

BELLWORK AS A STRATEGY TO INCREASE STUDENT'S ABILITY TO
ANALYZE GRAPH AND CHART DATA

by

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TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND1

2. CONCEPTUAL FRAMEWORK3

3. METHODOLOGY7

4. DATA AND ANALYSIS15

5. INTERPRETATION AND CONCLUSION27

6. VALUE30

REFERENCES CITED32

APPENDICES34

 APPENDIX A IRB Approval Form35

 APPENDIX B CITI Program Certificate40

 APPENDIX C ACT Science Test 2014-2015 Form 67C42

 APPENDIX D Likert Pre and Post Survey55

 APPENDIX E ACT Science Bellwork57

 APPENDIX F ACT Science Test 2016-2017 Form 72CPRE66

 APPENDIX G ACT Science Pretest and Posttest Scores79

 APPENDIX H Raw Excel Data82

LIST OF TABLES

1. Participant Demographic Data	9
2. Data Triangulation Matrix	11
3. Likert Survey Coding.....	14
4. ACT Science Pretest and Posttest Scores in a Paired t-Test.....	16
5. ACT Science Pretest and Posttest by Passage Type	16
6. ACT Science Pretest and Posttest by Passage Type of Questions Attempted.....	18
7. Likert Survey Mode Scores by Category	22
8. Student Discussion Results by Topic Responses.....	27

LIST OF FIGURES

1. ACT Science Pretest and Posttest by Passage Type18

2. ACT Science Pretest and Posttest by Passage Type of Questions Attempted.....19

3. ACT Science Pretest and Posttest by ELL, IEP students21

4. Likert Survey Mode Scores by Category23

5. Control Group Pre and Post-Survey Responses.....24

6. Experimental Group Pre and Post-Survey Responses25

ABSTRACT

Students leaving high school should possess certain tasks to be successful in the world. Reading, writing, and basic math skills seem obvious. However, in our ever-changing world where science and technology are advancing at a rapid pace, any adult consumer needs to be able to read data displayed as a chart or graph. This action research-based classroom project utilized the ACT science test as the basis for graph literacy. Data from student pre-and posttest scores are compared after three weeks of bellwork, lasting only 5-7 minutes per day. The small but significant increases in student confidence and skills, increased their number of completed questions and overall scores.

INTRODUCTION AND BACKGROUND

Project Background

I was a sophomore in high school when my geometry teacher told me I was a visual learner. We were discussing why I thought Algebra 1 was such a difficult class, but Geometry was so easy. My best friend felt the opposite was true. Graphs, triangles, and figures all made sense to me. I could “see it”, and yet my friend could not. I didn’t give it much thought until I received my ACT scores. I excelled at the test, but most noticeably in the science section, which my friends found very difficult. It was mainly graphs to read and analyze. One didn’t even need to remember much science to read the graphs. I couldn’t understand why everyone found it so hard.

Advance 20 years and I found myself teaching physical science to high school freshman. The students were all taking algebra and physical science at the same time; However, they could barely read a bar graph, which was not even an algebra skill. After my first year teaching the subject, I sought out to find a way to teach the students graphing without reteaching everything they were learning in algebra. This started my use of bellwork to teach graph literacy.

Problem Statement

This classroom research project involved evaluating the effectiveness of graph and chart related bellwork for student success in the science classroom. Bellwork was a required part of our school curriculum. It set the tone to start class on time and get students working quickly. Most colleagues used it to review the previous day’s main concept. I have been using this time to teach graph and chart reading.

The teaching methods I used are based on the American Modeling Teachers Association methods and curriculum. This involved hands on inquiry, regular laboratory experimentation, and application of mental models. The methods followed a routine where students addressed a misconception or lack of knowledge with laboratory or phenomenon based experimentation. Students presented their findings to their classmates in groups using whiteboards and worked toward forming a class consensus on the results. Students then applied their new model of the phenomenon to a new situation to be sure the method worked. Reworking of mental models was constant as new information was presented. Students were encouraged to create models with words, drawings, graphs, and equations when applicable. This method enforced the scientific method of discovery on a regular basis, but did not leave much room for standardized test practice. This led me to combine the bellwork section of class, which I did not see as useful, and the need for standardized test practice, into one.

The school's student population have typically done poorly on the science ACT section with an average score on the ACT Science of 14.7 out of 40 in 2013. This poor performance negatively impacted their composite score. I noticed a lack of graph reading skills in my freshman physical science class my first-year teaching at this school. I implemented a chart and graph reading bell work method two years ago. Last year, juniors came to me to tell me that the science ACT was everything they did in my class for bell work every day.

This research was to see if the use of the chart and graph bell work had an impact on student ability to read charts and graphs. In my school students took a science course based on their grade level. The freshman took a physical science course divided into two

sections, physics semester one and chemistry semester two. The students utilized graphs, in both semesters, from the lab work results. Sophomores took chemistry where they also incorporated basic graphs into their understanding of density and other concepts. The juniors I taught were in biology. They have already passed both physical science and chemistry.

If using graph and chart bell work made a difference for students in my biology class, then it should be recommended for all science courses to help students learn to analyze data. This will not only increase their understanding and conceptual knowledge in science class but give them the tools to do well on the science section of the ACT and produce graph literate adults as well. How does bellwork influence student performance and self-efficacy in graph reading and data analysis skills in the biology classroom?

CONCEPTUAL FRAMEWORK

The ability to read graphs is more than just a math and science skill. Data literacy is used in our everyday lives. Commercials on TV, products at the grocery store, and articles in the news expect their audience to be able to read charts and graphs. Along with that, the public needs to be able to recognize good data from skewed data when it comes to marketing.

The Need for Graph Literacy

Galesic (2009) assessed graphical literacy in adults regarding reading health-relevant risk information. His results show that about 15% of Americans were unable to read a bar chart or pie chart (Galesic, 2009). According to the US Census website, the American population was about 324 million. That worked out to around 48.6 million Americans who cannot read a bar or pie chart. According to the 2016 census about 280

million Americans had a high school diploma and about 95 million held a bachelor's degree (Census 2016). Over half of the Americans with a bachelor's degree could not read a bar chart or pie chart (assuming there are people who could who do not have a bachelor's degree). One would expect anyone with a high school diploma to be able to read a basic graph or chart.

Research has been done on teacher's effectiveness in reading graphs and creating graphical material for use in classrooms. Bowen and Roth (1999) analyzed the ability of pre-service science teachers to use data effectively. They found that few pre-service teachers, many with a bachelors or Master of Science, were able to utilize data literacy skills for creating classroom work for students. They made mistakes such as throwing out outliers in data, not drawing best fit lines, and not organizing data to find patterns. The pre-service teachers could not effectively create a research project of their own that collected good data. They concluded that pre-service teachers are not prepared to teach data literacy to students (Bowen & Roth 1999). Another study by Rule, Hallagan, & Shaffer (2009) evaluated graph teaching materials created from 72 pre-service elementary teachers. Thirty-five of these contained errors in vocabulary, over generalizing and nonspecific statements (Rule, Hallagan, & Shaffer, 2009). The ability to read graphs needs to be taught to students, but our teachers are underprepared in this area.

Techniques for Teaching Graphic Literacy

Masters' student research into this topic is not new. Action research has been completed on various methods to teach students to read and analyze graphs. Video games, analysis software such as Logger Pro, and Socratic seminars have been evaluated for their effectiveness in increasing graphing skills. TinkerPlots, used by O'Leary

(2015), is a graphing software that was utilized to teach students graphing literacy skills. The software teaches skills in a video game type setting. He saw a 53% increase in student's ability to prove a hypothesis, as well as increases in student motivation and vocabulary from using the program (O'Leary 2015). Vernier's program Logger Pro 3 was used in physics classes to assist students in graphing kinematics. Compared to paper question responses, the ability to create a video of the answer increased students' ability to analyze the shape of a graph. Adam Smith (2013) noticed fewer misconceptions and higher student motivation when using the software (Smith, A., 2013). Jennifer Smith's (2014) action research used Socratic seminars to allow students to discuss and defend ideas based off graphical data. Student discussions not only increased student success in graphing, but student confidence as well (Smith, J., 2014). Not every science class has the access to technology on a regular basis. Subscriptions to software and Vernier probes are expensive and outside of many district's budgets. Socratic seminars are effective if the teacher is properly prepared and the class is small enough to allow participation in a short class period. Technology and discussion formats are showing gains but what about teachers who do not have the training or budget for these methods?

Students should be able to read and analyze a graph before they leave high school. These everyday reasoning skills should be part of a good well-rounded science and math curriculum. Malamitsa, Kokkotas, and Kasoutas (2008) used a tool entitled "The Test for Everyday Reasoning", developed by Facione, to determine the ability of multiple ages of students in Greece to interpret graphs. This test gauges critical thinking skills through a series of questions including data and chart reading. Nine of the questions from the test covered graphs and charts. Both the primary and secondary students scored a median of

three out of nine questions, while university students' median was a seven (Malamitsa, Kokkotas, & Kasoutas, 2008). High school students scoring in the 33% range is not a very encouraging result. More needs to be done to teach students to read graph and chart data.

The ACT Science test was a set of six to seven passages about a scientific experiment or study followed by six to seven questions pertaining to the passage. Questions fell into three categories: research summaries, data representation, or conflicting viewpoints. Research summaries tested knowledge of the scientific method, proper design, identification of facts, graph literacy and application to new hypotheses. The data representation passages were followed by questions pertaining to facts, graph literacy, identifying trends, and calculations. The conflicting viewpoint category involved identifying similarities and differences between two viewpoints. The viewpoints are then used to answer questions about which data fits which hypothesis the best. (Seigal, 2015)

The method I am proposing will make use of small amounts of class time daily to incorporate graph reading into any curriculum. By using a graph analysis question as a daily bell work activity, students will be exposed to graphs daily in their science classes and this may influence their graph literacy.

METHODOLOGY

Introduction

This research project explored the influence of daily bellwork on ACT science test scores. The research question which was addressed was: How does bellwork influence student performance and self-efficacy in graph reading and data analysis skills

in the biology classroom? I taught two sections of high school Biology to juniors. My colleague taught the other two sections of Biology and her students were used as the control group.

Participants

The participants in this experiment included all students in my junior level Biology course and all students in my colleague's junior level Biology course as the control. My colleague and I each taught half the Biology students. We used the same room, same curriculum, and similar teaching styles. She is 20 years my elder but has only been teaching two years longer than me. We both pursued science in our undergrad, with a medical focus (hers in nursing and mine in veterinary medicine). We both taught preschool while our children were young, and then pursued high school teaching when our children were grown. My colleague taught eighth grade science for six years before she joined the high school two years ago. This was her first year teaching a full year Biology course. I taught ninth grade physical science for five years. This was my first year teaching a full year Biology course. Most of our students had my colleague as their eighth grade science teacher, and myself as their ninth grade science teacher.

The school I worked at specializes in preparing students for college. The school, a public charter school, served approximately 500 high school students in an inner city setting. The school has a very diverse population with most of their students being first or second-generation Americans. Many students lived in refugee camps for years without formal education before attending Horizon. The US Together refugee resettlement group in Columbus states that the average refugee spends nine years in a camp before being resettled into a resident city. Of the one million refugees on Earth,

only 1% are resettled into a new home country. Columbus Ohio has been accepting refugees for over a decade. The school was a Title 1 school with a 100% free and reduced lunch population. All students completed physical science as a freshman, chemistry as a sophomore, biology as a junior, and physics as a senior (any student who fails a course would repeat it the following year). The school provided assistance to students through English Language Learner courses and special education services. The college counselors' office worked with juniors and seniors in courses that prepared them for college through application assistance, FAFSA assistance, scholarship assistance, test preparation, and essay writing.

Control group

The control group were the students in my colleague's two biology courses. The demographics for this group are also in Table 1. The 37 students in the course included 12 males and 25 females. The classes had a similar diverse breakdown including three white students, 27 black students (12 African American, eight Somali, seven West African), three Latino, one Asian, two mixed race, and one student reporting as other. This student group included no English language learners or IDEA eligible students. Thirty-six students in this course were juniors, and one was a freshman who transferred to our school at the end of the first semester.

Table 1
Participant Demographic Data

Category	Experimental Group (number of students)	Control Group (number of students)
Total number	33	37
Males	15	12
Female	18	25
Ethnicity (student identified)		
White	1	3
Black	27	27
African American	8	12
Somali	11	8
West African	7	7
East African (non Somali)	1	0
Latino	2	3
Asian	0	1
Mixed Race	3	2
Other	0	1
English Language Learner	7	0
IEP	4	0

Note. Control group. ($N=37$). Experimental Group. ($N=33$). Data compiled from the school database Concept CIS and student self-reporting.

Experimental group

This group was the two Biology courses that I taught. The demographics for this group are shown in Table 1. The group was comprised of 33 students; 15 males and 18 females. This included 1 white student, 27 black students (8 African American, 11 Somali, 7 West African, and 1 East African), 2 Latino (from different Caribbean Islands), and 3 multiracial. Of the 33 students, 7 were English Language Learners in their first 3 years speaking English in the United States. Four of the students are identified as IDEA (Individuals with Disabilities Education Act) eligible. Their diagnosis ranged from

ADHD to cognitive delays. Thirty-two students were juniors, and one was a freshman that transferred to our school second semester.

These two groups were comparable in background education, current teaching style, and content covered throughout the school year. It is of note that the experimental group had a number of English Language Learners (ELL) and students on an Individual Education Plan (IEP). It was not feasible to change students' schedules to even this out, so the data was analyzed with all student data presented in Table 1. Students who received credit for the Project Lead the Way Principles of Biomedical Science course did test out of Biology and therefor removed many of the top performing students from the Biology course. Students in both the control and experimental groups had used bellwork all year long, so the implementation of bellwork was not new. Bellwork was a requirement of all courses that the students took over all years of high school. In Biology class, before the treatment began, the bellwork had focused on Ohio AIR test preparation through released questions.

Data Matrix

To assess the research question, I used the following three subquestions and data collection methods organized in Table 2.

1. How does bellwork influence student graph reading and data analysis skills?
2. How does bellwork that uses a step-by-step approach, influence student resiliency on problem solving tasks?
3. How does bellwork influence student confidence regarding their graphing and data analysis skills?

Table 2
Data Triangulation Matrix

	Data Collection Tools		
Question #1 Data Analysis Skills	Pre/Post Test ACT Science Scores	Daily Journals Student answers	Class Discussions Student answers
Question #2 Resiliency on Problem Solving	Pre/Post Test Number of questions answered	Likert Survey Ability and attitude category	Class Discussions Student answers
Question #3 Confidence in Skills	Likert Survey Confidence category	Class Discussions Confidence category	

The results of these collection tools were run through statistical analysis to test for significance in data differences. The ACT Science Pre and Post test scores were compared with a paired t-test. The survey results for pre and post survey were compared with an ANOVA test. Class discussion answers were also taken into consideration so that data could be triangulated for a result.

Data Collection Method 1

Experimental Group Procedures

Research Subquestion: How does bellwork influence student graph reading and data analysis skills?

This procedure was followed with both biology classes that I taught and all students in both classes. IRB approval (Appendix A) was granted and CITI certification (Appendix B) was completed before this experiment began.

Step 1: Students took a released ACT science test (2014-2015, Form 67C, Appendix C) to get baseline pretest scores. The test is timed at 35 minutes for 40 questions.

Step 2: Students were given a Likert survey (Appendix D) immediately following the ACT science test from Step 1.

Step 3: ACT scores were analyzed to see if there is a certain type of question that the students are more successful with or not.

Step 4: Experimental group students were given an ACT Prep Bellwork prompt (Appendix E) from the released ACT test (2014-2015, Form 67C, Appendix C) they used for the pretest. The teacher helped the students work through the passages in a systematic approach during bellwork time, the first five minutes of class. The bellwork and practice time was used for 15 days. The control group did not do the ACT Prep Bellwork.

