & Ahlgren, 1990), published under the auspices of AASA and *Benchmarks for Science Literacy* (AASA, 1993), punctuated the need for greater emphasis on experiential learning and higher order thinking. This publication also suggests the need to reduce the breadth of content coverage in order to increase the depth on significant concepts.

The National Research Council (NRC) working independently from AAAS produced *National Science Education Standards* (National Research Council, 1996). The standards suggested by the NRC and the benchmarks suggested by AAAS have many similarities. There is a clear common thread of increasing experimentation, and doing experiments before introducing theory, a greater emphasis on critical thinking, and a reduction in the number of topics in favor of a deeper and more extensive coverage.

In order to achieve either the benchmarks or the standards, changes must occur in the way children are taught and assessed as well as in the content covered. One significant obstacle to these changes may well be inadequate preparation of teachers. Marshall Smith, Undersecretary of Education, at a recent conference said: "...(There) is little science instruction in K-12 schools because most teachers are not properly trained and prepared."[1] Comments from AAAS president Bruce Albert at that same conference suggested that national standards would not be sufficient; there had to be reform from the bottom up.

Since reform is needed and teachers in our schools must be the ones to

[1] From an address delivered at the third annual forum on "Scientists, Educators, and National Standards: Action at the Local Level" sponsored by Sigma Xi, April 14-15, 1994 in Atlanta, Georgia.

change student's perceptions of science, it is appropriate to change the way future teachers are taught science.

The Problem

Accepting the current trend in science education standards, it becomes important to critically evaluate the way science is taught to future teachers. This study concentrates on the way earth science is taught to future elementary school teachers and investigates the effectiveness of traditional and reform approaches. Specifically the research team was interested in two sub problems:

1) Does the use of reform strategies, including smaller class size, produce more content knowledge on the part of students when compared to students receiving traditional instruction?

2) Does the use of reform strategies, including smaller class size, produce a more positive change in attitude toward earth science for the elementary classroom on the part of students when compared to students receiving traditional instruction?

Significance of the Problem

The need for change in light of national trends has been pointed out in the introduction to this research report. The state of Louisiana has been in the vanguard of the reform movement. Under grants from the National Science Foundation (NSF) and the Louisiana Education Quality Support Fund (LEQSF) the state has initiated reform on many levels. The Louisiana Systemic Initiatives Program (LaSIP) provides staff development activities for teachers currently serving the state schools, while the

Louisiana Collaborative for Excellence in the Preparation of Teachers (LaCEPT) provides support for programs designed to impact pre-service teachers. This research was initiated as part of a LaCEPT project at the University of Southwestern Louisiana. The course revisions were funded by a LaCEPT grant as were some of the research activities.

Current thinking recognizes that large lecture sections is not the best way to provide high quality instruction of the type recommended by the national standards and benchmarks. Unfortunately, many university classes still operate with very large lectures and separate laboratory sections. In order to implement reform strategies it is necessary to conduct classes with lower enrollment where the laboratory experiences are integrated with the nonlaboratory class activities. There has been some research to support the need for smaller class size. Feldman (1984) conducted a study comparing student evaluations of college instructors with class size and found a weak inverse relationship. A more extensive study conducted by Watkins (1990) at the University of Canterbury (England) involved 20,000 students and showed a strong relationship between small class size and higher ratings given to instructors. Toby (1988) found that when class sizes become very large (>100) even the best instructors loose their effectiveness. In another study Knight (1991) found that when class size was at 15 or less the students performed much better in the course and in subsequent courses.

Not all research on class size at the university level has demonstrated an inverse correlation between class size and instructional effectiveness. One study (Williams, 1984) examined over 300 sections of classes at Brigham Young University having enrollments from 13 to 1,008 students and found no significant relationship between class size and achievement. This study, however, used only standardized achievement tests and did not consider other types of assessments. In a more recent study at this university (Rieck, Clark, & Lopez, 1995) it was shown that there was no difference in achievement between large and small sections of freshman mathematics. However, in this case the difference between large and small sections was only about 15 students and the small sections still had over 30 students.

Class size research below the collegiate level has provided insight which has been applied in this project. A Washington state school district (Educational Service District #189, 1987) conducted a literature search and concluded that small class sizes, especially at the lower levels, produced increased performance on the part of students as well as more positive attitudes and behavior. Both this study and one conducted by Finn (1990) provide creditable evidence that when class size is 20 or less there is enhanced learning. While it may not be realistic for all university classes to contain 20 or fewer students, the investigation reported here limited the experimental sections to 18 students each.

While classes with large lecture, and separate laboratory, sections is still the predominant approach at the university level, there is mounting evidence that an integrated course with opportunities for different types of learning activities may result in better instruction. Holiday et al. (1996) suggests that geology courses should contain more application and higher order thinking activities. Several authors (Macdonald and Bykerk-Kauffman, 1995; Basu and Middendorm, 1995, and Manner, 1995) have presented strong arguments for the use of collaborative[2] group learning experiences in college level geology.

