

THE IMPACT OF DISCREPANT EVENTS ON A 10TH GRADE
BIOLOGY CLASSROOM

by

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INTRODUCTION AND BACKGROUND

Project Background

I teach at the most diverse high school in Sarasota, Florida, we have one third Caucasian, one third Hispanic, and one third African American students. The school also has the highest percentage of free and reduced lunch students in the district, 72%. Located in an historically African American neighborhood, the school is a source of pride for members of the local community who graduated from Booker High School. Community members often attend sporting events and performances. The school also has a visual and performing arts (VPA) magnet program that attracts students from all over the county and surrounding counties. Students in the VPA program can major in their talent area including, dance, theater, fine arts, vocal, instrumental, digital motion design, or film. So there is an incredible ethnic diversity, talent diversity, and academic diversity in the school. It is not uncommon to see a student pass by in the hall playing bongos, carrying violins, or singing their part for the upcoming musical. While there are problems, the feel in the hallway is that the students get along with each other with very little conflict.

Academically, the school has a different feel and is often described by colleagues as “a school within a school”. The VPA students are generally in the academically accelerated Cambridge International program while the students from the surrounding neighborhood are most likely in general education classes. The majority of our incoming freshmen come to us significantly below grade level, some years it is over 70%. In my on-level biology class I have a wide range of ability levels from approaching college

readiness reading levels to those students who are reading at a first or second grade reading level. The course has an end of course exam (EOC) and the test specifications state that the assessment is supposed to be written at a 9th grade reading level. Reading the test becomes the barrier and not necessarily the lack of biology knowledge.

Measuring achievement in biology class is now high stakes in the state of Florida. biology students take the state end of course standardized assessment in May. The stakes are high for all parties. For the students, the exam is worth 30% of their yearly grade. For me as the teacher it is worth 30% of my evaluation score. For my school, the passing rate is a component of the school grade, and the school receives extra funds if it earns an A grade. For the district, school grades factor into the grade as a district. The school earned a C last year. Raising academic achievement is a priority for me, and also for my co-workers. Because we had only 54% of our students pass the EOC in May 2016, the schoolwide goal has been set to 71% of our students passing in May of 2017. This year will be the 5th year I have taught biology with an EOC, and supposedly poor students have shocked me by passing. I truly believe my students can all be successful in biology class and on the end of course exam if they will engage their brain in class and struggle through the lesson.

I find that the first few minutes of class is the most critical. The students have a hard time settling in and switching their brain to the lesson at hand. If I lose them, it can take 15-20 minutes for them to become calm and focused which wastes almost half of the 47-minute class period. Students have seven classes each day so I recognize that it is

hard to switch gears when you are a struggling learner. I believe their brain needs some help to engage, and engaging in a discrepant event might be the way to do that.

I hope to engage the students as part of the 5E lesson cycle through the use of discrepant events. Discrepant events are designed to have an unexpected outcome, which puts the learner in a state of cognitive dissonance. An example of a discrepant event in biology class is observing osmosis in an egg. Raw eggs are decalcified in vinegar for a couple of days until the shell dissolves. The mass of two eggs is measured and recorded. One egg is placed in corn syrup and the other is placed in water. After one day, the eggs are carefully removed, massed, and the data recorded. The egg left in corn syrup becomes shriveled and the yolk is visible while the egg left in water swells and becomes taut. Students do not expect the water to leave the egg in corn syrup and enter the egg placed in water. The brain is stimulated to ask why the event happened and the learner becomes curious to explore further. The brain is set in motion down the path of knowledge acquisition. The rest of the 5E cycle is designed to bring the learner along until they reach the evaluation point. The parts of the 5E cycle are engage, explore, explain, elaborate, and evaluate.