Step 5: Both experimental and control group students were given a different science ACT test (2016-2017, Form 72CPRE, Appendix F) to see if their skills transferred to another test.

Step 6: Both experimental and control groups were given the same Likert Survey (Appendix D) immediately following the ACT Science test from Step 5.

Step 7: The results of Test 2016-2017, Form 72CPRE were analyzed to see if any questions were more successful than others. The Test 2016-2017, Form 72CPRE results were compared to the Test 2014-2015, Form 67C results to see if the students increased their scores. A paired t-test was used for statistical analysis.

Step 8: Student science journals were collected so that student bellwork can be read.

The control group completed the pretest and posttest on the same days as the experimental group. The control group answered the Likert survey (Appendix D) on the same day as well. The rest of the treatment was applied to the experimental group only.

The ACT tests given were from released ACT science tests. The ACT Science practice test from 2014-2015, Form 67C (Appendix C), was used as a pretest and the ACT Science practice test from 2016-2017, Form 72CPRE (Appendix F), was used as a posttest. The answer sheet for the test was printed from the GradeCam website. This allowed for the quick grading of the test through the GradecamGo! Application. The GradeCam software allowed for the data to be downloaded for analysis in three ways - by class, by individual, or by question.

Data Collection Method 2

Likert survey

Research Subquestion: How does bellwork that uses a step-by-step approach, influence student resiliency on problem solving tasks? How does bellwork influence student confidence regarding their graphing and data analysis skills?

A Likert survey (Appendix D) was developed to address student opinions on resiliency and confidence in their ability to take the ACT science test. This survey was given to students at the end of the pre-and post-test immediately after finishing the test. Again, the answers to the survey were collected through a GradeCam answer sheet for easy grading and data collection. Using the GradeCam answer breakdown allowed identification of students' answers. These results were also downloaded to an Excel spreadsheet and the answer choices were quantified. A comparison was made of the pre-and post-survey results to see if individual students had a positive or negative response to the ACT test prep bellwork.

This data was compiled by the three types listed in Table 3 and an average score was determined for each category. The survey included a scale of strongly agree, agree,

no opinion, disagree and strongly disagree. Points will be assigned to the scale from +2, +1, 0, -1, and -2 points respectively. Questions were worded so that a positive or negative change in score was quantified for each question asked from the beginning to the end of the treatment period.

Table 3
Likert Survey Coding

Answer Choice	Assigned Letter on Answer Sheet	Score Given to Answered response
Strongly Agree	A	+2
Agree	B	+1
No Opinion	C	0
Disagree	D	-1
Strongly Disagree	E	-2

The data collected was analyzed for statistical differences by an ANOVA test. The pre and posttest results for each question were ran with an ANOVA for all 10 questions on the survey. These questions addressed a student's ability to complete the test on time, and the student's confidence in finding the correct answer.

Data Collection Method 3

Student Discussions

Research Subquestion: How does bellwork influence student confidence regarding their graphing and data analysis skills?

As students attempted their bellwork assignments they could work in table groups to answer the questions to a passage. The teacher would assist and prompt students

through questioning to help them learn to read the graph data. Student responses during the sessions were recorded on paper by the teacher.

Methods Summary

These methods allowed collection of data from many students easily. The pre- and posttests and student surveys were administered to all students in both experimental and control classes. Daily journals of bellwork and class discussions were from the experimental group only.

DATA AND ANALYSIS

Data Collection

The research questions and collection methods previously described yielded a significant amount of data. The Data Triangulation Matrix in Table 2 was the basis for all data collection and subsequent analysis. After the pretest the students were organized by increasing test scores, on the pretest, and assigned unique ID numbers accordingly. The number of correct answers and number of questions attempted for both the pretest and posttest are listed in Appendix G and Table 4 and Table 5 along with the percent change in scores. Students who were not present to take the pretest or the posttest were not used in the data set.

Table 4
ACT Science Pretest and Posttest Scores in a Paired t-Test

Control Group			Experimental Group		
t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
	<i>C Pre</i>	<i>C Post</i>		<i>E Pre</i>	<i>E Post</i>
Mean	11.62	13.24	Mean	9.18	13.06
Variance	20.13	16.69	Variance	12.53	43.18
Observations	37.00	37.00	Observations	33.00	33.00
Pearson Correlation	0.44		Pearson Correlation	0.30	
Hypothesized Mean Difference	0.00		Hypothesized Mean Difference	0.00	
df	36.00		Df	32.00	
t Stat	-2.16		t Stat	-3.46	
P(T<=t) one-tail	0.02		P(T<=t) one-tail	0.00	
t Critical one-tail	1.69		t Critical one-tail	1.69	
P(T<=t) two-tail	0.04		P(T<=t) two-tail	0.00	
t Critical two-tail	2.03		t Critical two-tail	2.04	

Note. Control group. ($N=37$). Experimental group. ($N=33$).

Table 5
ACT Science Pretest and Posttest by Passage Type

Category	Control Group			Experimental Group		
	Pretest Average Score	Posttest Average Score	% change	Pretest Average Score	Posttest Average Score	% change
Research Summary Total	41%	37%	-10%	31%	32%	3%
Data Representation Total	19%	22%	16%	18%	28%	56%
Conflicting Viewpoints 1	26%	26%	0%	13%	43%	231%
Total Test Scores	29%	33%	14%	23%	33%	43%

Note. Control group. ($N=37$). Experimental group. ($N=33$).

Analysis of Pretest and Posttest Data

The mean scores for the experimental and control groups were compared with a paired T test as shown in Table 4. The t-test run on the pre and post test scores for the control rejected the null hypothesis that there is no difference between the pretest and post test scores for the control. The $p(T \leq t)$ value was 0.04, less than that 0.5 needed to accept the hypothesis. The t-test run on the experimental group's pretest and posttest scores had the same conclusion of rejecting the null hypothesis that there is no difference with a $P(T \leq t)$ value of 0.0.

The raw data downloaded in a color coded Excel spreadsheet (Appendix H). The correct answers, in white, were changed to a number 1 to calculate the number of correct answers. The pink boxes showed incorrect answers. The blank, or unanswered boxes, were filled in with red. When the data was printed and layed out on a desk to view, the number of unanswered questions was a glaring piece that was not considered in the setup of this experiment. The control group answered more questions in the post test than the pretest. The experimental group answered more questions in the post test than the pretest as well. It would have been inaccurate to use the total score data without taking into account the number of questions attempted.

The ACT science tests were analyzed by passage type. The results of the three types of passages are shown in Table 5, Table 6, Figure 1 and Figure 2.

Table 6
ACT Science Pretest and Posttest by Passage Type of Questions Attempted

Category	Control Group			Experimental Group		
	Pretest Average Score	Posttest Average Score	% change	Pretest Average Score	Posttest Average Score	% change
Research Summary Total	44%	43%	-2%	34%	37%	9%
Data Representation Total	30%	29%	-3%	31%	35%	13%
Conflicting Viewpoints 1	40%	44%	10%	21%	44%	110%
Total Test Scores	39%	40%	3%	37%	39%	5%
% Questions answered	78%	78%	0%	73%	81%	11%

Note. Control group. ($N=37$). Experimental group. ($N=33$).

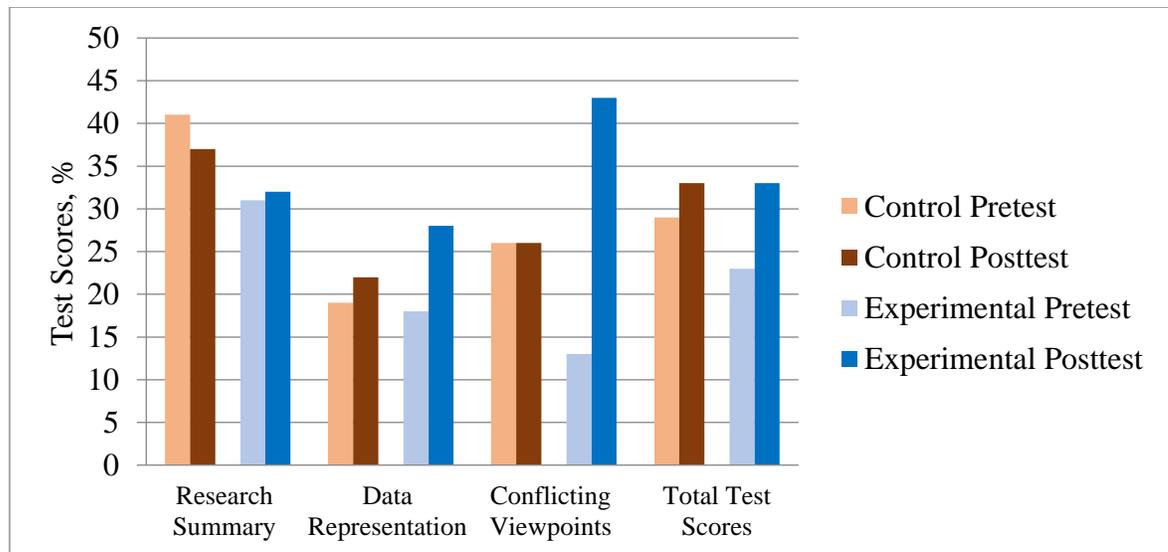


Figure 1. ACT science pretest and posttest scores in percentage correct by passage type, ($N=70$).

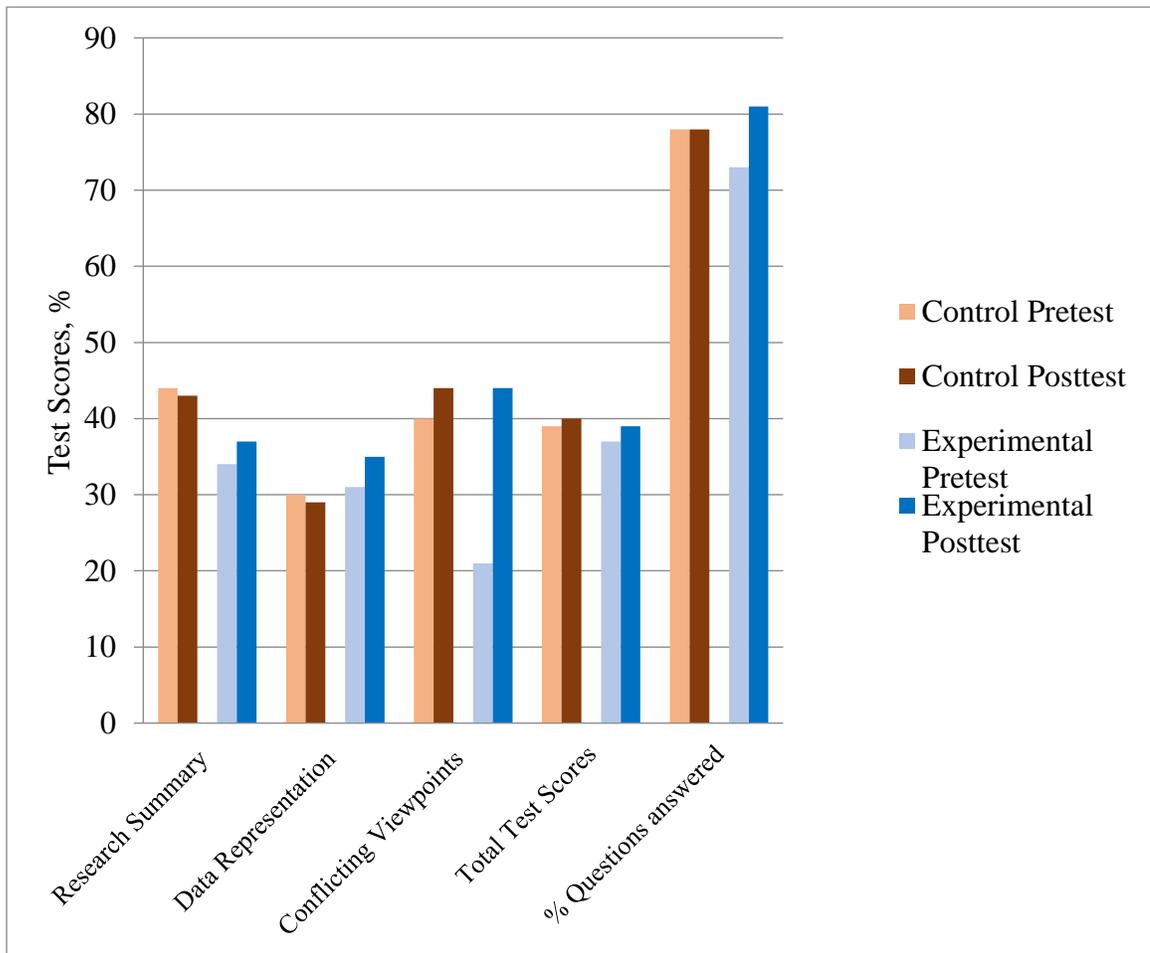


Figure 2. ACT science pretest and posttest scores in percentage of questions correct out of number of questions attempted by passage type, ($N=70$).

It is important to note that there were minor differences in the number of questions for each section between the pretest and posttest. The Research Summary passages had 18 questions in the pretest and 20 questions in the posttest. The Data Representation passages had 15 questions in the pretest and 13 in the post. The Conflicting Viewpoints passages had seven questions in the pretest and seven in the post. The percentage results shown in Table 5 and Table 6 are based on the number of correct answers for each of these question types.

The students in the experimental group increased in their ability to answer all question types, and the overall score showed a percent change of 43% compared to the control groups' percent change of 14% as shown in Table 5. Initial analysis of the data showed that students in the experimental group completed more questions in the posttest than the pretest. The adjusted score was calculated using the number of questions completed, instead of the total possible, this data was compiled in Table 6. Again, an increase was shown. The students not only completed more questions, but also had more correct answers.

The experimental group showed a percent change of five percent total correct, compared to the control's percent change of three percent. However, the experimental group answered 11% more questions on the posttest, while the control answered the same amount on both the pretest and posttest. Increasing the student's number of answered questions did increase the student's overall score.

Analysis of Treatment on Special Groups

A large population, about 75%, of HSA students did not speak English at home. Many students were in ELL, English Language Learner, course while enrolled at the high school. These students received education on speaking, reading, and writing in English. Also, around five percent of the students were enrolled in special education services for cognitive delays, attention deficit, or other learning disabilities that required an IEP, individualized education plan. The ACT is written in college level language that could impact a student's ability to read the test, and therefore answer the questions correctly.

The data was broken down to compare the impact of this treatment to ELL or IEP students. All students who were ELL or IEP were in the experimental group. Their results are compared to the rest of the students in the course in Figure 3.

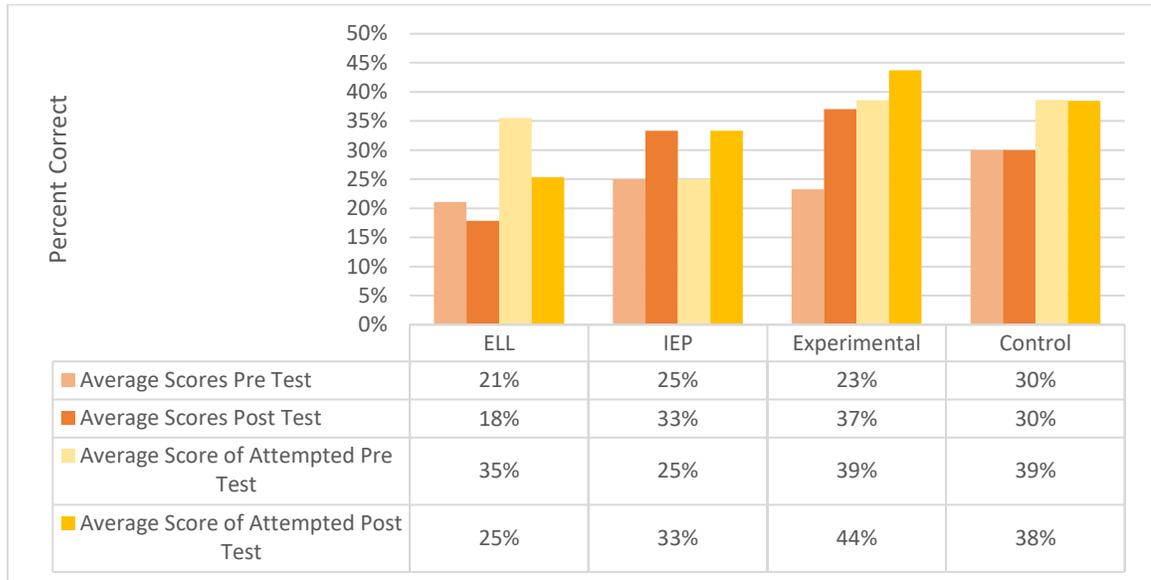


Figure 3. Average test scores for ELL (N=7), IEP (N=3), the rest of the experimental group (N=23), and the control group (N=37).