Hypotheses

Several hypotheses are being tested in this study:

1) There will be no significant difference in growth of content knowledge between

[2] I use the term collaborative to distinguish regular group work from the various models of cooperative learning (Johnson & Johnson, Slavin) which have specific requirements.

the experimental and control groups.

2) Neither the control nor experimental groups will demonstrate a significant change in attitude toward earth science in the elementary school.

3) There will be no significant difference in the change in attitude toward earth science for elementary schools between the experimental and control groups.

4) There will be no significant correlation between change in content knowledge and change in attitude toward earth science in the elementary school.

Definitions and Descriptions

1) GEOL 225 is a three credit course on introductory earth science. The course has been designed for individuals intending to become elementary school teachers. The course is required of all elementary education majors.

2) Control group is that group of students who enrolled in GEOL 225 and experienced the course in the traditional way. This included a lecture section of approximately 90 students and separate laboratory sections of approximately 18 students each taught by a graduate assistant. Lectures are held in a large auditorium while the lab is conducted in a regular laboratory facility.

3) Experimental group is that group of students who enrolled in GEOL 225 and experienced the course under reform strategies, including a class size of 18 students where laboratory and "lecture" were integrated, taught in the same room, and taught by the same instructor. Reform strategies also included an

increased emphasis on group work and high order problem solving skills.

4) Attitudes toward earth science in the elementary school includes attitudes deemed appropriate for potential elementary school teachers who would be required to teach science. The attitudes were identified by the geologists in the program and include:

a) Earth science is enjoyable to learn at any level.
b) Knowledge of earth science enriches our daily lives.
c) Earth science is important to help a person become a good teacher
d) The earth science class will make a person a better teacher.
e) Earth science is not difficult to learn.
f) Earth science experiments are interesting.
g) Earth science experiments are enjoyable.

5) Likert type attitudinal instrument is an instrument developed by the educational researcher to measure the attitudes identified by the geologists.

6) Content test is a test on geological principles used as the pre and post tests in this research. The test items were developed by the geologists and reviewed by the educational researcher for form and objective match.

7) Interviews refer to interviews conducted between the educational researcher and selected students after the students had completed GEOL 225.

Research Methods

Population

The initial population consisted of 72 students at the University of Southwestern Louisiana who were eligible to enroll in GEOL 225. Half of the students were enrolled in the experimental sections of GEOL 225 and half were randomly selected from students in the traditional sections of GEOL 225. One experimental and one traditional (control) section was conducted during each of the semesters during the 1995-96 academic year so the initial population was divided equally as shown in table one, below.

Table One
Initial Population Distribution

GROUP	# IN FALL	# IN SPRING	TOTAL
Experimental	18	18	36
Control	18	18	36
			72

The final population consisted of 49 students. The difference between the initial and final populations is accounted for by 23 students who did not take all four of the assessment instruments (content and attitude, pre and post tests) either due to absence or course attrition. The final population distribution is shown on table two, below.

Table Two
Final Population Distribution

GROUP	# IN FALL	# IN SPRING	TOTAL
Experimental	10	14	24
Control	12	13	25
			49

Likert Type Attitudinal Instrument

To measure student attitudes toward earth science for elementary education, and the change in those attitudes, a Likert - type scale was developed. The geologists involved in the development of the revised GEOL 225 produced a list of attitude attributes they considered appropriate for future elementary school teachers to have relative to earth science. A conference was then held with the educational researcher where refinement of the original set of attributes was accomplished. A fourteen item Likert - type instrument was then developed by the educational researcher. The instrument was then reviewed by the geologists. Based on that review, the instrument was considered to have face validity.

The attitude inventory was administered to all students involved in the study on the first day of class and again in one of the final days of the course. For purposes of determining instrument reliability the first administration was scored on a split test basis. A correlation was conducted to determine half test reliability which was 0.670. This split test correlation was then subjected to the Fisher r to z treatment as described by Sager (1992) which converts correlation values to probability. The result indicated that the correlation had a $p<.001$. As a further measure the split test correlation was converted to whole test correlation using the Spearman - Brown prophecy formula as suggested by Mueller (1986) which produced a whole test correlation value of 0.802. Based on these outcomes the instrument was considered reliable.

A pre test / post test format was used. Within each group a two tailed paired t-test was used to determine if there was a significant change in attitude. Between groups the changes in attitudes were subjected to a two tailed unpaired t-test. An analysis of variance was also conducted in comparing groups.

Cognitive (Content Knowledge) Growth

The geologists developed a content test to be used as the pre and post test instrument for both the control and experimental groups. Test items were then reviewed by the educational researcher and suggestions were made on phrasing and structure to require more higher order thinking. The geologists then redesigned the test in accordance with the suggestions made. Based on a comparison between the course objectives and the assessment items the test had face content validity.

Within each group a two tailed t-test was used to ascertain if the cognitive growth was significant. To determine if there were significant differences between groups both a two tailed unpaired t-test and an analysis of variance were conducted.