Focus Questions

The primary research question my project addressed was, “How does the use of discrepant events impact student academic achievement in biology class?” The first sub question I investigated was, “Are students willing to struggle through the lesson if their brain has been engaged through a discrepant event?” Sub question two was, “How do

discrepant events affect students' confidence?" Finally, the third sub question was, "What effect do discrepant events have on me as the teacher?"

CONCEPTUAL FRAMEWORK

Research literature

The research literature was mostly about the 5E learning cycle and how it affects students' understanding rather to study discrepant events on their own. The 5E model follows the steps engage, explore, explain, elaborate and evaluate. Two studies both conducted in Turkey in chemistry classes show the 5E model increases students' understanding. The first tested the effect of the 5E model on students' understanding of the gas concept. A teacher was selected and two classes with 40 students total participated in the study. The researcher randomly selected one class to be the control group and the other to be the experimental group. The control group was taught using the traditional teacher-centered approach and the experimental group was taught using the 5E model. A pre-assessment and post-assessment was administered. The researcher found no significant difference between control and treatment by using a t-test on the pretest. A t-test conducted with the posttest showed a significant difference between control and treatment group. The researcher concluded the 5E model was more successful in improving students' understanding than traditional teaching (Yadigaroglu & Demircioglu, 2012).

The second study was similar and studied the effect of laboratory activities based on the 5E model on 9th grade students' understanding of solution chemistry. This study was more focused on laboratory activities. Fifty-two students participated with twenty-

six in the experimental group and twenty-six were in the control group. The students were randomly assigned to the treatment group. Pretests and posttests were used. In the explore stage, students performed four different lab activities. The researchers do not elaborate on the teaching methods used in the control group, and say, “the control group used the same number of lessons, but was taught with traditional approach.” (p. 3122). A t-test was performed on the pretest and found no statistical significance between the control and treatment groups. After treatment, the t-test showed a statistically significant difference between control and treatment groups (Demircioğlu & Çağatay, 2014).

Another observational study found that discrepant events occurred as a result of the lab procedure. Thirteen students attended a four-week workshop about bacterial growth. Students were videotaped and the researchers analyzed the videos for comparison. First, the students participated in laboratory procedures where they grew bacteria, and observed what happened. Next the students conducted internet research about bacteria and bacterial growth. Then they participated in a whiteboard session to write the stages of bacterial growth with the end goal to create and program a computer model of bacterial growth (Blikstein, Fuhrmann, & Salehi, 2016).

The researchers found that the students encountered discrepant events after they ran the computer models. For example, students observed colonies growing on the Petri dishes spread out and formed colonies with different shapes. In the computer model, the bacterial colonies grew on top of each other. The discrepancy generated a curiosity that prompted students to discuss and ask more questions. In total the researchers found five instances where students encountered discrepant events on different topics about bacteria

and bacterial growth. The researchers concluded that these episodes were concept builders rather than detrimental to the students' learning (Blikstein, Fuhrmann, & Salehi, 2016).

Sadi and Çakiroğlu focused on investigating the relationships between students' relevant prior knowledge, meaningful learning orientation, reasoning ability, self-efficacy, focus of control, attitudes toward biology, and achievement. The researchers developed a 5E unit for the human circulatory system and taught the teachers how to teach the unit. As part of the pretests, they tested for motivational variables like self-efficacy and locus of control. They cited studies that showed students with high self-efficacy are more likely to, "carry on a subject and to use more complicated learning processes and strategies" (p.1999). People with an internal locus of control had more academic success than those with an external locus of control (Sadi & Çakiroğlu, 2014).

For this action research project, these studies are helpful because they provide data that the 5E model is producing statistically significant results in increasing student understanding of the concepts taught in the study. Also, discrepant events can occur naturally throughout the scientific process. These events further student learning.