Students who are ELL decreased their scores after the treatment. Even when the data considered the questions they attempted, and not unanswered questions, their scores still decreased. IEP students showed similar increases to the rest of the experimental group.

Analysis of Likert Survey Data

The Likert Survey was split into three categories for analysis. Questions pertaining to the ability to complete the test (questions 1 and 2), confidence in answering questions on the test (questions 3 through 7), and attitudes toward taking the test (question 10) (Table 7). The Likert Survey asked students to answer Strongly Agree, Agree, No opinion, Disagree, or Strongly Disagree to a series of statements. The options

were scored as 2, 1, 0, -1, and -2 respectively in the spreadsheet. The mode of each question was then found and reported in Table 7 and Figure 4. All responses for the control and experimental groups are recorded in Figure 5 and Figure 6.

Table 7
Likert Survey Mode Scores by Category

Category	Control Group (N=37)		Experimental Group (N=33)	
	Pre-Survey Mode	Post-Survey Mode	Pre-Survey Mode	Post-Survey Mode
Ability to complete the test				
Question 1	-1	2	-1	2
Question 2	0	1	1	1
Confidence in answering questions on the test				
Question 3	-1	-1	0	1
Question 4	1	0.5	1	1
Question 5	1	1	1	2
Question 6	1	1	1	1
Question 7	1	1	1	2
Attitudes toward taking the test				
Question 10	0	0	0	1

Note. 2=Strongly Agree, 1=Agree, 0=No Opinion, -1=Disagree, -2=Strongly Disagree. (N=70).

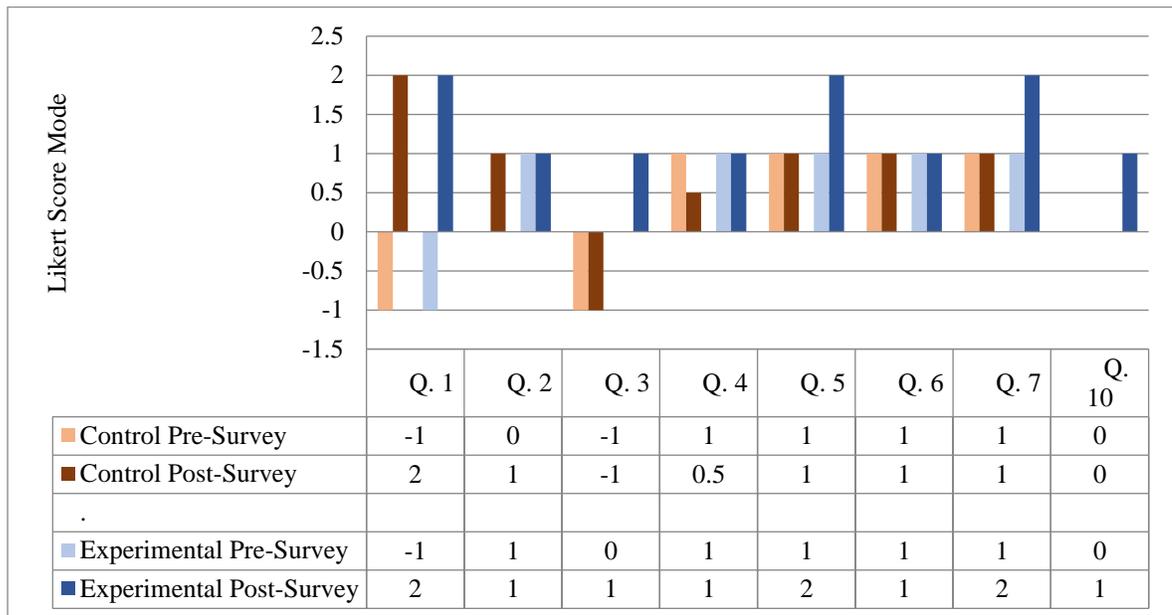


Figure 4. Likert survey mode scores by category. Pre and post survey modes are shown for the control and experimental groups for each of the ten questions, ($N=70$).

Students in both the control and experimental groups increased from a -1 (disagree), to a 2 (strongly agree) for the first question about time to finish the test. Looking at individual student responses, there is a shift toward strongly agree. This shows that more students in the control group were able to complete the test with 14 responding agree or strongly agree in the pre-survey, and 18 responding the same in the post-survey. However, the control group answered the same average number of questions on both the pretest as the posttest according to Table 6. The experimental group had a similar increase from 12 pre-survey to 18 post-survey choosing to agree or strongly agree for having enough time to complete the test, however, the experimental group did increase in the number of questions the students were able to answer by 11% according to Table 6. So, students in both groups felt like they had more time during the posttest, but only the experimental increased in questions answered.

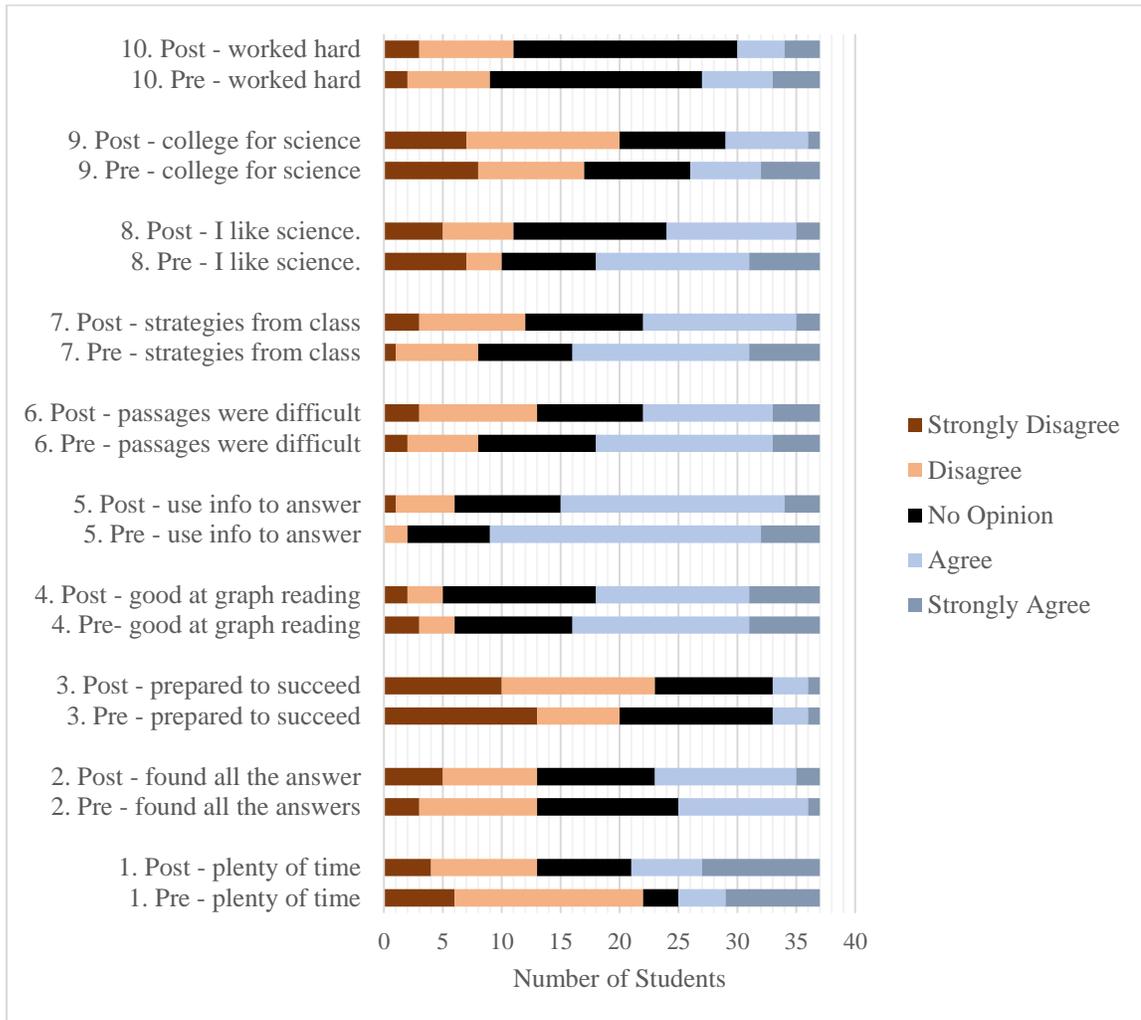


Figure 5. Pre and post survey responses for the control group by the number of responses for each question, (N=37).

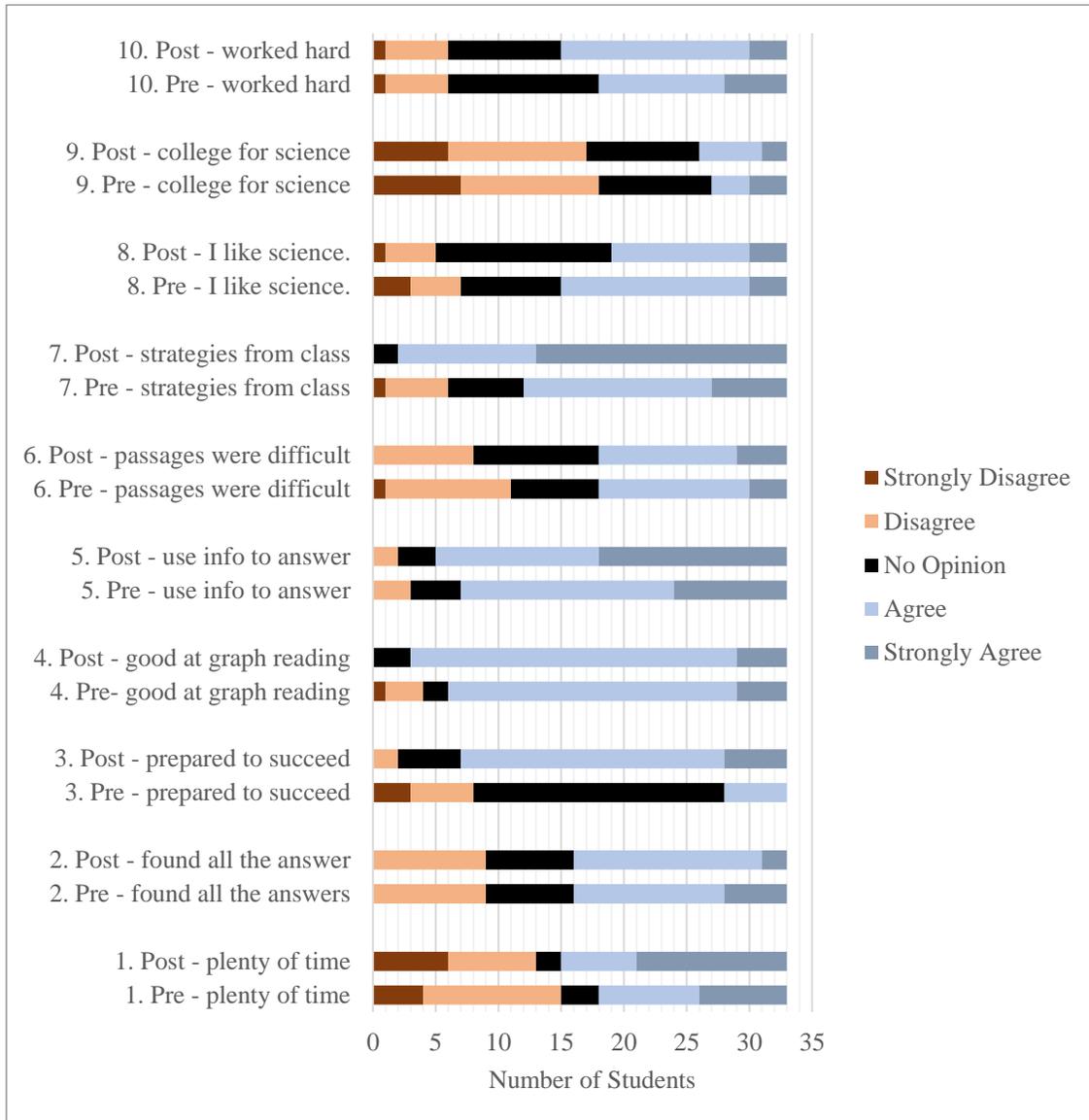


Figure 6. Pre and post survey responses for the experimental group showing increased confidence in questions 3, 4, 6 and 7, (N=30).

Student responses to the ability to answer all the questions show little change. This is consistent with the student’s scores for the attempted questions which only increased by five percent for the experimental, and three percent for the control. In both groups the students’ confidence in the ability to find the answers did not change. The control group survey data showed little change for all questions asked (Figure 5). The

experimental group had large increases in the students' confidence at graph reading (question 4) where no students disagreed in the post survey (Figure 6). They also reported more favorably at feeling prepared to succeed on the test (question 3). Students reported on the post test that they used the strategies presented in class to answer the questions (question 7).

An ANOVA test was run for all ten questions comparing the control pre and post survey data and the experimental pre and post survey data. Questions 1,3,4,5,7, and 10 all had a p value under 0.5 indicating they are statistically significant. These questions focus on time management, preparation for success, graph reading confidence, reading graphs, classroom strategies, and working hard on the test to increase their chance of getting into college. A significant increase in the students' responses regarding time management and ability to read the graphs using the classroom strategies all go together. Their confidence in taking the test went up because they felt prepared to be more successful on the test. I was surprised, but excited, to see that the responses to question 10 went up indicating they were taking the test seriously and working hard on the test.

The questions which were not statistically significant, 2, 6, 8 and 9 were the ability to find all the answers, the reading passages were difficult, liking science, and planning to attend college for science. This just means that there were minor changes to the student's ability to improve on finding the answers. They also had minimal changes on the difficulty of the passages. By changing the pretest and posttest this could happen with each new ACT test they try. More data from more ACT Science tests would be necessary to explore this more. It did not surprise me that the changes in the students liking of science and choosing a science major was minimally impacted and not

significant. I did not expect learning to pass the ACT in science to spark an interest in science.

Student discussion data was compared qualitatively by response topics. The topics have been collected in Table 8 according to the questions found in Appendix B's survey. These responses were representative of the many responses recorded as I questioned students to help them with their daily bellwork and using the strategies.

Table 8
Student Interview Results by Topic Responses

Question	Sample Response
1	The questions ask too much.
2	I didn't even read all the questions – not enough time.
3	When you don't read the passage, it is less confusing. I'm just reading graphs now.
4	I can read the graphs easier than I can read the passages.
5	
6	I don't even know what this passage is about.
7	Yes – Not reading passages I answered more questions.
8	
9	

Most of the student's responses were similar from group to group, and between the two classes. The overwhelming theme was that the test was too long for the time given, and that the reading passages included too many words the students did not know. After teaching the students to skip the passages and focus on the questions and graphs, students felt more confident to answer more questions correctly.