Interviews

In an effort to probe deeper into possible attitudinal aspects of the experimental research interviews were scheduled with seven students. Two of the students did not appear for the scheduled interviews, leaving five students who were interviewed. A structured interview was developed similar to the guided question format suggested by Patton (1990) and analyzed using a domain and taxonomy approach similar to Spradley (1979, 1980). All of the interviews were conducted after the course was completed.

Assumptions

Because both the experimental and control sections of GEOL 225 were taught by the same instructor it was assumed the instruction was of equal quality. The exception to this is that laboratory sections of the control group were taught by graduate assistants under the direct supervision of the instructor.

Because enrollment in GEOL 225 sections was self selected by students it was assumed that the range of abilities within both the experimental and control groups was the same.

Limitations

This research was limited to those students enrolling in GEOL 225 during the fall and spring semesters of the 1995-96 academic year at the University of Southwestern Louisiana.

Results

Hypothesis One

"There will be no significant difference in growth of content knowledge between the experimental and control groups."

While intuition would suggest that there would be significant change in knowledge within groups there can be no such intuitive approach to a comparison between groups.[3] The two tailed unpaired t-test , as can be seen in table three below,

Table Three
Unpaired t-test Comparing Cognitive Growth

Mean Difference	t-value	p-value
3.292	0.994	0.3257

resulted in a p value of 0.3257 which demonstrates no significant difference between groups. This result is supported by the analysis of variance as shown in table four on page 11 which shows the exact same p-value of 0.3257. Based on these statistics the first null hypothesis is accepted.

[3] In point of fact a paired two tailed t-test was conducted to verify that there was significant learning within groups. In each case p<.001, thus justifying the "intuition".

Table Four
Analysis of Variance Comparing Cognitive Growth

	Sum of Squares	Mean Square	F-Value	P-Value
Class	130.021	130.021	0.987	0.3257
Residual	6,059.458	131.727		

Hypothesis Two

"Neither the control or experimental groups will demonstrate a significant change in attitude toward earth science in the elementary school."

For within group statistics only the paired t-test was used. As can be seen in table five, below, the p value for the control group was not statistically significant while the value for the experimental group showed strong statistical significance. These results cause a rejection of the null hypothesis with respect to the experimental group and acceptance with respect to the control group.

Table Five
Paired t-Test Comparing Attitude Change Within Groups

Group	Mean Difference	t- value	p- value
Control	1.667	1.700	0.1025
Experimental	7.583	4.207	0.0003

Hypothesis Three

"There will be no significant difference in the change in attitude toward earth science for elementary schools between the control and experimental groups."

Both unpaired t-tests and F-tests were used in testing this hypothesis. As can be seen from the data displayed in tables six and seven both of the tests resulted in a p value of 0.0053 which causes rejection of the null hypothesis. Clearly the change in attitude was more significant in the experimental group.

Table Six
Unpaired t-Test Comparing Attitude Change

Mean Difference	t-Value	P- Value
6.000	2.927	0.0053

Table Seven
Analysis of Variance Comparing Attitude Change

	Sum of Squares	Mean Square	F-Value	P-Value
Class	432.000	432.000	8.565	0.0053
Residual	2,320.042	50.436		

Hypothesis Four

"There will be no significant correlation between change in content knowledge and change in attitude toward earth science in the elementary school."

As seen in table eight on page 13 the correlations conducted by group and total population were all at or below 0.341 and the Fisher r to z probabilities were at or above 0.11. Based on these data the null hypothesis is accepted.

Interviews

Qualitative interviews are not intended to support or reject a particular hypothesis, rather they assist in shedding light on particular attitudes or opinions of those individuals who were interviewed. A taxonomical analysis of the data shows a

Table Eight
Correlations and Probabilities Comparing Cognitive and Attitude Changes

	Correlation	P- Value
Experimental	-0.083	0.7109
Control	0.341	0.1124
Total	0.111	0.4634

high level of consistency in the responses of the five students interviewed as part of this study. The domains of responses related to positive attributes of the course, negative attributes, changes students would like to see, and student perceptions of their attitude changes.

All five of the interviewed students provided one or more positive attributes of the course. Table nine displays a frequency distribution of the types of positive attributes mentioned by students.

Table Nine
Frequency Distribution of Positive Attributes

Attribute	Frequency
Small class size enhanced learning	3
Hands on experiences enhanced learning	3
Use of small groups was helpful	1
Discovery approach to labs helped learning	1[4]
Having the same instructor for lecture and lab	1
The time line project	1

[4] This is probably related to hands on experiences, but only one student specifically used the term discovery.

It is useful to "hear the voices" of students on the subject of positive attributes. Certainly the small class size was very important:

Amy's Voice: " I realized the class size would be smaller which for me is always helpful because I can ask questions of the teacher."

"When I took it before (Amy had taken the class in the traditional form, but withdrew before completing the course) the classes were larger, there were grad students teaching. When you asked questions it was hard for them to break it down and explain it. Mrs. Tucker could do that and you could talk to her after class."