Theoretical articles

When someone witnesses something that is opposite of what is expected it is a discrepant event. The person starts to wonder why and feels the need to have their questions answered. This can be explained according to Piaget's theory of cognitive development. Piaget's two mechanisms for cognitive development are assimilation and accommodation. Assimilation happens when someone applies their current knowledge to

a situation and accommodation is when someone changes their way of thinking to fit a new object or event. These two mechanisms are in opposition to each other so there is a conflict and the person attempts to balance the situation and reach equilibrium. When students experience a discrepant event, they reach a state of disequilibrium. They realize their old knowledge is not sufficient so they start to gather information and modify their thinking, mental growth can occur (Thompson, 1989).

An advantage to using discrepant events is, “that they motivate students to learn science principles” (p. 27). In addition, they, “motivate students to learn science principles” (p. 27). Discrepant events also, “provide students with meaningful problems to be solved” (Thompson, 1989, p.27). One caution about the use of discrepant events is that the activity following is important so ineffective learning is not a result. Also if the disequilibrium is too much, assimilation will not take place at all and if no disequilibrium exists, information is assimilated without change (Fensham & Kass, 1988). In other words, discrepant events might not work with all students because some find it too discrepant and others not enough.

One idea to consider is that different inconsistencies exist in the science and also the teaching of science and can be considered discrepant events. The authors cite numerous chemistry examples; such as new names are added to improve communication, but old names still exist in the literature and old textbooks. Also inconsistencies exist as classifications and definitions have been changed. Discrepancies exist between student and teacher perceptions. For example, the teacher knows the lesson is part of a related set of experiences, but the student might see it as an isolated event. The consequence of this

discrepancy is that students do not use prior important experiences and apply it to the current lesson. In the end, the authors argue that if discrepant events can be used to help students achieve mental growth, the inconsistencies in the practice of teaching science should also be used as an advantage (Fensham & Kass, 1998).

Classroom examples

The literature contains a lot of chemistry and physics examples, but not a lot of biology examples. One article that contained a biology example was about teaching contained a unit on ecology about using two liter bottles to create a botanical garden during an ecology unit. The engagement portion of the lesson was to challenge students with a “life or death” scenario to design an ecosystem that can survive for three weeks inside the bottle. After they gave that challenge, they took the students outside to explore the pond at the school to get ideas. The authors found that students were able to create surprisingly complex ecosystems in the bottles and that the students were excited about their projects and learning (Brown, Friedrichsen, & Mongler, 2008).

METHODOLOGY

Treatment

Four general biology classes were used for the treatment. At the end of the day I have four biology classes in a row and I find myself getting fatigued by the time eighth period arrives. I find myself getting impatient with answering the same questions over and over again, and it is not the fault of the students in eighth period. For that reason, I split the treatment into two groups because I find that it is easier to do different lessons so I do not become impatient with eighth period. I randomly selected the fifth and seventh

period (Group 1) to receive their treatment together and sixth and eighth period (Group 2) to receive their treatment together. Group 1’s comparison unit was evolution and their treatment unit was heredity. Group 2’s comparison unit was heredity and their treatment unit was evolution.

During the study, the comparison unit received a traditional treatment such as a know, want to know, and learned (KWL) chart or discussion based question. The treatment unit received a discrepant event that I created. I found it difficult to find existing discrepant events for biology so a co-worker helped talk me through what could be discrepant events. The criteria for a discrepant event was that something unexpected would happen. After the engagement portion of the 5E cycle, the rest of the lessons were kept the same.

Table two contains the treatment for the heredity unit and table three contains the treatment for the evolution unit. Discrepant events are described in the treatment column of the tables while the traditional engagement events are described in the comparison column of the table. Lessons from other parts of the 5E cycle are listed. Those lessons will be the same for all classes.