INTERPRETATION AND CONCLUSION

The data collected was used to answer the research questions asked in this study. The use of bellwork, just 5 minutes a day, did increase the students' success, confidence, and resiliency on the ACT Science test. The experimental group showed gains in all

three passage types on the posttest. They also answered 11% more questions on the posttest than the pretest. The experimental groups survey responses were consistent with their results showing students who were more confident to move through the material, answer more questions, and read the graphs.

Evidence of Results

Research Question: How does bellwork influence student performance and self-efficacy in graph reading and data analysis skills in the biology classroom?

Subquestion 1: How does bellwork influence student graph reading and data analysis skills?

The data shown in the study indicates that the bellwork time was effective in increasing the student's graph reading and data analysis skills. The test scores increased by five percent in the experimental group compared to the control group's three percent increase when you look at the questions they attempted. The students work in class showed their understanding as they practiced problems and worked them out in their groups. A big increase in their ability was more the language of the graphs than the math involved. Student's did not know what "Figure 1" meant, so they were often looking at graph titles to guide them to the graph of interest instead of the graph the question told them to look at. This simple explanation brought many "Ooohhhh" reactions from the students. They were spending more time finding which graph to read than needed. By learning the language, the test used the students could find the correct graph and use their existing skills to read the graph.

Subquestion 2: How does bellwork that uses a step-by-step approach, influence student resiliency on problem solving tasks?

Resiliency was shown by the number of questions the students answered. The average number of questions answered for the control group did not change. However, the experimental group increased by 11%. The students were able to answer more questions and complete more of the test. This showed up in their surveys as they indicated they felt prepared to succeed, were good at graph reading, and used the information to answer the test questions. As the students worked on problems in class they became faster at finding answers and reading the graphs, and therefore were completing more questions during the bellwork time as the weeks went on. The strategy of teaching the students to skip the passages and go straight to the questions and graphs led to student resiliency. One student stated, “When you don’t read the passage, it is less confusing. I’m just reading graphs now”. This allowed students more time to find more correct answers.

Subquestion 3: How does bellwork influence student confidence regarding their graphing and data analysis skills?

The student’s confidence in their ability was shown in the Likert Survey. Again, their reporting of feeling prepared to succeed, good at reading graphs and being able to find the answers created confidence in the students which led to resiliency. In class, students needed less help finding answers, and just reassurance that their answers were correct. Students stated, “I can read the graphs easier then I can read the passages.” Learning to read the graphs was an easier skill then deciphering what the passages were about. Students developed the confidence to work independently and find answers on their own.

Overall, the combination of using bellwork to teach graph reading led to confidence which led to resiliency. The bell work, just three to five minutes a day, increased the students' abilities in three short weeks. This did not take time out of the regular Biology class or interfere with the standard curriculum for the course. When I use this again in the future, I will increase the weeks spent on the ACT preparation to increase students' time spent with the test. I would use one passage a week, instead of one passage type per week, so the students have more time to work out questions in class. Most science ACT tests have six to seven passages, so I would expand this treatment to six to seven weeks long to see if the increase in scores would improve.

This method did not benefit the ELL student population. The ACT science test is above their reading level which made the test very difficult for these students. From speaking with students in class, they did increase their ability to read and interpret graphs. However, the ACT science test was not a good indication of their abilities. The language used in the questions were difficult for the students to figure out what was being asked. The passages were almost unreadable to the ELL students.

VALUE

Giving students the tools to tackle the test paid off in both test scores, and student confidence. Just five minutes at the beginning of class made a difference in the student's ability. My administration has required bellwork as a portion of our lesson, however, I did not see the value in this exercise and sought out ways to make it worthwhile. This project has shown me that these have not been wasted minutes but have impacted student learning. I will continue to use bellwork as a teaching time to impress skills that are not specific to my curriculum, but still increase the student's skillset to better read scientific

data. This method should be expanded to other courses in the department to see if a large-scale change can be made in the students' ability to read charts and graphs.

Teaching students to read charts and graphs is a skill any person will use in their adult life. From determining calories in their fast food hamburger, to reading pamphlets at the doctor's office, data is used as evidence of discovery. Knowing how to read data accurately is important for understanding.

This experience has brought my teaching to a new level. I have always enjoyed working with data to see growth (or lack thereof) in my students work. Running a large-scale project such as this taught me to tie together what I wanted to test with the procedures needed to run statistical analysis. It's one thing to think a method is working, and another to prove that it does have significant impact. Going forward I would like to see the changes in student graph literacy when a whole year bellwork initiative is implemented.

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APPENDICES

APPENDIX A

IRB APPROVAL FORM

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt
MSSE Research Projects Only
(6/16/14)

THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.
Confirmation Date:
Application Number:

DATE of SUBMISSION: 12/5/2017

Address each section - do not leave any section blank.

I. INVESTIGATOR:

Name: **Jamie R. Doup**
Home or School Mailing Address: **11985 Trenton Rd., Galena, Ohio 43021**
Telephone Number: **614-202-2036**
E-Mail Address: **jmedoup@gmail.com**
DATE TRAINING COMPLETED: 2-25-2017 [Required training: CITI training; see website for link]

Investigator Signature 

Name of Project Advisor: **Marcie Reuer**
E-Mail Address of Project Advisor: **marcie.reuer@ecat.montana.edu**

II. TITLE OF RESEARCH PROJECT:

Bellwork as a Strategy to Increase Student's Ability to Analyze Graph and Chart Data

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a survey/questionnaire, provide a copy).

Forty-five students from two high school junior level biology classes will be participating in this study. Students will take a pretest and posttest that are both a released ACT science test. All students who take the pretest and posttest will also take a survey after each test. Nine students will be selected to participate in a voice recorded interview. Between the pre- and posttests, students will participate in daily bellwork exercises that teach graph reading skills based on the ACT science graphs they used for the pretest. A copy of the ACT released test, survey, and interview questions are attached to this file.

IV. RISKS AND INCONVENIENCES TO SUBJECTS (do not answer 'None'):

Students could experience stress and inconveniences in participant in the pretest and posttest ACT science administration. Students could be inconvenienced by participating in the interview portion of the experiment.

V. SUBJECTS:

- A. Expected numbers of subjects: 45
- B. Will research involve minors (age <18 years)? **Yes** - **Students will range from 16 to 19 years of age. To test the effectiveness of the treatment on high school students, it is not possible to wait until they are eighteen.**
(If 'Yes', please specify and justify.)
- C. Will research involve prisoners? **No**
- D. Will research involve any specific ethnic, racial, religious, etc. groups of people?
(If 'Yes', please specify and justify.) **No**

VI. FOR RESEARCH INVOLVING SURVEYS OR QUESTIONNAIRES:

(Be sure to indicate on each instrument, survey or questionnaire that participation is voluntary.)

- A. Is information being collected about:
- | | | |
|---------------------------------------|-----|-----------|
| Sexual behavior? | Yes | No |
| Criminal behavior? | Yes | No |
| Alcohol or substance abuse? | Yes | No |
| Matters affecting employment? | Yes | No |
| Matters relating to civil litigation? | Yes | No |
- B. Will the information obtained be completely anonymous, with no identifying information linked to the responding subjects? **Yes No**
- C. If identifying information will be linked to the responding subjects, how will the subjects be identified? (Please circle or bold your answers)
- | | | |
|----------------------------------|------------|-----------|
| By name | Yes | No |
| By code | Yes | No |
| By other identifying information | Yes | No |
- D. Does this survey utilize a standardized and/or validated survey tool/questionnaire? (If yes, see **IRB website for required wording on surveys and questionnaires.**) **Yes No**

VII. FOR RESEARCH BEING CONDUCTED IN A CLASSROOM SETTING INVOLVING NORMAL EDUCATIONAL PRACTICES:

- A. This research project must be approved by your Principal or School Administrator, unless there are circumstances or policies that do not make this possible. **Provide a copy of the principal's signed approval.** If such approval is not possible, please explain.
- B. **Participation of your students in research must be voluntary** and can never affect their rights. Please make this issue clear on all of your research surveys (use introductory text, see below) and/or interviews (use introductory verbal statement, see below). The following wording or something similar can be used for the introductory text or statement: **Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.**

- C. Extra credit should not be used to encourage participation. If you absolutely need to use extra credit, then an alternative activity involving the same amount of time and effort must be provided for those who choose not to participate. This must be clearly described in your IRB application.
- E. Depending on your school policies, **consent forms may or may not be required for your research**. Please indicate whether you will be using consent forms or not. If you are not using consent forms, please justify (e.g., school policy, etc.). **If you do use consent forms, you must include signature lines for parental consent AND student assent.** (Please use accepted format from our website and provide a stand-alone copy. Do not include form here.)

Jamie Doup
11985 Trenton Rd.
Galena, OH 43021

December 5, 2017

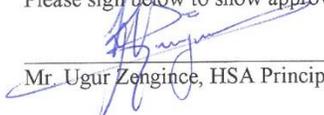
Mr. Ugur Zengince
Principal
Horizon Science Academy High School
1070 Morse Rd.
Columbus, OH 43229

Dear Mr. Zengince,

I am in my final year of my Master's of Science in Science Education degree through Montana State University. For degree completion I am conducting an action research project on utilizing bellwork to teach students graph and chart reading skills. Enclosed you can find my IRB application to Montana State University with the details of this study.

This project will run from January 2018 through February 2018 for the students in my two Biology courses. Students will participate in two ACT science practice tests, six weeks of bellwork exercises in graph reading skills, two surveys and select students will participate in two voice recorded interviews during their lunch period. All student and teacher names will be number coded to ensure confidentiality in this action research paper. This project will use two full class periods for administering of the ACT science pre-and posttests. Other than those days, this project will not affect the teaching of Biology to the students which will still take place daily during the treatment period after the ACT based bellwork.

Please sign below to show approval for this project.



Mr. Ugur Zengince, HSA Principal

12/06/2017
Date

Sincerely,

Jamie Doup
Science Department Head
Science Teacher
614-202-2036
jmedoup@gmail.com

APPENDIX B
CITI PROGRAM CERTIFICATE



Completion Date 25-Feb-2017
Expiration Date 25-Feb-2020
Record ID 22454414



This is to certify that:

Jamie Doup

Has completed the following CITI Program course:

Social and Behavioral Research Investigators/ Faculty (Curriculum Group)
Social & Behavioral Research - Basic/Refresher (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Montana State University



Verify at www.citiprogram.org/verify/?w6d263b86-c972-4284-9706-267a002804d8-22454414

APPENDIX C

ACT SCIENCE RELEASED PRACTICE TEST 2014-2015 FORM 67C PRETEST



SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are several passages in this test. Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

You are NOT permitted to use a calculator on this test.

Passage I

Finch beak depth (see Figure 1) is an *inheritable* trait (it can be passed from parents to offspring).



Figure 1

Researchers studied the beak depth of 2 species of finches, *Geospiza fortis* and *Geospiza fuliginosa*. Both species live on Island A. *G. fortis* alone lives on Island B, and *G. fuliginosa* alone lives on Island C. For both species, the primary food is seeds. Birds with shallower beaks can efficiently crush and eat only small seeds. Birds with deeper beaks can crush and eat both large and small seeds, but they prefer small seeds.

Study 1

Researchers captured 100 *G. fortis* finches and 100 *G. fuliginosa* finches on Island A. They tagged each bird, measured its beak depth, and released it. Then they calculated the percent of birds having each of the beak depths that had been measured. The researchers followed the same procedures with 100 *G. fortis* finches from Island B and 100 *G. fuliginosa* finches from Island C. The results of this study are shown in Figure 2.

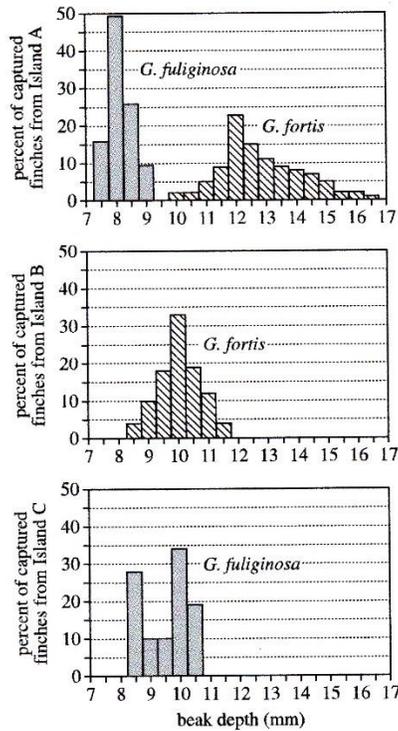


Figure 2

Study 2

After completing Study 1, the researchers returned to Island B each of the next 10 years, from 1976 to 1985. During each visit, the researchers captured at least 50 *G. fortis* finches and measured their beak depths. Then

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they calculated the average *G. fortis* beak depth for each of the 10 years. The researchers noted that, during the 10-year period, 3 years were exceptionally dry, and 1 year was very wet (see Figure 3). Small seeds are abundant during wet years. During dry years, all seeds are less abundant, and the average size of the available seeds is larger.

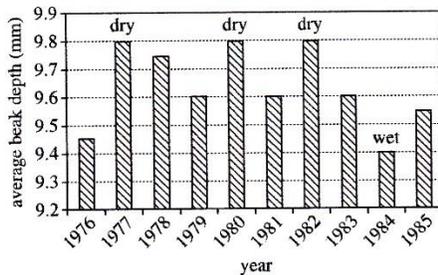


Figure 3

Figures adapted from Neil A. Campbell, Jane B. Reece, and Lawrence G. Mitchell, *Biology*, 5th ed. ©1999 by Benjamin/Cummings.

1. Based on the results of Study 1, the highest percent of finches on Island B and Island C had a beak depth of:

	Island B	Island C
A.	8 mm	8 mm
B.	9 mm	12 mm
C.	10 mm	8 mm
D.	10 mm	10 mm

2. During which of the following years were small seeds likely most abundant on Island B?

F. 1977
G. 1980
H. 1982
J. 1984

3. Study 1 differed from Study 2 in which of the following ways?

A. *G. fortis* finches were captured during Study 1 but not during Study 2.
B. *G. fuliginosa* finches were captured during Study 1 but not during Study 2.
C. The beak depth of captured birds was measured during Study 1 but not during Study 2.
D. The beak depth of captured birds was measured during Study 2 but not during Study 1.

4. It is most likely that the researchers tagged the birds that they captured during Study 1 to:

F. determine how beak depth was affected by rainfall on Island A.
G. determine the average age of each finch population.
H. ensure that the beak depth of each finch was measured multiple times during Study 1.
J. ensure that the beak depth of each finch was measured only once during Study 1.

5. Based on the results of Study 2, would a finch with a beak depth of 9.4 mm or a finch with a beak depth of 9.9 mm more likely have had a greater chance of survival during 1977?

A. A finch with a beak depth of 9.4 mm, because, on average, the size of available seeds is larger during dry years.
B. A finch with a beak depth of 9.4 mm, because, on average, the size of available seeds is smaller during dry years.
C. A finch with a beak depth of 9.9 mm, because, on average, the size of available seeds is larger during dry years.
D. A finch with a beak depth of 9.9 mm, because, on average, the size of available seeds is smaller during dry years.

6. A researcher hypothesized that there would be more variation in the beak depths measured for the *G. fortis* finches when they were forced to compete with another finch species for seeds. Do the results of Study 1 support this hypothesis?

F. Yes; the range of beak depths measured for *G. fortis* finches was greater on Island A than on Island B.
G. Yes; the range of beak depths measured for *G. fortis* finches was greater on Island B than on Island A.
H. No; the range of beak depths measured for *G. fortis* finches was greater on Island A than on Island B.
J. No; the range of beak depths measured for *G. fortis* finches was greater on Island B than on Island A.

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Passage II

Substances in the atmosphere, such as Cu^{2+} , Zn^{2+} , Cl^- , and SO_4^{2-} ions, are carried down to Earth's surface by precipitation. This process is known as *wet deposition*. Cu^{2+} and Zn^{2+} ions are put into the atmosphere by high-temperature combustion processes. The presence of Cl^- and SO_4^{2-} ions in the atmosphere can be attributed to road-salt dust and electrical power generation, respectively.