Doris' Voice: "The first really big point was my lecture teacher and lab teacher were the same and I thought that was fabulous. When I took my biology there were 300 in lecture and 25 in lab with different grad assistants and that was tough. With our small class size I felt very close to my teacher at all times and we had discussions and I could ask questions."

Ellen's Voice: "The class we had very few people, maybe 20, if that many. We could ask questions any time and the answers were down to earth. I would say this method, the way they did the course, was excellent."

The fact that Amy had taken the course before gave her an excellent basis for comparison. While other students could compare to other science classes, Amy could compare the two approaches to the same course.

Students seemed to like the use of "hands on" to describe the course, and one directly related this type of experience to discovery learning. Some of the comments from students:

Amy's Voice: "If you are interested in learning this class is great. There are lots of hands on activities which help you learn.

Barbara's Voice: "I liked the instruction because it was very hands on."

Connie's Voice: "I liked the idea of the hands on (approach) and of students discovering things on their own, but with the teacher's ideas on what to look for. I thought that was neat."

While most student comments were very positive in support of the approach used in the experimental section, there were three attributes which were cited as negative:

Barbara"s Voice: "Yeah, like we had one lab where we looked at rocks and minerals and then we would be quizzed on too much detail. It was overboard. Like maybe OK for some basic ones, but some were real challenging and too much for someone not majoring in geology."

Ellen's Voice: "There were a couple of labs I did not enjoy, like the water sample lab; I don't think there was a point to it."

It should be noted that the negative attributes related to specific activities of depth of content rather than the basic approach to the course. It is not reasonable that all students would find each laboratory project equally enjoyable or the assessment procedures to be at a level of generality a student may prefer.

During the interviews some students suggests changes they would like in the course to make it more effective:

Barbara's Voice: "I would like more outside assignments because they are hands on, like the time line assignment. Why not collect specimens from outside and classify them? That would have more meaning."

Ellen's Voice: "As far as the labs are concerned I wish the time could be extended so we would not be so rushed."

It is interesting to note that Barbara, who was concerned about scheduled laboratory experiences, suggested more out of class projects and specifically mentioned the time line project. Doris gives support to this concept and embellishes on the value of the time line project:

Doris' Voice: "We did a time scale from the beginning of the world and um I think it was confusing, but after we did it I realized that Biblically speaking Jesus was 2,000 years and I though he was like decrepidated old, but I realized he was not old, I was astonished by that. I am going to keep my time line and show it to my kids and I think it will help them, especially since they will see it visually."

While the quantitative data showed a statistically significant positive change in attitude toward earth science and its use in elementary schools, it was still gratifying that the personal interviews strongly supported the quantitative data. While each of the five students indicated a positive attitudinal change, there are three comments worthy of special note:

Connie's Voice: "Taking this earth science course this semester has me looking forward to teaching earth science because the instructor gave us a lot of ideas of what to do in our classes. I never thought I would look forward to doing anything with earth science."

Doris' Voice: "I was always kind of interested in earth science, but this class really made me enthusiastic. It really boosted my attitude toward earth science and I would like to take another class like this."

Ellen's Voice: "I did not know what to expect. I was scared and heard it was really hard and boring. I thought 'oh my god, what is she going to do?' I had been putting the class off because of being scared, but it turned out to be my best class this semester. I learned so much like I took a trip to Las Vegas and went to Hoover Dam and told all my friends about the rocks and how the mountains were formed."

Discussion and Implications

There is no doubt that a statistically significant difference in actual content learning can not be supported. However, the students in the experimental section did tend to score slightly higher on the content test suggesting that there may be a learning advantage in using the reform strategies, but the advantage is not significant enough to justify using reform strategies for that purpose.

With respect to attitude changes in students it was clearly established that the students in the experimental section showed a significant positive change in attitude while students in the control group did not show a significant positive change. When the changes were compared it was found that the difference was significant at the $p=.0053$ level which satisfies even the most stringent test.

The quantitative attitudinal results were strongly supported by the individual student interviews. Every student interviewed reported they felt positively toward earth science and were anxious to use their knowledge at the elementary school level.

Based on the student interviews it is possible that additional project work outside of class would strengthen the overall course. It is, perhaps, also appropriate to review the current laboratory experiences for appropriateness and detail. There was nothing to suggest any type of major overhaul of the course, just the opposite. The new course is superior to the traditional course.

Unfortunately, there is a strong probability that the reform approach can not be implemented on a full scale basis. The costs associated with having five lecture/laboratory sections as opposed to one lecture and five laboratory sections may be prohibitive. In the former case , assuming a maximum load of twelve credit hours, 1.25 instructors would be required. In the latter case one instructor could handle the entire load and assume other responsibilities.

Table Ten
A Comparison of Load Factors With a 12 Credit Hour Load

	TRADITIONAL	REFORM
Lecture	1 sect. X 2 cr = 2 cr	5 sect. X 2 cr = 10 cr
Lab	5 sect X 1 cr = 5 cr	5 sect. X 1 cr. = 5 cr
Total Load	12 cr	15 cr
Instructors required	.58	1.25

In the best case scenario the reform approach should be used exclusively because of the attitudinal considerations. However, if this is not possible, every effort should be made to incorporate as many reform strategies as possible within the traditional organizational pattern. To effectively do this, the laboratory instructors must work very closely with the lecture instructor who must have overall control of the course.