Table 1
Treatment Description for Heredity Unit

Date	Comparison Unit (Group 2)	Treatment Unit (Group 1)	Topic
January 23, 2017	KWL on Punnett squares	Solve a problem through inquiry.	Introduction to heredity and Punnett squares

Date	Comparison Unit (Group 2)	Treatment Unit (Group 1)	Topic
January 24, 2017	Discussion question: If dominant is better than recessive, why are there not many people with Huntington's disease?	Huntington's disease video	Dominant is better than recessive misconception.
January 25, 2017	Extension lesson dominant disorder	Extension lesson dominant disorder	Students choose a dominant disorder and prepare a short presentation.
January 26, 2017	I wrote "co-dominance" on the board and we broke the word apart as a class. Discussion question: What happens when white fur cow and red fur bull mate? What coat color will their offspring be.	Story time with Ms. R. I told a story from the dragon genetic genome. I found a pink dragon. The pink dragon mated with a purple dragon and they let me take skin samples from the baby. The baby was both pink a purple. I passed out skin samples upside down and the students turned them over and were surprised.	Student solve problems using Punnett Square focusing on co-dominant traits.
January 27, 2017	Extension lesson on ABO blood groups.	Extension lesson on ABO blood groups.	Students solve problems with ABO blood groups.
January 30, 2017	I told the students that red flowers crossed with white flowers give pink flowers and asked what was happening. Think pair share.	I had a red snapdragon and a white snapdragon. I asked what they would produce. Students made a prediction. Then I pulled a pink snapdragon out from a box.	Students solve problems with incomplete dominance.

Date	Comparison Unit (Group 2)	Treatment Unit (Group 1)	Topic
January 31, 2017	Discussion based question about X-linked traits. Students participated in a colorblind test online.	Students do a Punnett square with colorblindness as a trait. They were given actual numbers of male and female percentages of colorblindness and were asked to figure out why. They also participated in a colorblindness test online.	Students solve problems with X-linked traits.
February 1, 2017	Review day	Review day	Students review for the posttest
February 2, 2017	Posttest	Posttest	Posttest

Table 2
Treatment Description for Evolution Unit

Date	Comparison Unit (Group 1)	Treatment Unit (Group 2)	Topic
February 6, 2017	This was discussion based. We looked at all of the printed horse fossils and talked about how the horse has changed up to modern day. They did the horse fossil assignment without jigsaw and collected data on all fossils.	I cut strings the length of the fossil horse relative <i>Hyracotherium</i> . Students brainstormed what species was that height, and the revealed it was an early ancestor of the horse. Students worked on a jigsaw activity where they measured fossils and put them in order from oldest to youngest.	How do fossils show evidence for evolution?
February 7, 2017	All students participated in a mystery fossil	All students participated in a mystery fossil	How do fossils show evidence for evolution?

Date	Comparison Unit (Group 1)	Treatment Unit (Group 2)	Topic
	assignment. They gathered data on fossils and then made a guess as to what modern species they were related to.	assignment. They gathered data on fossils and then made a guess as to what modern species they were related to.	
February 8, 2017	Students discussed how they could look at a DNA sequence and then decide how closely related two species are.	Students matched pictures on the board for the species they thought were most closely related. We then looked at how animals DNA can be analyzed to see how closely related they are.	How does DNA show evidence for evolution?
February 9, 2017	Explore lesson: Students matched continents with fossils printed on them to make a puzzle of Pangea.	Explore lesson: Students matched continents with fossils printed on them to make a puzzle of Pangea.	How does biogeography show evidence for evolution?
February 10, 2017	Pictures of labeled embryos were displayed, and the class had a discussion about the similarities and differences between embryos.	Students had card with embryo stages on them. They were asked to match three phases with each species. After the discrepant event, students completed an online explore lesson.	How does comparing embryos show evidence for evolution?
February 13, 2017	Review day	Review day	Review for evidence for evolution posttest.
February 14, 2017	Posttest	Posttest	Posttest