Study 1

A rain gauge, placed on the roof of a 1-story building, at a specific urban site was used to collect precipitation over a 12-month period. At the same time each evening, the amount of precipitation in the rain gauge was recorded, after which the collected precipitation was emptied from the gauge and stored. (Assume no measurable evaporation occurred during any day.) Figure 1 shows the measured monthly precipitation in centimeters.

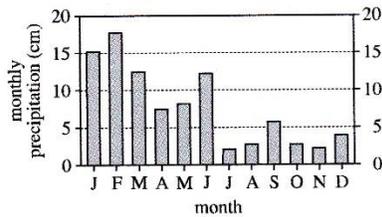


Figure 1

At the end of each month, all the samples collected during that month were mixed, and some of this combined sample was analyzed for the concentrations of Cu^{2+} and Zn^{2+} ions. Using these data, the monthly wet deposition of each substance, in micrograms (μg) per meter², was calculated (see Figure 2).

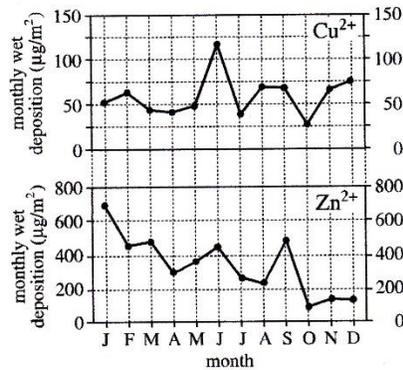


Figure 2

Study 2

Another portion of the combined sample for each month was analyzed for the concentrations of Cl^- and SO_4^{2-} ions. Using these data, the monthly wet deposition of each substance, in milliequivalents (meq) per m², was calculated (see Figure 3).

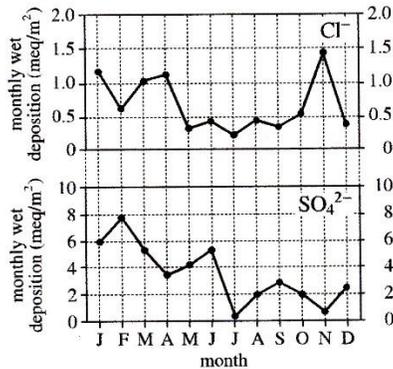


Figure 3

Study 3

The *annual* wet deposition of Cu^{2+} and of Zn^{2+} for the 12-month period, in $\mu\text{g}/\text{m}^2$, was calculated for the urban site (the source of the Cu^{2+} and Zn^{2+}) and also for Rural Sites 1 and 2, located 50 km and 100 km east, respectively, of the urban site (see Figure 4).

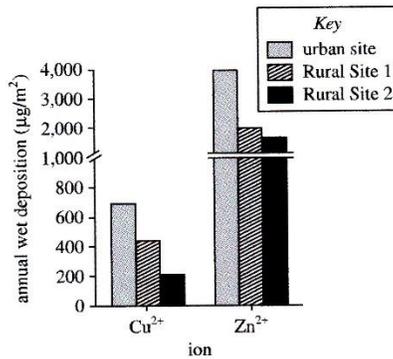
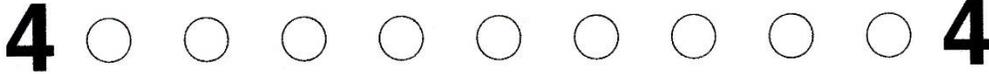


Figure 4

Figures adapted from Kathryn Conko et al., "Atmospheric Wet Deposition of Trace Elements to a Suburban Environment, Reston, Virginia, USA." ©2004 by Elsevier, Ltd.



7. According to Figure 1, over the 12-month period, the monthly precipitation at the urban site was maximum in February and minimum in July. According to Figures 2 and 3, the wet deposition of which ion was also maximum in February and minimum in July?
- Cu^{2+}
 - Zn^{2+}
 - Cl^-
 - SO_4^{2-}
8. Based on the results of Study 1, the average monthly wet deposition for Cu^{2+} over the 12-month period was:
- less than $50 \mu\text{g}/\text{m}^2$.
 - between $50 \mu\text{g}/\text{m}^2$ and $75 \mu\text{g}/\text{m}^2$.
 - between $75 \mu\text{g}/\text{m}^2$ and $100 \mu\text{g}/\text{m}^2$.
 - greater than $100 \mu\text{g}/\text{m}^2$.
9. Is the statement "The values for Cl^- wet deposition were greater during the winter and early spring when road salt is typically applied" supported by the results of Study 2?
- Yes, because Cl^- wet deposition values were, on average, greater from November to April than they were from May to October.
 - Yes, because Cl^- wet deposition values were, on average, less from November to April than they were from May to October.
 - No, because Cl^- wet deposition values were, on average, greater from November to April than they were from May to October.
 - No, because Cl^- wet deposition values were, on average, less from November to April than they were from May to October.
10. Suppose there had been no precipitation during 1 entire month of the 12-month period. Based on the information provided, during that month there would have been:
- significant wet deposition of all 4 substances.
 - significant wet deposition of Cu^{2+} and Zn^{2+} , but no wet deposition of Cl^- and SO_4^{2-} .
 - no wet deposition of any of the 4 substances.
 - no wet deposition of Cu^{2+} and Zn^{2+} , but significant wet deposition of Cl^- and SO_4^{2-} .
11. According to Study 3, as distance from the urban site increased, the annual wet deposition:
- increased for both Cu^{2+} and Zn^{2+} .
 - increased for Cu^{2+} but decreased for Zn^{2+} .
 - decreased for both Cu^{2+} and Zn^{2+} .
 - remained the same for both Cu^{2+} and Zn^{2+} .
12. Which of the following variables was kept constant in Study 2?
- Site
 - Monthly rainfall
 - Wet deposition of Zn^{2+}
 - Wet deposition of Cl^-

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage III

Cloud cover is the percent of Earth's surface covered by clouds. Cloud cover may increase because of an increase in the cosmic ray flux (number of high-energy particles from space reaching Earth per m² per hour). Table 1 shows how Earth's cover of low clouds (0 km to 3.2 km altitude) varies with the cosmic ray flux. Figures 1–3 show the relative cosmic ray flux, RCRF (the percent below the flux measured on October 1, 1965), and the monthly average cover of high clouds (6.0 km to 16.0 km altitude), middle clouds (3.2 km to 6.0 km altitude), and low clouds, respectively, from January 1980 to January 1995.

Cosmic ray flux (particles/m ² /hr)	Cover of low clouds (%)
340,000	27.8
360,000	28.1
380,000	28.4
400,000	28.7
420,000	29.0

Table 1 adapted from E. Palle Bagó and C. J. Butler, "The Influence of Cosmic Rays on Terrestrial Clouds and Global Warming." ©2000 by Institute of Physics Publications, Ltd.

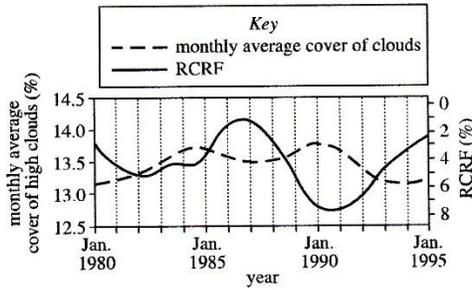


Figure 1

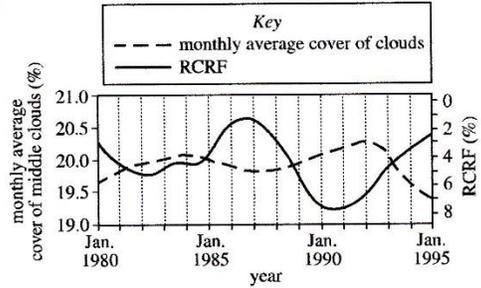


Figure 2

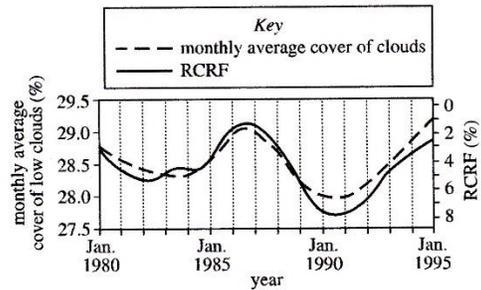
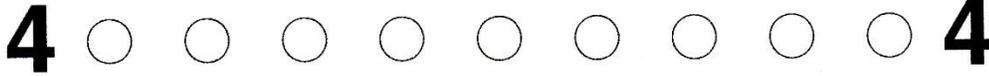


Figure 3

Figures adapted from Nigel Marsh and Henrik Svensmark, "Low Cloud Properties Influenced by Cosmic Rays." ©2000 by The American Physical Society.

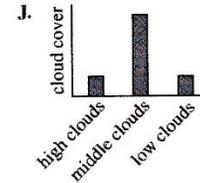
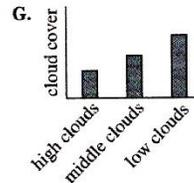
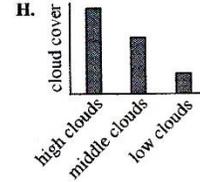
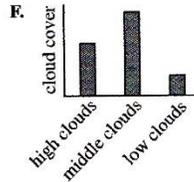


13. The percent of Earth's surface covered by high clouds in January 1987 was closest to which of the following?
- A. 13.0%
 - B. 13.5%
 - C. 14.0%
 - D. 14.5%

14. Based on Table 1, a cosmic ray flux of 440,000 particles/m²/hr would correspond to a cover of low clouds that is closest to which of the following?
- F. 28.7%
 - G. 29.0%
 - H. 29.3%
 - J. 29.6%

15. Is the statement "The monthly average cover of low clouds is more directly correlated with cosmic ray flux than is the monthly average cover of high clouds" consistent with Figures 1 and 3?
- A. Yes, because the plot for the monthly average cover of low clouds more closely parallels the plot for RCRF.
 - B. Yes, because the plot for the monthly average cover of high clouds more closely parallels the plot for RCRF.
 - C. No, because the plot for the monthly average cover of low clouds more closely parallels the plot for RCRF.
 - D. No, because the plot for the monthly average cover of high clouds more closely parallels the plot for RCRF.

16. Which of the following figures best represents the monthly average cover of high, middle, and low clouds in January 1992?



17. High clouds are composed primarily of ice crystals, whereas low clouds are composed primarily of water droplets. This difference is most likely because the average air temperature at altitudes from:
- A. 0 km to 3.2 km is at or below 0°C, whereas the average air temperature at altitudes from 3.2 km to 6.0 km is above 0°C.
 - B. 0 km to 3.2 km is at or below 0°C, whereas the average air temperature at altitudes from 6.0 km to 16.0 km is above 0°C.
 - C. 0 km to 3.2 km is above 0°C, whereas the average air temperature at altitudes from 3.2 km to 6.0 km is at or below 0°C.
 - D. 0 km to 3.2 km is above 0°C, whereas the average air temperature at altitudes from 6.0 km to 16.0 km is at or below 0°C.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage IV

Acid-base titration is a technique in which precise volumes of a *titrant* (an acid or base solution) are added incrementally to a known volume of a *sample solution* (a base or acid solution, respectively). This process can be monitored by adding an *acid-base indicator* (a substance that changes color over a certain pH range) to the sample solution or by measuring the sample solution's *conductivity*. Conductivity (measured in kilosiemens per centimeter, kS/cm) is a measure of a substance's ability to conduct electricity.

Two titration experiments were done at 25°C using a 0.10 M sodium hydroxide (NaOH) solution and either a 0.0010 M hydrochloric acid (HCl) solution or a 0.0010 M acetic acid solution (where M is moles of acid or base per liter of solution). All solutions were aqueous. An acid-base indicator solution of *nitrazine yellow* was also used. Nitrazine yellow is yellow if the pH is less than 6.0 or blue if the pH is greater than 7.0.

Experiment 2

Experiment 1 was repeated, except that the acetic acid solution was used instead of the HCl solution (see Figure 2).

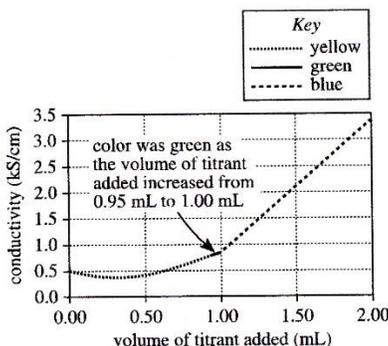


Figure 2

Figures adapted from J. West Loveland, "Conductance and Oscillometry," in Gary D. Christian and James E. O'Reilly, eds., *Instrumental Analysis*, 2nd ed. ©1986 by Allyn and Bacon, Inc.

Experiment 1

A drop of nitrazine yellow solution was added to a flask containing 100.0 mL of the HCl solution. A probe that measures conductivity was placed in the solution. The NaOH solution was slowly added to the HCl solution in small increments. After each addition, the HCl solution was stirred and then the solution's color and conductivity were recorded (see Figure 1).

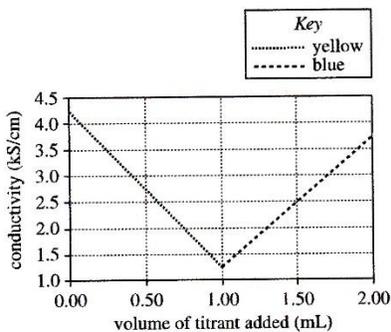


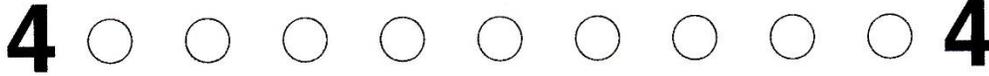
Figure 1

18. In Experiment 1, the sample solution was yellow at which of the following values for the volume of titrant added?

- F. 0.80 mL
- G. 1.20 mL
- H. 1.60 mL
- J. 2.00 mL

19. In Experiment 2, the sample solution was neutral at which of the following values for the volume of titrant added?

- A. 0.50 mL
- B. 1.00 mL
- C. 1.50 mL
- D. 2.00 mL



20. In Experiment 1, if 2.30 mL of titrant had been added to the sample solution, the conductivity would most likely have been:
- F. less than 0.80 kS/cm.
 - G. between 0.80 kS/cm and 2.30 kS/cm.
 - H. between 2.30 kS/cm and 3.80 kS/cm.
 - J. greater than 3.80 kS/cm.
21. In Experiment 2, which solution was the titrant and which solution was the sample solution?
- | | <u>titrant</u> | <u>sample solution</u> |
|----|----------------|------------------------|
| A. | acetic acid | NaOH |
| B. | HCl | NaOH |
| C. | NaOH | acetic acid |
| D. | NaOH | HCl |
22. In Experiments 1 and 2, the probe that was placed in the sample solution most likely did which of the following?
- F. Cooled the solution to its freezing point
 - G. Heated the solution to its boiling point
 - H. Detected the concentration of nitrazine yellow in the solution
 - J. Passed an electrical current through a portion of the solution
23. A chemist claimed that in Experiment 2, the pH of the sample solution was greater at a value of 0.2 mL of titrant added than at a value of 1.8 mL of titrant added. Do the results of Experiment 2 support this claim?
- A. No; at a value of 0.2 mL of titrant added, the sample solution was yellow, and at a value of 1.8 mL of titrant added, the sample solution was blue.
 - B. No; at a value of 0.2 mL of titrant added, the sample solution was blue, and at a value of 1.8 mL of titrant added, the sample solution was yellow.
 - C. Yes; at a value of 0.2 mL of titrant added, the sample solution was yellow, and at a value of 1.8 mL of titrant added, the sample solution was blue.
 - D. Yes; at a value of 0.2 mL of titrant added, the sample solution was blue, and at a value of 1.8 mL of titrant added, the sample solution was yellow.