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UNIVERSITY OF SOUTHWESTERN LOUISIANA

DEPARTMENTS OF GEOLOGY AND CURRICULUM & INSTRUCTION

Survey of Attitudes Toward Earth Science

STUDENT PID:_______________________________Male___ Female___

Below are a series of statements to which you are asked to indicate your honest feelings by placing a check (√) mark on the line from "strongly disagree" on the left of the line to "strongly agree" on the right side as shows below.

1	2	3	√ 4	5
strongly disagree	disagree	neutral	agree	strongly agree

This form **will not be seen by your instructor** and will be used only to compile statistical information as part of a research project.

1) I enjoy learning about the solar system, atmosphere, oceans, lands, and the Earth's interior.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

2) Knowledge of Earth science enriches my daily life.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

3) Earth science is important because it will help me in teaching my elementary students.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

4) Earth science is dull.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

Please turn the page over

5) Earth science is difficult to learn.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

6) Experiments in Earth science are interesting.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

7) Earth science is really important only for people who want to go into science as a career.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

8) Earth science is challenging, but not that hard to learn.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

9) I do not think I will be effective teaching Earth science.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

10) Given a choice I would rather do almost anything else rather than do an Earth science lab.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

11) Earth science is not important for elementary school teaching.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

12) Earth science labs are enjoyable.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

13) Earth science labs are boring verifications of what we learned in class.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

14) I am capable of teaching Earth science to elementary school students.

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

SSN: ____________________

EARTH SCIENCE

SELECT THE LETTER OF THE CHOICE THAT BEST ANSWERS THE QUESTION:

1. YOU HAVE DECIDED TO SPEND AUGUST IN THE MOUNTAINS OF COLORADO BECAUSE IT IS COOLER THAN LOUISIANA. WHY IS IT COOLER?
   A. BECAUSE THE MESOSPHERE HAS COOLER TEMPERATURES THAN ANY OTHER LAYER OF THE EARTH'S ATMOSPHERE
   B. BECAUSE COLORADO IS CLOSER TO THE ANTARCTIC CIRCLE THAN LOUISIANA
   C. BECAUSE TEMPERATURES DROP PROGRESSIVELY FROM THE EARTH'S SURFACE UPWARD IN THE TROPOSPHERE
   D. BECAUSE LOUISIANA IS IN THE THERMOSPHERE AND COLORADO IS IN THE STRATOSPHERE
   E. BECAUSE THE ROCKS IN THE MOUNTAINS RADIATE LESS HEAT THAN THE COASTAL PLAIN

2. THE EARTH AND ITS SATELLITE OR MOON APPARENTLY WERE FORMED ABOUT THE SAME TIME 4.6 BILLION YEARS AGO. IN THE FIRST SEVERAL HUNDREDS OF MILLIONS OF YEARS AFTER THEIR FORMATIONS, THEY WERE BOMBARDED BY LARGE NUMBERS OF METEORITES. THE MOON, EVEN THROUGH A LOW POWER TELESCOPE, SHOWS CLEAR EVIDENCE OF THIS BOMBARDMENT BY THE LARGE NUMBER OF CRATERS ON ITS SURFACE. HOWEVER, THE EARTH, ASSUMED TO HAVE BEEN SUBJECTED TO A SIMILAR BOMBARDMENT, SHOWS FEW METEOR CRATERS, AND MANY OF THEM ARE OBSCURE AND HARD TO DETECT. WHAT HAS HAPPENED TO THE EARTH'S MANY CRATERS?
   A. THE MOON, IN ITS ORBIT AROUND THE EARTH, SHIELDED THE EARTH FROM MOST OF THE INCOMING METEORS.
   B. THE EARTH ACTUALLY WAS FORMED SEVERAL HUNDREDS OF MILLIONS OF YEARS AFTER THE MOON WAS FORMED.
   C. THE PRESENCE OF AN ATMOSPHERE AND THE EFFECTS OF THE HYDROLOGICAL CYCLE HAVE CAUSED CONTINUOUS EROSIONAL AND DEPOSITIONAL PROCESSES, WHICH HAVE DESTROYED MOST OF THE METEOR CRATERS
   D. A LARGE NUMBER OF CRATERS ARE STILL PRESENT ON THE EARTH'S SURFACE, BUT HEAVY VEGETATION IN MANY PLACES PREVENTS THEM FROM BEING OBSERVED.
   E. THE ABUNDANT CARBON DIOXIDE IN EARTH'S ATMOSPHERE HAS DESTROYED MOST OF THE METEOR CRATERS.