Demographics

Periods five and seven (Group 1) were randomly selected to be grouped together and periods six and eight (Group 2) were randomly selected to be grouped together. Group one consists of 56% male students and 44% female students. The ethnic makeup of group one is 38% African American students, 31% Caucasian American students, and 31% Hispanic American students. Group one contains nine percent classified as exceptional student education (ESE) students, nine percent are classified as 504 students, three percent are classified as gifted students, and three percent are classified as English speakers of other languages (ESOL) students. Group two contains 61% male students and 39% female students. The ethnic makeup of group two is 53% African American students, 26% Hispanic American students, and 22% Caucasian American students. Of those students in group two, twelve percent are classified as ESE students, twelve percent are classified as ESOL students, and three percent are classified as 504 plan students. Seventy percent of the students in the school qualify for free and reduced lunch. The mean grade point average (GPA) was calculated for each group. Group 1 had a mean GPA of 2.4 and Group 2 was slightly lower at 2.1. From my observation, Group 2 had more struggling and disengaged students in it. Group 2 contained sixth period and that was the period I had to have security remove students several times throughout the year.

Research methods

Data were collected using the instruments listed in Table 1.

Table 3
Research Matrix

Research question	Pretest	Posttest	Student interest surveys	Student interviews	Teacher observations	Assignment Completion	Teacher journal
How does the use of discrepant events impact student academic achievement in biology?	X	X		X	X	X	
Are students willing to struggle through the lesson if their brain has been engaged through a discrepant event?			X		X	X	X
How do discrepant events affect students' confidence levels?	X	X		X			
What impact do discrepant events have on me as a teacher?			X		X		X

My primary research question was answered by using pretest data and comparing to posttest data. Formative assessments were used to gauge student understanding and instruction was adjusted accordingly. A random sample of students were selected and student interviews were conducted to see if students knew more than the pretests and posttests measured. Instruments were piloted with classes and proofread by colleagues in the fall to ensure validity and reliability.

Sub question one, "Are students willing to struggle through the lesson if their brain has been engaged through a discrepant event"? It was answered using Likert surveys with students to see how willing they were to complete the assignment. The student

observations sheet was used to conduct observations using tally marks to see who was working and who was not working, how many times do I had to redirect students, and how many times students asked for help. A teacher journal was kept to note what happened in the classroom.

To answer sub question two, “How do discrepant events affect students’ confidence?”. I used observations from the student observation form, pretest posttest data, and interview questions.

My final sub question was, “What effect do discrepant events have on me as a teacher?” This question was answered by keeping a journal. Also I used data from the Likert survey and I gave my co-workers Likert surveys and also interviewed them.

The student observation form, found in Appendix A helped to answer the sub question, “Are students willing to struggle through the lesson if their brain has been engaged through a discrepant event?” The student observation form was a way for me to observe how students reacted record their behavior, and make notes on their behavior and reactions in class. This information helped to understand how many students were working or not working, how many were struggling and what kind of help are they asking for. The form was open ended so that I can jot down any observations I have.

My thinking was that students who are willing to struggle will be working with minimal redirection; they will need content clarified and not instructions clarified. In class I see that students who are not willing to work have to be constantly redirected to the point that I have to go to each table and ask them to get their papers and pencils out, when I leave the table, they go back to being off task until I circulate and redirect them. I

also saw students who were willing to struggle through a lesson would be working throughout the lesson, and I did not have to redirect them at all during the lesson or possibly once per lesson. I find that I spend more of my time clarifying directions rather than clarifying content. A student who is struggling will be asking me content questions which I labeled “C” on the observation form and not what to do (labeled with an “I” for instruction).

The form was used with an entire class. Spaces were numbered on the form to correspond to their spot on the roster so student names were not printed on the form. The form was kept on a clipboard and used while circulating throughout the class.

Completed sheets were stored in a three ring binder. The data was compiled and stored electronically in a Microsoft Excel spreadsheet. The number of students working and not working will be totaled in a data table. The research methodology in this project received an exemption from Montana State University’s Institutional Review Board (IRB) and compliance for working with human subjects was upheld and is found in Appendix B.