Passage V

An astronomy class is given the following facts about stellar evolution.

1. A star's evolution can be divided into 3 stages: *pre-main sequence* (pre-MS), *main sequence* (MS), and *post-main sequence* (post-MS).
2. Gravity causes part of a cloud of gas and dust to collapse and heat up, creating a pre-MS star. The star's hot dust and gas emit its energy.
3. A pre-MS star becomes an MS star when the star produces the majority of its energy by fusing hydrogen nuclei (protons) at its center to make helium nuclei.
4. An MS star becomes a post-MS star when the star expands in volume and produces the majority of its energy by fusing hydrogen to make helium in a shell surrounding its center.
5. The more massive a star, the more rapidly the star passes through each of the 3 stages of its evolution.

Two students discuss the evolution of the *Algol system*—Algol A, a 3.6-solar-mass MS star; Algol B, a 0.8-solar-mass post-MS star; and Algol C, a 1.7-solar-mass MS star. (One solar mass = the Sun's mass.) The 3 stars orbit a mutual center of mass, with Algol A and Algol B much closer to each other and to the center of mass than to Algol C.

Student 1

The 3 stars of the Algol system formed at the same time from the same cloud of gas and dust. Algol B, originally the most massive of the 3 stars, became a post-MS star and expanded in volume while Algol A remained an MS star. Because the matter in the outer parts of Algol B was more strongly attracted to Algol A than to the matter in the inner parts of Algol B, this matter flowed from Algol B to Algol A, and, over time, Algol A became more massive than Algol B.

Student 2

Algol B was not part of the original Algol system (Algol A and Algol C). Algol B and the original Algol system formed in different clouds of gas and dust at different times and moved in 2 different but intersecting orbits around the center of the galaxy. During a particular orbit, Algol B encountered the original Algol system at the intersection of the 2 orbits and became part of the Algol system.

Algol B became a post-MS star while Algol A and Algol C remained MS stars. Algol B never lost mass to Algol A. Algol B was always less massive than Algol A.

24. Based on Student 2's discussion, Algol B is part of the present Algol system because of which of the following forces exerted on Algol B by the original Algol system?

- F. Electric force
- G. Magnetic force
- H. Gravitational force
- J. Nuclear force

25. Based on Student 1's discussion and Fact 4, while matter flowed between Algol A and Algol B, Algol B produced the majority of its energy by fusing:

- A. hydrogen nuclei to make helium nuclei at its center.
- B. hydrogen nuclei to make helium nuclei in a shell surrounding its center.
- C. helium nuclei to make hydrogen nuclei at its center.
- D. helium nuclei to make hydrogen nuclei in a shell surrounding its center.

26. Suppose that chemical composition is uniform among stars formed from the same cloud of gas and dust, but that chemical composition varies among stars formed from different clouds of gas and dust. Student 2 would most likely agree with which of the following statements comparing the chemical compositions of the stars in the present-day Algol system at the time they formed?

- F. Algol A and Algol B had the most similar compositions.
- G. Algol A and Algol C had the most similar compositions.
- H. Algol B and Algol C had the most similar compositions.
- J. Algol A, Algol B, and Algol C had the same composition.

27. If the mass of the Sun is 2.0×10^{30} kg, what is the mass of Algol C?

- A. 1.6×10^{30} kg
- B. 2.0×10^{30} kg
- C. 3.4×10^{30} kg
- D. 7.2×10^{30} kg

28. Which of the following statements best explains why the reaction described in Fact 3 requires a high temperature and pressure?

- F. All protons are positively charged, and like charges attract each other.
- G. All protons are positively charged, and like charges repel each other.
- H. All electrons are negatively charged, and like charges attract each other.
- J. All electrons are negatively charged, and like charges repel each other.



29. Based on Fact 5 and Student 1's discussion, which of the 3 stars in the Algol system, if any, was most likely the first to become an MS star?
- A. Algol A
 - B. Algol B
 - C. Algol C
 - D. The 3 stars became MS stars at the same time.
30. Based on Fact 5, would Student 2 agree that by the time Algol A stops being an MS star, Algol A will have spent as much time being an MS star as Algol B spent being an MS star?
- F. Yes, because according to Student 2, Algol A has always been more massive than Algol B.
 - G. Yes, because according to Student 2, Algol A has always been less massive than Algol B.
 - H. No, because according to Student 2, Algol A has always been more massive than Algol B.
 - J. No, because according to Student 2, Algol A has always been less massive than Algol B.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage VI

Three experiments were done using CO_2 , krypton (Kr), or O_2 . For each gas:

1. A 3 L steel vessel was fitted with a cap that contained a gas inlet valve and a pressure and temperature sensor.
2. Air was pumped out of the vessel until the pressure measured 0.00 torr.
3. The vessel was placed on a balance, and the balance was reset to 0.000 g.
4. Some of the gas was added to the vessel.
5. When the gas in the vessel reached room temperature (22°C), mass and pressure were recorded.
6. Steps 4 and 5 were repeated several times.

The experiments were then repeated, except that a 6 L vessel was used (see Figures 1 and 2).

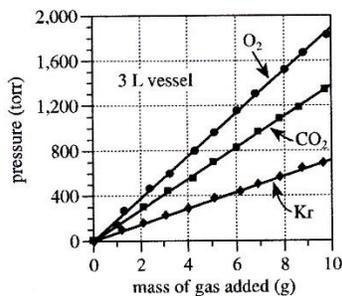


Figure 1

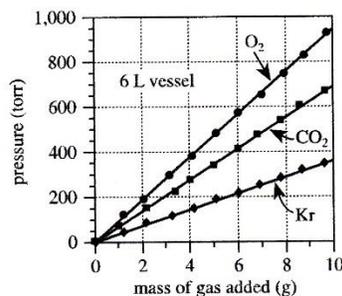


Figure 2

31. Based on Figure 2, if 13 g of Kr had been added to the 6 L vessel, the pressure would have been:

A. less than 200 torr.
 B. between 200 torr and 400 torr.
 C. between 400 torr and 600 torr.
 D. greater than 600 torr.

32. Suppose the experiments had been repeated, except with a 5 L vessel. Based on Figures 1 and 2, the pressure exerted by 7 g of CO_2 would most likely have been:

F. less than 500 torr.
 G. between 500 torr and 1,000 torr.
 H. between 1,000 torr and 1,500 torr.
 J. greater than 1,500 torr.

33. Based on Figures 1 and 2, for a given mass of O_2 at 22°C , how does the pressure exerted by the O_2 in a 6 L vessel compare to the pressure exerted by the O_2 in a 3 L vessel? In the 6 L vessel, the O_2 pressure will be:

A. $\frac{1}{2}$ as great as in the 3 L vessel.
 B. the same as in the 3 L vessel.
 C. 2 times as great as in the 3 L vessel.
 D. 4 times as great as in the 3 L vessel.

34. Which of the following best explains why equal masses of O_2 and CO_2 at the same temperature and in the same-size vessel had different pressures? The pressure exerted by the O_2 was:

F. less, because there were fewer O_2 molecules per gram than there were CO_2 molecules per gram.
 G. less, because there were more O_2 molecules per gram than there were CO_2 molecules per gram.
 H. greater, because there were fewer O_2 molecules per gram than there were CO_2 molecules per gram.
 J. greater, because there were more O_2 molecules per gram than there were CO_2 molecules per gram.

35. Suppose the experiment involving O_2 and the 6 L vessel had been repeated, except at a room temperature of 14°C . For a given mass of O_2 , compared to the pressure measured in the original experiment, the pressure measured at 14°C would have been:

A. less, because pressure is directly proportional to temperature.
 B. less, because pressure is inversely proportional to temperature.
 C. greater, because pressure is directly proportional to temperature.
 D. greater, because pressure is inversely proportional to temperature.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage VII

The *human threshold of hearing* is the minimum intensity at each sound frequency required for a sound to be heard by humans. The *human threshold of pain* is the maximum intensity at each sound frequency that humans can tolerate without pain.

The figure below displays, for sounds in water and in air, the human thresholds of hearing and of pain. The figure also shows S , the percent increase in air density and water density that accompanies the compression of air and water by sound waves of given intensities. Sound intensities are given in decibels (db) and frequencies are given in hertz [(Hz); 1 Hz = 1 cycle/sec].

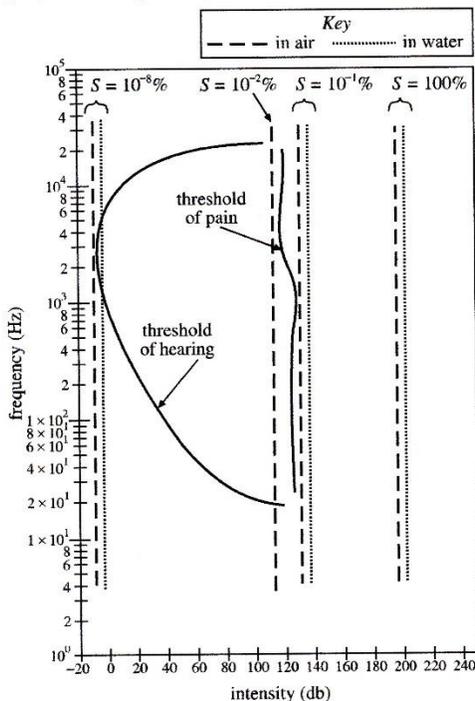
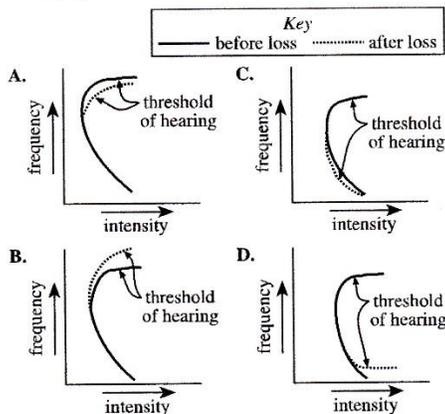


Figure adapted from Rita G. Lerner and George L. Trigg, eds., *Encyclopedia of Physics*, 2nd ed. ©1991 by VCH Publishers, Inc.

36. According to the figure, which of the following is closest to the lowest frequency that can be heard by a human being?
- F. 8 Hz
 - G. 20 Hz
 - H. 1,000 Hz
 - J. 20,000 Hz

37. As humans age, it is common for selective hearing loss to occur at high sound frequencies. Which of the following figures best illustrates this loss?



38. Based on the figure, a sound of a given frequency will have the highest intensity for which of the following sets of conditions?

Sound is passing through:	S
F. water	100%
G. water	$10^{-8}\%$
H. air	100%
J. air	$10^{-8}\%$

39. A student hypothesized that sounds of any intensity at a frequency of 10^5 Hz would be painful for humans to hear. Do the data in the figure support this hypothesis?
- A. Yes, because the threshold of pain is relatively constant with changes in frequency.
 - B. Yes, because as frequency increases above 10^5 Hz, the threshold of pain increases.
 - C. No, because humans cannot hear sounds at 10^5 Hz.
 - D. No, because the threshold of pain is relatively constant with changes in frequency.
40. Based on the figure, does S depend on the frequency of a sound wave of a given intensity?
- F. Yes, because as frequency increases, S increases.
 - G. Yes, because as frequency increases, S remains constant.
 - H. No, because as frequency increases, S increases.
 - J. No, because as frequency increases, S remains constant.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

[See Note on page 52.]

APPENDIX D

LIKERT PRE AND POST SURVEY QUESTIONS

Pre-and Post-Test Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Please answer the following questions regarding the ACT science test you just completed.

For each question mark the letter of the answer chosen on your answer document.

A – Strongly Agree B - Agree C – No Opinion D – Disagree E – Strongly Disagree

1. I had plenty of time to finish the test
2. I was able to find the answer to all of the questions.
3. I felt prepared to succeed on this test.
4. I am good at reading graphs.
5. I was able to read the graphs and use that information to answer the questions.
6. The reading passages were difficult to read.
7. I used the strategies from class on the test.
8. I like science.
9. I plan to go to college for a science related field.
10. I worked hard on this test to help me get into college.

For the following questions use the answers provided

11. Who was your physical science teacher?
 - A. Ms Doup B. Ms. A C. Mr P
 - D. I did not take physical science at this school.
12. Who was your chemistry teacher?
 - A. Ms H B. Mr Y C. I did not take chemistry at this school.
13. Who was/is your biology teacher?
 - A., I am in Ms. Doup's class now B. Mrs. D C. Mrs. C

APPENDIX E
ACT SCIENCE BELLWORK

Day 1 - 3 Types of Questions

Research Summaries (45% - 55%) Usually 3 passages

- Skills: Scientific Method, Data Analysis
- Look for headings "Experiment 1, Experiment 2"

Data Representation (30% - 40%) 2 to 3 passages

- Skills: Read Graphs, Analyze Results

Conflicting Viewpoints (15% - 20%) Usually only 1 passage

- Skills: Find similarities and differences in views
- Look for headings "Scientist 1, Scientist 2", "Hypothesis 1, Hypothesis 2"

Go through your ACT test and mark the passages with the labels above.

Day 2 - Research Summaries

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for keywords in the passage. Again, do not waste time reading the whole passage.

Questions seen here could be

1. Experimental design
2. Hypothetical or what would happen...
3. Interpret with two part answers

Choose 1 passage that is a research summary and answer the questions using the strategy above.

Day 3 - Research Summaries

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for keywords in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be

1. Experimental design
2. Hypothetical or what would happen...
3. Interpret with two part answers

Choose 1 passage that is a research summary and answer the questions using the strategy above.

Day 4 - Research Summaries

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for keywords in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be

1. Experimental design
2. Hypothetical or what would happen...
3. Interpret with two part answers

Choose 1 passage that is a research summary and answer the questions using the strategy above.

Day 5 - Research Summaries

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for keywords in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be

1. Experimental design
2. Hypothetical or what would happen...
3. Interpret with two part answers

Choose 1 passage that is a research summary and answer the questions using the strategy above.

Day 6 - Data Representation

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for key words in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be:

1. Facts - usually found in graphs, sometimes found in passage
2. Trends in data (relationships) - two part answers
3. Calculations - use data or graphs

Choose a data representation passage and answer the questions using the strategies above.

Day 7 - Data Representation

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for key words in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be:

1. Facts - usually found in graphs, sometimes found in passage
2. Trends in data (relationships) - two part answers
3. Calculations - use data or graphs

Choose a data representation passage and answer the questions using the strategies above.

Day 8 - Data Representation

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for key words in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be:

1. Facts - usually found in graphs, sometimes found in passage
2. Trends in data (relationships) - two part answers
3. Calculations - use data or graphs

Choose a data representation passage and answer the questions using the strategies above.

Day 9 - Data Representation

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for key words in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be:

1. Facts - usually found in graphs, sometimes found in passage
2. Trends in data (relationships) - two part answers
3. Calculations - use data or graphs

Choose a data representation passage and answer the questions using the strategies above.

Day 10 - Data Representation

Strategy

DO NOT READ THE PASSAGE

1. Answer as many questions as you can off the data.
2. Then go back to questions you cannot answer on data alone. Look for key words in the passage.
Again, do not waste time reading the whole passage.

Questions seen here could be:

1. Facts - usually found in graphs, sometimes found in passage
2. Trends in data (relationships) - two part answers
3. Calculations - use data or graphs

Choose a data representation passage and answer the questions using the strategies above.

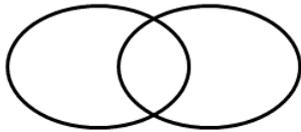
Day 11 - Conflicting Viewpoints

Strategy

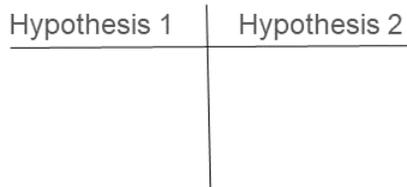
For this type of passage only spend time reading the passage first. List, underline, or circle the similarities or differences you find as you read.