3. THE OLDEST ROCKS THAT UNDERLIE THE EARTH'S OCEAN BASINS ARE ABOUT 200 MILLION YEARS OLD. BUT SOME OF THE WATER IN THESE OCEAN BASINS IS BELIEVED TO BE SEVERAL BILLIONS OF YEARS OLD. IF THIS IS TRUE, HOW IS THIS APPARENT PARADOX POSSIBLE?
   A. WATER IN THE OCEAN BASINS HAS BEEN CONTINUOUSLY MOVED THROUGH THE HYDROLOGICAL CYCLE THROUGH TIME, BUT ROCKS OT THE OCEAN FLOORS HAVE REMAINED IN THE SAME PLACE.
   B. THERE ARE NO ROCKS ON THE PLANET OLDER THAN 200 MILLION YEARS, BUT WATER HAS BEEN MOVED THROUGH THE HYDROLOGICAL CYCLE FOR BILLIONS OF YEARS.
   C. THERE ARE OLDER ROCKS IN THE OCEAN BASINS, BUT THEY ARE BURIED BENEATH THE ONES THAT ARE LESS THAN 200 MILLION YEARS OLD.
   D. THE ROCKS IN THE OCEAN BASINS ARE CONTINUALLY FORMED AND DESTROYED THROUGHOUT TIME BY THE PROCESSES ASSOCIATED WITH PLATE TECTONICS, BUT WATER HAS BEEN ACCUMULATING THROUGH TIME AS A BYPRODUCT OF VOLCANIC PROCESSES.
   E. THOSE WHO HAVE STUDIED THE EARTH ARE WRONG. BOTH THE ROCKS OF THE OCEAN BASINS AND THE WATER WITHIN THEM ARE LESS THAN 200 MILLION YEARS OLD.

4. YOU HAVE FOUND INCLUSIONS OF A GRANITE IN A SEDIMENTARY CONGLOMERATE. WHAT CAN YOU DETERMINE ABOUT THE AGE OF THE GRANITE?
   A. THE CONGLOMERATE IS OLDER THAN THE GRANITE.
   B. THE GRANITE IS OLDER THAN THE CONGLOMERATE.
   C. THEY ARE THE SAME AGE.
   D. THE CONGLOMERATE IS INTRUSIVE INTO THE GRANITE.
   E. THE GRANITE IS INTRUSIVE INTO THE CONGLOMERATE.

5. THESE SPECTACULAR BODIES HAVE BEEN COMPARED TO LARGE, DIRTY SNOWBALLS, SINCE THEY ARE MADE OF FROZEN GASES WHICH HOLD TOGETHER SMALL FRAGMENTS OF ROCKY MATERIAL.
   A. COMETS
   B. ASTEROIDS
   C. SATELLITES
   D. METEOROIDS
   E. METEORITES

6. OXBOW LAKES AND NATURAL LEVEES ARE CHARACTERISTIC OF STREAMS IN WHICH STAGE?
   A. YOUTH
   B. MATURITY
   C. OLD AGE
   D. GRADED
   E. FLOOD STAGE

7. WHY ARE WE ABLE TO SEE ONLY ONE SIDE OF THE MOON FROM THE EARTH?
   A. THE MOON'S ORBITAL PERIOD IS THE SAME AS ITS ROTATIONAL PERIOD.
   B. THE MOON DOES NOT TURN ON ITS AXIS.
   C. THE SUN SHINES ONLY ON ONE SIDE OF THE MOON.
   D. THE MOON DOES NOT ORBIT THE SUN.
   E. THE MOON'S ROTATIONAL PERIOD IS THE SAME AS THE EARTH'S ROTATIONAL PERIOD.

8. WHICH OF THE FOLLOWING SEQUENCES OF EVENTS IS THE BEST INTERPRETATION OF A DISCONFORMITY?
   A. DEPOSITION OF SEDIMENTARY UNITS--UPLIFT AND EROSION--DEPOSITION OF SEDIMENTARY UNITS
   B. DEPOSITION OF SEDIMENTARY UNITS--GRANITIC INTRUSION--UPLIFT AND EROSION
   C. DEPOSITION OF SEDIMENTARY UNITS--INTRUSION OF A DIKE AND EXTRUSION OF LAVA
   D. DEPOSITION OF SEDIMENTARY UNITS--FOLDING--UPLIFT AND EROSION--DEPOSITION OF SEDIMENTARY UNITS
   E. DEPOSITION OF SEDIMENTARY UNITS--BURIAL AND METAMORPHISM--UPLIFT AND EROSION--DEPOSITION OF SEDIMENTARY UNITS

9. GROUNDWATER POLLUTION SOURCES INCLUDE:
   A. AIR POLLUTANTS.
   B. SOLUBLE METALS.
   C. SEWAGE.
   D. FERTILIZERS.
   E. ALL OF THESE CHOICES.