DATA AND ANALYSIS

In the heredity unit pretest and posttest data for the two treatment classes (N=23) and the two comparison classes (N=27) were collected and analyzed. Statistical analyses were conducted using the statistical software package, R. Both groups showed a statistically significant difference between the pretest data and the posttest data when analyzed using a paired t-test. The comparison group had a p-value of 0.0002306. This is statistically significantly different at a 95% confidence interval because the p-value is

less than the alpha value of 0.05. The treatment group had a p-value of 0.000014, also below the alpha value of 0.05. Therefore, both groups improved their mean test scores from the pretest to posttest.

Evolution unit pretest and posttest scores were also analyzed. Again, both groups showed a statistically significant improvement from pretest to posttest mean scores calculated with a paired t-test. The comparison group (N=26) had a p-value of 0.000019 which is less than the alpha level of 0.05. P-value for the treatment group (N=30) was 0.000013, also less than the alpha level of 0.05. To summarize, both groups showed a statistically significant improvement in their test scores from pretest to posttest.

Comparing the posttest scores for the groups yielded some different results. Group 2 received the comparison group for the heredity unit and the treatment group for the evolution unit. This was the calendar order in which the units were taught. When a Welch's two sample t-test was calculated, it showed a statistically significant difference between the unit without discrepant events and the unit with discrepant events; see Table 4 for a summary. The p-value for the Welch's two-sample t-test test was 0.011, which is below the alpha level of 0.05 and shows statistical significance. Group 1 received the treatment unit for the heredity unit and the comparison group for the evolution unit. The Welch's two-sample t-test was calculated; it showed no statistically significant difference between the comparison unit and the treatment unit for Group 1. The p-value was 0.1252, above the limit of 0.05 so the conclusion for this test is that there was no significant difference between discrepant events and traditional events for Group 1. Only one group, Group 2, showed a statistically significant improvement when discrepant

events were used, the other group, Group 1, did not show a statistically significant improvement. While both groups did not show statistical significance, Group 1 did have a higher posttest average for the discrepant event unit.

A comparison of pretest scores was conducted to see if they were statistically significantly different from each other so any difference in posttest scores would show that it was due to the treatment and not differences in the units. A Welch's t-test was performed for Group 1 and Group 2. For Group 1, the p-value was 0.2858 so the two pre-tests were not statistically significantly different. Group 2 had a different result; their p-value was 0.04056, which is statistically significantly different at an alpha level of 0.05. So for Group 1 their improvement with discrepant events was probably due to the discrepant event and not some other difference. Comparing the pretest means, Group 2 showed significance of 0.04 which is under an alpha level of 0.05, but not by a lot. Their improvement in scores may be due a difference in units and not the discrepant events.

A decision was made to combine all groups and run the statistics again even though the classes were exposed to different units for comparison and treatment. When all groups were combined, the pretest mean for the comparison units was not significantly different from the pretest means for the treatment units. The p-value was 0.5519, above an alpha level of 0.05. Combining the posttest results yielded an interesting result, the mean score improved by 11.3% from 58.9% to 70.2%. A Welch's t-test showed that the p-value of 0.003629 was well below the alpha level of 0.05. The discrepant event unit produced a statistically significantly better result when all groups were combined. The pretest means were not different, so the result was most likely the result of the discrepant

events when looking at the data from all groups combined.

Table 4
Welch's t-test Data Summary

Classes	P-value	Alpha level above or below 0.05	Statistically significant
Group 1	0.1252	Above	No
Group 2	0.011	Below	Yes
All groups	0.003629	Below	Yes

Looking at the data in a slightly different way shows that both groups did improve during the units they received discrepant events. The boxplot (Figure 1) for Group 2 shows that the mean (the line in the middle of the box) increased and the bottom quartile (the line located at the bottom of the box) increased. The boxplot (Figure 2) of Group 1 also shows improvement in the mean and the bottom quartile. Group 2 received their comparison unit first and the discrepant event unit second. Group 1 received their discrepant event unit first and then the comparison unit second. Therefore, the mean test scores of Group 1 went down when they did not have discrepant events while the mean scores of Group 2 went up when they did have discrepant events. A boxplot of all data (Figure 3) also shows the improvement in the mean for the units with discrepant events. The bottom quartile increased, and the range decreased.