You may find it helpful to create a T Chart or Venn Diagram to list the similarities and differences as you read the passage.

Scientist 1 Scientist 2



Hypothesis 1 Hypothesis 2



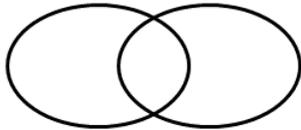
Day 12 - Conflicting Viewpoints

Strategy

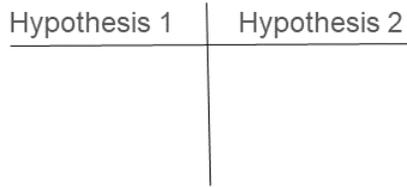
For this type of passage only spend time reading the passage first. List, underline, or circle the similarities or differences you find as you read.

You may find it helpful to create a T Chart or Venn Diagram to list the similarities and differences as you read the passage.

Scientist 1 Scientist 2



Hypothesis 1 Hypothesis 2



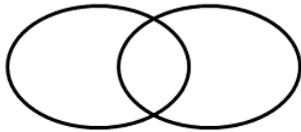
Day 13 - Conflicting Viewpoints

Strategy

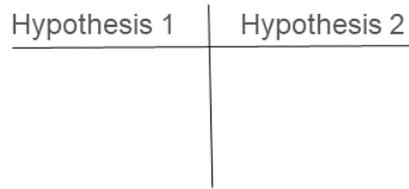
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Scientist 1 Scientist 2



Hypothesis 1 Hypothesis 2



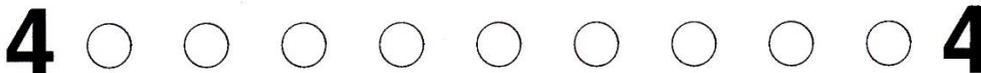
Day 14 – ACT Prep

- Check your answers to the questions you worked on during bellwork with the key.

Day 15 – ACT Prep

- Go through the passages and look at the ones that are incorrect.
- What type of question did you miss?
- What type of passage was your strongest? Your weakest?
- What can you do to increase your score on the ACT?

APPENDIX F
ACT SCIENCE RELEASED PRACTICE TEST
2016-2017 Form 72CPRE
POSTTEST



SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are several passages in this test. Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

You are NOT permitted to use a calculator on this test.

Passage 1

Researchers studied how diet and the ability to smell food can affect the life span of normal fruit flies (Strain N) and fruit flies unable to detect many odors (Strain X).

Study 1

Three tubes (Tubes 1–3), each with 15% sugar yeast (SY) medium (a diet with 15% sugar and 15% killed yeast), were prepared. Then, 200 virgin female Strain N fruit flies less than 24 hr old were added to each tube. No additional substance was added to Tube 1. Additional odors from live yeast were added to Tube 2, and live yeast was added to Tube 3. The percent of fruit flies alive was determined every 5 days for 75 days (see Figure 1).

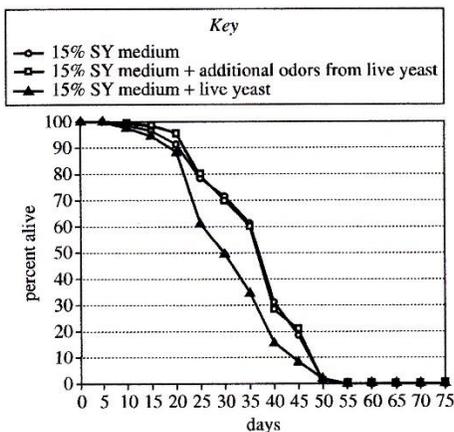


Figure 1

Study 2

Three tubes (Tubes 4–6), each with 5% SY medium (a diet with 5% sugar and 5% killed yeast), were prepared. Then, 200 virgin female Strain N fruit flies less than 24 hr old were added to each tube. No additional substance was added to Tube 4. Additional odors from live yeast were added to Tube 5, and live yeast was added to Tube 6. The percent of fruit flies alive was determined every 5 days for 75 days (see Figure 2).

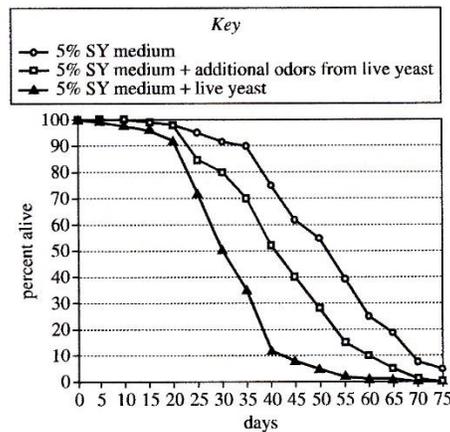
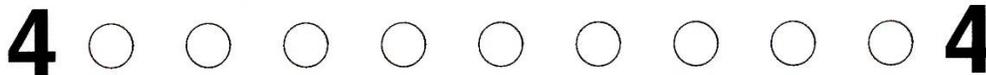


Figure 2



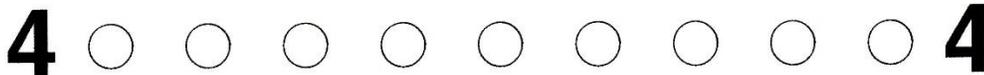
Study 3

Strain N fruit flies were modified to produce Strain X fruit flies. Strain X fruit flies lack *Or83b* (a protein required to detect a wide range of odors); therefore, they cannot detect many odors. The average life span was determined for virgin female Strain N and virgin female Strain X fruit flies fed with various SY media (see Table 1).

Strain	SY medium		Average life span (days)
	% sugar	% killed yeast	
Strain N	3	3	50.1
	5	5	50.1
	7.5	7.5	43.9
	10	10	44.8
	15	15	41.6
Strain X	3	3	61.6
	5	5	62.5
	7.5	7.5	58.9
	10	10	58.6
	15	15	55.6

Table and figures adapted from Sergiy Libert et al., "Regulation of *Drosophila* Life Span by Olfaction and Food-Derived Odors." ©2007 by the American Association for the Advancement of Science.

- In which of Studies 1 and 2 did some of the fruit flies live for more than 75 days, and what diet were those fruit flies fed?
 - Study 1; 5% SY medium
 - Study 1; 15% SY medium
 - Study 2; 5% SY medium
 - Study 2; 15% SY medium
- During Studies 1 and 2, why did the size of the fruit fly population in each tube decrease rather than increase?
 - The birthrate was 0, because the initial population contained only males.
 - The birthrate was 0, because the initial population contained only virgin females.
 - The death rate was 0, because the initial population contained only males.
 - The death rate was 0, because the initial population contained only virgin females.
- Study 1 differed from Study 2 in which of the following ways?
 - Female fruit flies were tested in Study 1, whereas male fruit flies were tested in Study 2.
 - Male fruit flies were tested in Study 1, whereas female fruit flies were tested in Study 2.
 - The SY medium tested in Study 1 contained a lower percent of sugar than did the SY medium tested in Study 2.
 - The SY medium tested in Study 1 contained a higher percent of sugar than did the SY medium tested in Study 2.
- Suppose that an additional trial in Study 3 had been performed using a 12% SY medium (a diet with 12% sugar and 12% killed yeast). The average life span of the Strain X fruit flies in this trial would most likely have been:
 - less than 55.6 days.
 - between 55.6 days and 58.6 days.
 - between 58.6 days and 61.6 days.
 - greater than 61.6 days.
- The researchers had predicted that decreasing a fruit fly's ability to detect odors would increase its life span. Are the results of Study 3 consistent with this prediction?
 - No; for each SY medium tested, the average life span of Strain X fruit flies was longer than the average life span of Strain N fruit flies.
 - No; for each SY medium tested, the average life span of Strain N fruit flies was longer than the average life span of Strain X fruit flies.
 - Yes; for each SY medium tested, the average life span of Strain X fruit flies was longer than the average life span of Strain N fruit flies.
 - Yes; for each SY medium tested, the average life span of Strain N fruit flies was longer than the average life span of Strain X fruit flies.
- Suppose the researchers wanted to determine whether a defect in the ability to detect odors would change the life span of fruit flies fed 15% SY medium when live yeast is added to the diet or when additional odors from live yeast are added to the diet. Which of the following experiments should be performed?
 - Repeat Study 1 except with Strain X fruit flies
 - Repeat Study 1 except with Strain N fruit flies
 - Repeat Study 2 except with Strain X fruit flies
 - Repeat Study 2 except with Strain N fruit flies
- The results for which 2 tubes should be compared to determine how a reduced calorie diet affects life span in the absence of live yeast and additional odors from live yeast?
 - Tube 1 and Tube 4
 - Tube 1 and Tube 2
 - Tube 2 and Tube 5
 - Tube 5 and Tube 6



Passage II

In the fall, monarch butterflies (*Danaus plexippus*) in eastern North America migrate to Mexico, where they overwinter in high-altitude forests of *oyamel fir* (an evergreen conifer). The butterflies store (accumulate) body lipids to use as a source of energy at a later time. Consider the following 3 hypotheses pertaining to when the butterflies store lipids and when the energy from the stored lipids is used, with respect to migration and overwintering.

Hypothesis 1

Monarch butterflies require energy from stored lipids for migration and during the overwintering period. The butterflies first store lipids before they begin their migration. During migration, as stored lipids are converted to energy, lipid mass continuously decreases. When the butterflies reach the overwintering sites, ending their migration, they must store lipids again before beginning the overwintering period.

Hypothesis 2

Monarch butterflies require energy from stored lipids for migration but not during the overwintering period. The butterflies store lipids before they begin their migration. During migration, as stored lipids are converted to energy, lipid mass continuously decreases. Because energy from stored lipids is not required during the overwintering period, the butterflies do not store lipids while at the overwintering sites.

Hypothesis 3

Monarch butterflies require energy from stored lipids during the overwintering period but not for migration. The butterflies do not store lipids before they begin their migration. Instead, lipids are stored during migration; therefore, lipid mass continuously increases from the beginning of migration until the end of migration. The butterflies arrive at the overwintering sites with enough lipids to provide themselves with energy during the overwintering period, so they do not store lipids while at the overwintering sites.

8. Which hypothesis, if any, asserts that monarch butterflies store lipids during 2 distinct periods?

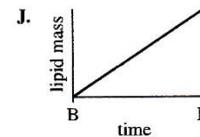
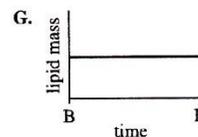
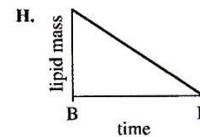
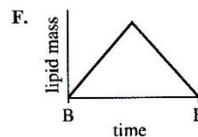
F. Hypothesis 1
G. Hypothesis 2
H. Hypothesis 3
J. None of the hypotheses

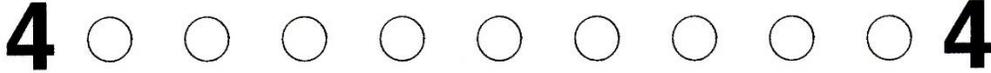
9. Which hypothesis, if any, asserts that monarch butterflies require energy from stored lipids neither for migration nor during the overwintering period?

A. Hypothesis 1
B. Hypothesis 2
C. Hypothesis 3
D. None of the hypotheses

10. Based on Hypothesis 3, which of the following figures best depicts the change in the lipid mass of a monarch butterfly from the beginning of migration to the end of migration?

(Note: In each figure, B represents the beginning of migration and E represents the end of migration.)



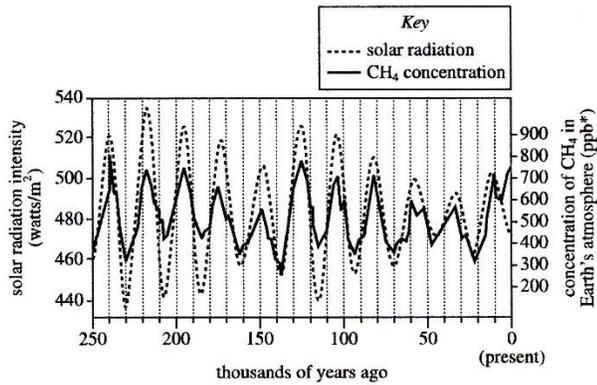


11. Assume that changes in the body mass of a monarch butterfly are caused only by changes in the mass of the butterfly's stored lipids. The statement "The percent of a monarch butterfly's body mass that is made up of lipids is greater at the beginning of migration than at the end of migration" is supported by which of the hypotheses?
- A. Hypothesis 1 only
 - B. Hypothesis 2 only
 - C. Hypotheses 1 and 2 only
 - D. Hypotheses 1, 2, and 3
12. To store lipids, monarch butterflies convert sugar from nectar they have consumed into lipids. A supporter of which hypothesis, if any, would be likely to claim that to ensure the butterflies can store lipids for the overwintering period, nectar must be present at the butterflies' overwintering sites?
- F. Hypothesis 1
 - G. Hypothesis 2
 - H. Hypothesis 3
 - J. None of the hypotheses
13. Which of the following statements about lipids in monarch butterflies is consistent with all 3 hypotheses?
- A. The butterflies' lipid masses do not change during the overwintering period.
 - B. The butterflies' lipid masses change during migration.
 - C. The butterflies use energy from stored lipids during the overwintering period.
 - D. The butterflies use energy from stored lipids for migration.
14. When the monarch butterflies use their stored lipids, the lipids must be broken down to produce energy-rich molecules that can be readily used by cells. Which of the following molecules is produced as a direct result of the breakdown of the lipids?
- F. ATP
 - G. Starch
 - H. DNA
 - J. Amino acids



Passage III

Greenhouse gases such as methane (CH₄) warm Earth's climate. Figure 1 shows the concentration of CH₄ in Earth's atmosphere and the solar radiation intensity at Earth's surface for tropical Europe and Asia over the past 250,000 years. As the figure shows, the CH₄ concentration and the solar radiation intensity have increased and decreased at the same times over most of this period. Figure 2 shows the same types of data for the same region over the past 11,000 years. This figure is consistent with the hypothesis that the greenhouse gases from human activities may have begun warming Earth's climate thousands of years earlier than once thought.



*ppb = parts per billion

Figure 1

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

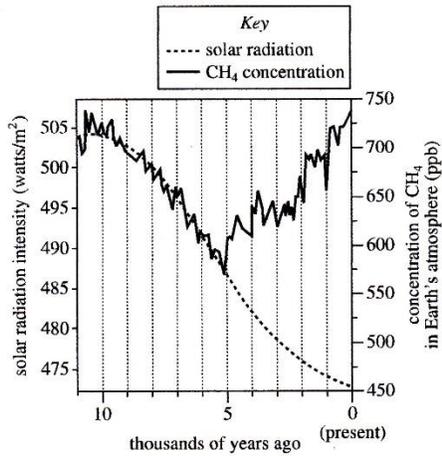
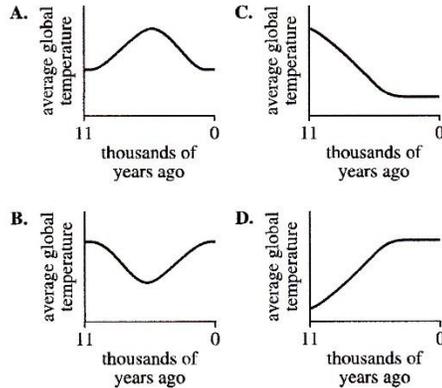


Figure 2

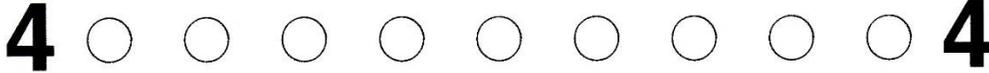
Figures adapted from William Ruddiman, *Plows, Plagues & Petroleum*. ©2005 by Princeton University Press.