10. FOSSILS OF LAND ANIMALS FROM THE PLEISTOCENE ICE AGE, WHICH ENDED ABOUT 11,000 YEARS AGO, HAVE BEEN FOUND UNDER SEVERAL HUNDREDS OF FEET OF WATER IN SEDIMENTS OF THE CONTINENTAL SHELVES ALONG NORTH AMERICA'S ATLANTIC SEABOARD. HOW DID FOSSILS OF THESE LAND ANIMALS HAPPEN TO BE PRESERVED UNDER THE SEA?
    A. THE ANIMALS WERE SWEPT TO SEA IN RIVERS DURING HUGH FLOODS ALONG THE ATLANTIC COAST, THEN THEY SANK TO THE BOTTOM OF THE SEA WHERE THEY WERE FOSSILIZED.
    B. PLATE TECTONIC MOVEMENTS HAVE MOVED THE EASTERN MARGIN OF NORTH AMERICA TOWARDS THE EAST OVER THE PAST TWO MILLION YEARS, ALLOWING THE SEA TO FLOOD THE CONTINENTAL MARGIN.
    C. THE MELTING OF THE PLEISTOCENE AGE GLACIERS HAS RAISED SEA LEVEL SEVERAL HUNDREDS OF FEET, FLOODING CONTINENTAL SHELF AREAS THAT USED TO BE PART OF THE CONTINENTAL ENVIRONMENT.
    D. SUBMERGENCE OF THE ATLANTIC COAST OF NORTH AMERICA HAS OCCURRED SINCE THE END OF THE PLEISTOCENE BECAUSE OF THE PRESENCE OF A PLATE TECTONIC SUBDUCTION ZONE IN THE WESTERN ATLANTIC OCEAN.
    E. THE SO-CALLED PLEISTOCENE AGE FOSSILS HAVE BEEN MISIDENTIFIED AND ACTUALLY ARE FROM AN OLDER GEOLOGIC AGE WHEN NORTH AMERICA'S ATLANTIC COAST WAS IN THE INTERIOR OF THE CONTINENT.

11. WHICH OF THE FOLLOWING IS AN EXAMPLE OF BIOGENOUS SEDIMENT?
   A. FORAMINIFERAL OOZE
   B. MANGANESE NODULES
   C. CONTINENTAL-DERIVED MARINE SEDIMENT
   D. METEORITIC DUST
   E. STREAM FLOOD DEPOSITS

12. WHICH OF THE FOLLOWING LISTS CONTAINS ONLY METAMORPHIC ROCKS?
   A. SHALE, MARBLE, CHLORITE
   B. SHALE, SLATE, QUARTZITE
   C. SLATE, GNEISS, MARBLE
   D. SLATE, SHALE, MARBLE
   E. SLATE, SHALE, CALCITE

13. THE GEOGRAPHIC DISTRIBUTION OF MESOSAURUS, A SMALL SWIMMING REPTILE THAT LIVED DURING THE LATE PALEOZOIC, PROVIDES EVIDENCE THAT:
   A. ENGLAND WAS COVERED BY A SHALLOW SEA DURING THE LATE PALEOZOIC.
   B. MIGRATION BETWEEN NORTH AMERICA AND ENGLAND WAS POSSIBLE.
   C. SOUTH AMERICA AND AFRICA WERE ONCE JOINED.
   D. A LAND BRIDGE EXISTED BETWEEN AUSTRALIA AND INDIA.
   E. THE PACIFIC OCEAN DID NOT EXIST DURING THIS TIME PERIOD.

14. A RIVER ORIGINATES 200 METERS ABOVE SEA LEVEL AND TRAVELS 400 KILOMETERS TO THE OCEAN. WHAT IS THE AVERAGE GRADIENT IN METERS PER KILOMETER?
   A. 0.5 M/KM
   B. 2 M/KM
   C. 5 M/KM
   D. 0.2 M/KM
   E. NONE OF THESE IS CORRECT.

15. THE TWO MOST IMPORTANT HEAT ABSORBING GASES IN THE LOWER ATMOSPHERE ARE:
   A. OXYGEN AND NITROGEN
   B. WATER VAPOR AND CARBON DIOXIDE
   C. ARGON AND OXYGEN.
   D. OZONE AND CHLOROFLUOROCARBON.
   E. NONE OF THE ABOVE.

16. DINOSAURS WERE ABUNDANT AND DIVERSE FROM APPROXIMATELY 200 - 70 MILLION YEARS AGO. DURING WHICH GEOLOGIC ERA WAS THIS?
   A. MESOZOIC
   B. PALEOZOIC
   C. CENOZOIC
   D. PROTEROZOIC
   E. QUATERNARY

17. THE EPICENTER OF AN EARTHQUAKE CAN BE DETERMINED USING:
A. DATA FROM A SINGLE SEISMOGRAPH.
B. DATA FROM TWO SEPARATE SEISMOGRAPHS AT THE SAME LOCALITY.
C. DATA FROM TWO SEISMOGRAPHS AT DIFFERENT LOCALITIES.
D. DATA FROM THREE OR MORE SEISMOGRAPHS AT DIFFERENT LOCALITIES.
E. DATA FROM THE LOW VELOCITY ZONE.