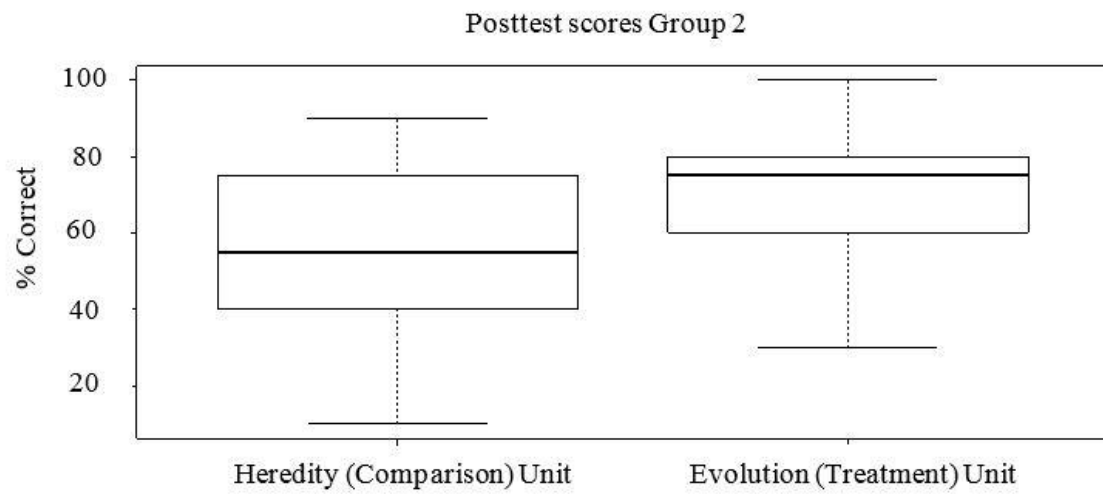


Figure 1. Boxplot of posttest scores Group 2, ($N=33$).

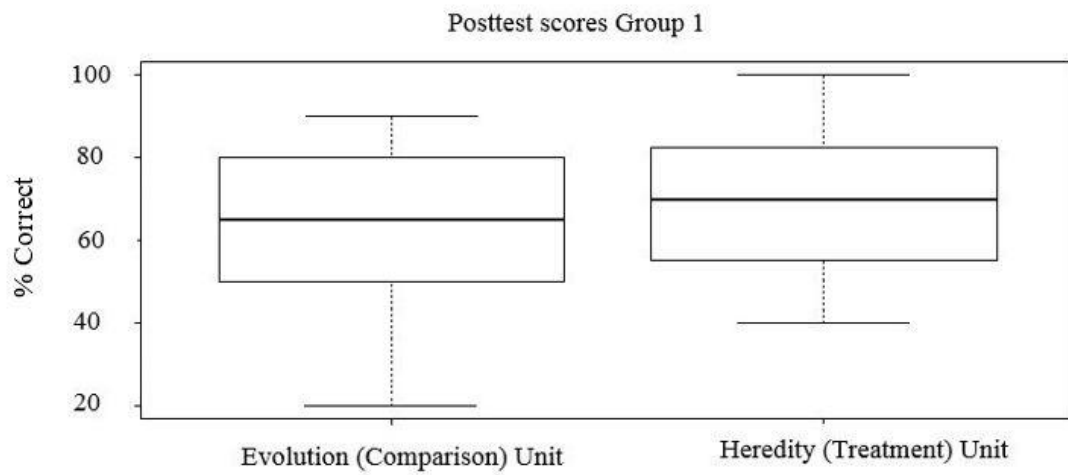


Figure 2. Boxplot of posttest scores group 1, ($N=32$).