15. According to Figure 2, the solar radiation intensity 8,000 years ago was closest to which of the following?
- 490 watts/m²
 - 495 watts/m²
 - 500 watts/m²
 - 505 watts/m²
16. According to Figure 2, if the trend in the CH₄ concentration had continued to match the trend in the solar radiation intensity, the CH₄ concentration at present would most likely be:
- less than 550 ppb.
 - between 550 ppb and 600 ppb.
 - between 600 ppb and 650 ppb.
 - greater than 650 ppb.

17. Suppose that whenever the CH₄ concentration increases, a corresponding, immediate increase in average global temperature occurs, and that whenever the CH₄ concentration decreases, a corresponding, immediate decrease in average global temperature occurs. Based on Figure 2, which of the following graphs best represents a plot of average global temperature over the past 11,000 years?



18. Based on Figure 1, the average solar radiation intensity over the past 250,000 years was closest to which of the following?
- 400 watts/m²
 - 440 watts/m²
 - 480 watts/m²
 - 520 watts/m²
19. One *solar radiation cycle* is the time between a maximum in the solar radiation intensity and the next maximum in the solar radiation intensity. According to Figure 1, the average length of a solar radiation cycle during the past 250,000 years was:
- less than 15,000 years.
 - between 15,000 years and 35,000 years.
 - between 35,000 years and 55,000 years.
 - greater than 55,000 years.
20. Which of the following statements best describes the primary effect of CH₄ on Earth's climate?
- CH₄ gives off visible light to space, cooling Earth's climate.
 - CH₄ gives off ultraviolet radiation to space, warming Earth's climate.
 - CH₄ absorbs heat as it enters Earth's atmosphere from space, cooling Earth's climate.
 - CH₄ absorbs heat that comes up from Earth's surface, warming Earth's climate.



Passage IV

In 2 experiments, a student pulled each of 3 blocks in a straight line across a flat, horizontal surface.

In Experiment 1, the student measured the *pulling force* (the force required to move each block at a constant speed) and plotted the pulling force, in newtons (N), versus block mass, in kilograms (kg). The results are shown in Figure 1.

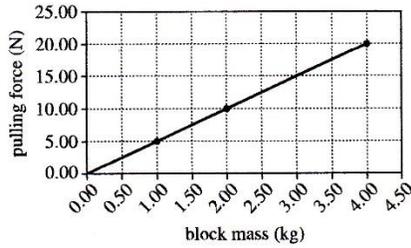


Figure 1

In Experiment 2, the student measured the speed versus time of a 2.00 kg block, a 2.50 kg block, and a 3.00 kg block as each block was pulled across the surface with a constant 30 N force. The results are shown in Figure 2.

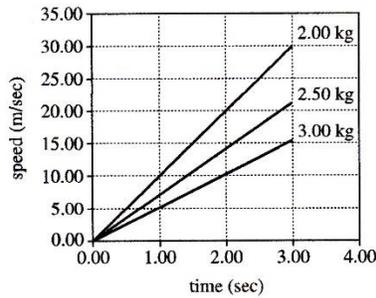


Figure 2

21. If a block was pulled toward the east, the frictional force exerted on the block by the surface was directed toward the:

A. north.
 B. south.
 C. east.
 D. west.

22. Based on Figure 2, what is the order of the 3 blocks, from the block that required the shortest time to reach 15 m/sec to the block that required the longest time to reach 15 m/sec ?

F. 2.00 kg block, 2.50 kg block, 3.00 kg block
 G. 2.00 kg block, 3.00 kg block, 2.50 kg block
 H. 3.00 kg block, 2.00 kg block, 2.50 kg block
 J. 3.00 kg block, 2.50 kg block, 2.00 kg block

23. Based on Figure 2, what was the approximate value of the acceleration of the 3.00 kg block?

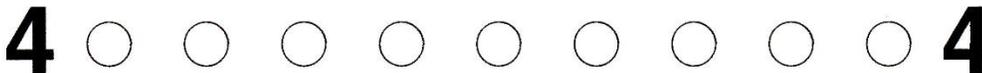
A. 0.0 m/sec²
 B. 5.0 m/sec²
 C. 15.0 m/sec²
 D. 20.0 m/sec²

24. Based on Figure 1, the results of Experiment 1 are best modeled by which of the following equations?

F. Block speed (m/sec) = 0.2 × time (sec)
 G. Block speed (m/sec) = 5.0 × time (sec)
 H. Pulling force (N) = 0.2 × block mass (kg)
 J. Pulling force (N) = 5.0 × block mass (kg)

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ **4**

25. At each of the times plotted in Figure 2 (except 0.00 sec), as block mass increased, block speed:
- A. increased only.
 - B. decreased only.
 - C. varied, but with no general trend.
 - D. remained the same.
26. Based on Figure 1, an applied force of 30.00 N would most likely have been required to maintain the constant speed of a block having a mass of:
- F. 4.00 kg.
 - G. 5.00 kg.
 - H. 6.00 kg.
 - J. 7.00 kg.

**Passage V**

A typical *acid-base indicator* is a compound that will be one color over a certain lower pH range but will be a different color over a certain higher pH range. In the small range between these pH ranges—the *transition range*—the indicator's color will be an intermediate of its other 2 colors.

Students studied 5 acid-base indicators using colorless aqueous solutions of different pH and a *well plate* (a plate containing a matrix of round depressions—*wells*—that can hold small volumes of liquid).

Experiment 1

The students added a pH = 0 solution to 5 wells in the first column of the well plate, then added a pH = 1 solution to the 5 wells in the next column, and so on, up to pH = 7. Next, they added a drop of a given indicator (in solution) to each of the wells in a row, and then repeated this process, adding a different indicator to each row. The color of the resulting solution in each well was then recorded in Table 1 (B = blue, G = green, O = orange, P = purple, R = red, Y = yellow).

Indicator	Color in solution with a pH of:							
	0	1	2	3	4	5	6	7
Metanil yellow	R	R	O	Y	Y	Y	Y	Y
Resorcin blue	R	R	R	R	R	P	P	B
Curcumin	Y	Y	Y	Y	Y	Y	Y	Y
Hessian bordeaux	B	B	B	B	B	B	B	B
Indigo carmine	B	B	B	B	B	B	B	B

Experiment 2

Experiment 1 was repeated with solutions that had a pH of 8 or greater (see Table 2).

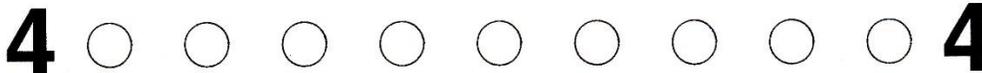
Indicator	Color in solution with a pH of:						
	8	9	10	11	12	13	14
Metanil yellow	Y	Y	Y	Y	Y	Y	Y
Resorcin blue	B	B	B	B	B	B	B
Curcumin	O	R	R	R	R	R	R
Hessian bordeaux	B	R	R	R	R	R	R
Indigo carmine	B	B	B	B	G	Y	Y

Experiment 3

Students were given 4 solutions (Solutions I–IV) of unknown pH. The well plate was used to test samples of each solution with 4 of the 5 indicators (see Table 3).

Indicator	Color in Solution:			
	I	II	III	IV
Metanil yellow	Y	Y	Y	O
Resorcin blue	B	B	R	R
Curcumin	R	R	Y	Y
Indigo carmine	B	Y	B	B

Tables adapted from David R. Lide, ed., *CRC Handbook of Chemistry and Physics*, 78th ed. ©1997 by CRC Press LLC.



27. One way Experiment 2 differed from Experiment 3 was that in Experiment 2:
- the solutions to which indicators were added were of known pH.
 - the solutions to which indicators were added were of unknown pH.
 - metanil yellow was used.
 - metanil yellow was not used.
28. Based on the description of the well plate and how it was used, the empty well plate would most likely have been which of the following colors?
- Black
 - Blue
 - Red
 - White
29. Based on the results of Experiments 1 and 2, which of the following is a possible transition range for curcumin?
- pH = 3.9 to pH = 7.3
 - pH = 4.2 to pH = 6.6
 - pH = 7.4 to pH = 8.6
 - pH = 8.4 to pH = 9.5
30. A chemist has 2 solutions, one of pH = 1 and one of pH = 6. Based on the results of Experiments 1 and 2, could indigo carmine be used to distinguish between these solutions?
- No; indigo carmine is blue at both pH = 1 and pH = 6.
 - No; indigo carmine is blue at pH = 1 and is yellow at pH = 6.
 - Yes; indigo carmine is blue at both pH = 1 and pH = 6.
 - Yes; indigo carmine is blue at pH = 1 and is yellow at pH = 6.
31. The indicator *propyl red* has a transition range of pH = 4.6 to pH = 6.8. If propyl red had been included in Experiments 1 and 2, it would have produced results most similar to those produced by which of the 5 indicators?
- Metanil yellow
 - Resorcin blue
 - Curcumin
 - Indigo carmine
32. A student claimed that Solution III has a pH of 7.3. Are the results of Experiments 1–3 consistent with this claim?
- No, because in Solution III metanil yellow was yellow.
 - No, because in Solution III resorcin blue was red.
 - Yes, because in Solution III metanil yellow was yellow.
 - Yes, because in Solution III resorcin blue was red.
33. Based on the results of Experiments 1–3, which of Solutions I–IV has the *lowest* pH?
- Solution I
 - Solution II
 - Solution III
 - Solution IV



Passage VI

Drilling mud (DM) is a suspension of clay particles in water. When a well is drilled, DM is injected into the hole to lubricate the drill. After this use, the DM is brought back up to the surface and then disposed of by spraying it on adjacent land areas.

A cover of DM on plants and soil can affect the *albedo* (proportion of the total incoming solar radiation that is reflected from a surface), which in turn can affect the soil temperature. The effect of a cover of DM on the albedo and the soil temperature of an unsloped, semiarid grassland area was studied from July 1 to August 9 of a particular year.

On June 30, 3 plots (Plots 1–3), each 10 m by 40 m, were established in the grassland area. For all the plots, the types of vegetation present were the same, as was the density of the vegetation cover. At the center of each plot, a soil temperature sensor was buried in the soil at a depth of 2.5 cm. An instrument that measures incoming and reflected solar radiation was suspended 60 cm above the center of each plot.

An amount of DM equivalent to 40 cubic meters per hectare (m^3/ha) was then sprayed evenly on Plot 2. (One hectare equals $10,000 m^2$.) An amount equivalent to $80 m^3/ha$ was sprayed evenly on Plot 3. No DM was sprayed on Plot 1.

For each plot, the albedo was calculated for each cloudless day during the study period using measurements of incoming and reflected solar radiation taken at noon on those days (see Figure 1).

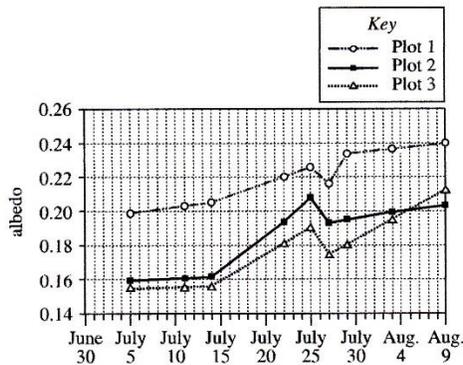


Figure 1

For each plot, the sensor recorded the soil temperature every 5 sec over the study period. From these data, the average soil temperature of each plot was determined for each day (see Figure 2).

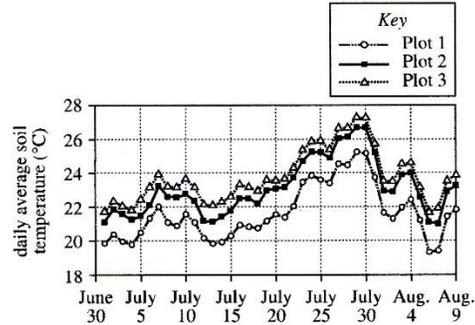


Figure 2

Figures adapted from Francis Zvomuya et al., "Surface Albedo and Soil Heat Flux Changes Following Drilling Mud Application to a Semiarid, Mixed-Grass Prairie." ©2008 by the Soil Science Society of America.

34. Albedo was measured at noon because that time of day is when solar radiation reaching the ground is:
- F. 100% reflected.
 - G. 100% absorbed.
 - H. least intense.
 - J. most intense.
35. Why was the study designed so that the 3 plots had the same types of vegetation present and the same density of vegetation cover? These conditions ensured that any variations in albedo and soil temperature would most likely be attributable only to variations among the plots in the:
- A. amount of DM sprayed.
 - B. type of soil present.
 - C. plot area.
 - D. plot slope.



36. On one day of the study period, a measurable rainfall occurred in the study area. The albedo calculated for the cloudless day just after the rainy day was lower than the albedo calculated for the cloudless day just before the rainy day. On which day did a measurable rainfall most likely occur in the study area?
- F. July 10
G. July 12
H. July 26
J. July 28
37. For each plot, the number of temperature readings recorded by the soil temperature sensor every minute was closest to which of the following?
- A. 5
B. 12
C. 50
D. 60
38. According to Figure 1 and the description of the study, was July 20 a cloudless day?
- F. No, because albedo data were not collected on that day.
G. No, because albedo data were collected on that day.
H. Yes, because albedo data were not collected on that day.
J. Yes, because albedo data were collected on that day.
39. According to the results of the study, did the presence of a cover of DM increase or decrease the albedo, and did the presence of a cover of DM increase or decrease the soil temperature?
- | | <u>albedo</u> | <u>soil temperature</u> |
|----|---------------|-------------------------|
| A. | increase | increase |
| B. | increase | decrease |
| C. | decrease | decrease |
| D. | decrease | increase |
40. Based on Figure 1, on August 3, what percent of incoming solar radiation was NOT reflected from Plot 2 ?
- F. 20%
G. 40%
H. 60%
J. 80%

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

[See Note on page 52.]

APPENDIX G
ACT SCIENCE PRETEST AND POSTTEST SCORES FOR THE
CONTROL AND EXPERIMENTAL GROUPS

ACT Science Pretest and Posttest Scores Control (N=37).

Student Number	Pretest Score	Post Test Score	% change
42	6	10	67%
43	6	15	150%
44	6	10	67%
45	7	16	129%
46	7	9	29%
47	7	14	100%
48	8	11	38%
49	8	17	113%
50	8	9	13%
51	8	6	-25%
52	8	8	0%
53	9	16	78%
54	9	12	33%
55	10	16	60%
56	10	10	0%
57	10	10	0%
58	11	15	36%
59	12	8	-33%
60	12	12	0%
61	12	8	-33%
62	12	8	-33%
63	12	15	25%
64	13	18	38%
65	13	16	23%
66	13	19	46%
67	14	10	-29%
68	14	13	-7%
69	15	12	-20%
70	15	17	13%
71	16	12	-25%
72	16	9	-44%
73	16	14	-13%
74	17	19	12%
75	20	23	15%
76	22	17	-23%
77	23	20	-13%
Average	11.80556	13.16667	22%

ACT Science Pretest and Posttest Scores Experimental Group (N=33).

Student Number	Pretest Score	PostTest Score	% change
1	2	10	400%
2	3	9	200%
3	4	15	275%
4	4	18	350%
5	4	7	75%
6	5	10	100%
7	5	11	120%
8	7	7	0%
9	7	7	0%
10	7	5	-29%
11	8	12	50%
12	8	14	75%
13	8	7	-13%
14	9	12	33%
15	9	16	78%
16	9	28	211%
17	9	13	44%
18	10	20	100%
19	10	20	100%
20	11	10	-9%
21	11	10	-9%
22	11	13	18%
23	11	8	-27%
24	12	11	-8%
25	12	16	33%
26	12	13	8%
27	13	9	-31%
28	13	19	46%
29	13	5	-62%
30	13	5	-62%
31	14	19	36%
32	14	17	21%
33	15	35	133%
Average	9.18	13.06	68%

APPENDIX H
RAW EXCEL DATA