18. IF YOU WANTED TO DRAW THE BOUNDARIES OF ACTIVE LITHOSPHERIC PLATES ON A GLOBE, WHICH OF THE FOLLOWING WOULD GIVE YOU THE MOST COMPLETE INFORMATION?
A. A MAP SHOWING ACTIVE VOLCANOES
B. A MAP SHOWING MID-OCEANIC RIDGES
C. A MAP SHOWING EARTHQUAKE DISTRIBUTION
D. A MAP SHOWING THE EDGES OF CONTINENTAL SHELVES
E. A MAP SHOWING THE GLOBAL DISTRIBUTION OF HOT SPOTS.

19. WHEN USING A PSYCHROMETER AND THE TWO TEMPERATURES READ NEARLY THE SAME, YOU CAN CONCLUDE THAT:
A. YOUR INSTRUMENT READING IS ACCURATE.
B. A CHANGE IN TEMPERATURE IS LIKELY.
C. THE DEW POINT TEMPERATURE IS VERY LOW.
D. THE AIR HAS A HIGH RELATIVE HUMIDITY.
E. NONE OF THE ABOVE.

20. AT 9:00 A.M. THE OUTSIDE AIR TEMPERATURE WAS 62 DEGREES F. AT 3:00 P.M. THE SAME DAY, THE OUTSIDE AIR TEMPERATURE WAS 75 DEGREES F. IF THE SPECIFIC HUMIDITY DID NOT CHANGE, WHAT (IF ANYTHING) HAPPENED TO THE RELATIVE HUMIDITY?
A. IT STAYED THE SAME.
B. IT DECREASED.
C. IT INCREASED.
D. IT MAY HAVE DONE ANY OF THE ABOVE.
E. MORE INFORMATION IS NEEDED TO ANSWER THE QUESTION.

21. WHAT DIAGNOSTIC CHARACTERISTIC MAY BE USED TO DISTINGUISH FOSSIL BIVALVES (CLAMS) FROM OTHER COMMON MARINE INVERTEBRATES?
A. SHELLS COILED IN A PLANE
B. SHELLS COILED IN A SPIRE
C. PENTAMERAL (FIVE-RAYED) SYMMETRY
D. MIRROR PLANE OF SYMMETRY CUTS THROUGH OR ACROSS THE SHELLS
E. MIRROR PLANE OF SYMMETRY GOES BETWEEN THE SHELLS

22. A METAMORPHOSED ROCK LAYER LIES BELOW AN UNMETAMORPHOSED SEDIMENTARY ROCK LAYER. THE METAMORPHISM, THEREFORE, MUST HAVE OCCURRED:
A. AFTER BOTH LAYERS WERE DEPOSITED.
B. BEFORE THE SEDIMENTS OF THE TOP LAYER WERE DEPOSITED.
C. AT SOME TIME SINCE COMPACTION OF THE TOP UNIT.
D. BEFORE BOTH LAYERS WERE DEPOSITED.
E. NONE OF THESE CHOICES.

23. WHERE WOULD YOU EXPECT GROUNDWATER EROSION TO BE EXCEPTIONALLY WELL-DEVELOPED?
    A. IN THE LIMESTONES OF FLORIDA
    B. IN THE BASALTS OF HAWAII
    C. IN THE SANDSTONES AND SHALES OF LOUISIANA
    D. IN THE GRANITES OF THE SIERRA NEVADA MOUNTAINS
    E. IN THE GNEISSES AND GRANITES OF CANADA

24. ON A TOPOGRAPHIC MAP, A SERIES OF CONCENTRIC CLOSED CONTOURS WOULD INDICATE:
    A. AN ANTICLINE.
    B. A BATHOLITH.
    C. A CLIFF.
    D. A HILL.
    E. A STREAM VALLEY.

ANSWER THE FOLLOWING IN ONE OR TWO PARAGRAPHS:

25. A THIRD GRADE STUDENT COMES TO YOU WITH A PIECE OF SANDSTONE SHE HAS FOUND. YOU SHOW HER THE LAYERS IN THE ROCK AND THE SMALL MINERAL GRAINS THAT MAKE UP THE ROCK. DISCUSS HOW YOU WOULD EXPLAIN SEDIMENTARY ROCK FORMATION TO THIS STUDENT.

26. SKETCH A CROSS-SECTION OF PART OF THE EARTH'S CRUST WITH AN UNCONFORMITY (DISCONFORMITY, ANGULAR UNCONFORMITY, OR NONCONFORMITY). LABEL THE TYPE OF UNCONFORMITY YOU HAVE DRAWN AND NUMBER THE ROCK UNITS FROM OLDEST (#1) TO YOUNGEST.

27. THERE HAS BEEN A NET LAND LOSS ALONG THE LOUISIANA COAST DURING THE PAST 50 YEARS. USING WHAT YOU HAVE LEARNED ABOUT NATURAL PROCESSES (STREAM AND WAVE ACTION) AND HUMAN ACTIVITY (MAN-MADE LEVEES, OYSTER REEF MINING), BRIEFLY EXPLAIN WHY LOUISIANA IS LOSING LAND AND WHAT MIGHT BE DONE TO EITHER SLOW OR STOP THE LAND LOSS.

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