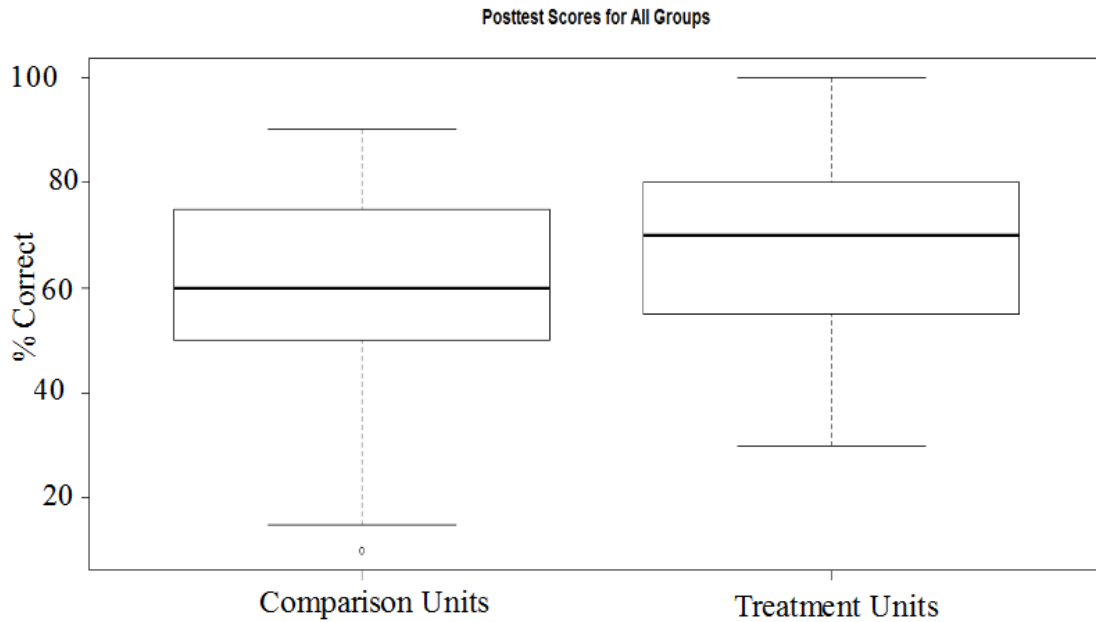


Figure 3. Boxplot of posttest scores all groups, ($N=65$).

The standard deviation between comparison group and treatment group also got smaller (Table 5). Standard deviation measures how far apart the numbers are spread. So a smaller standard deviation means the posttest scores of the students were closer together. The range between the highest and lowest score also decreased. When receiving discrepant events, the students performed more similarly and had less of a spread between high scores and low scores.

Table 5
Summary of Mean and Standard Deviation for Posttest Scores

Classes	Comparison	Treatment	Change
Group 1	Mean= 62.3%	Mean = 70.4%	+8.1%
Group 1	Standard deviation= 19.50	Standard deviation = 16.98	-2.52 standard deviations
Group 2	Mean = 55.7%	Mean = 70.0%	+14.3%
Group 2	Standard deviation= 21.1	Standard deviation = 19.8	-1.3 standard deviations

A random sample of assignments for each unit was selected and completion percentages were calculated and displayed in Figure 4; the total number of students for Group 1 were 32 and the total number of students for Group 2 were 35. Two assignments were selected from the heredity unit and two assignments were selected from the evolution unit. Students in discrepant event classes completed a higher percentage of assignments than students in classes without discrepant events. Because of the higher amount of assignment completion, it appears that students were more willing to work in the class after they were exposed to a discrepant event. This willingness to work is a possible reason that mean test scores were higher during the discrepant event unit.

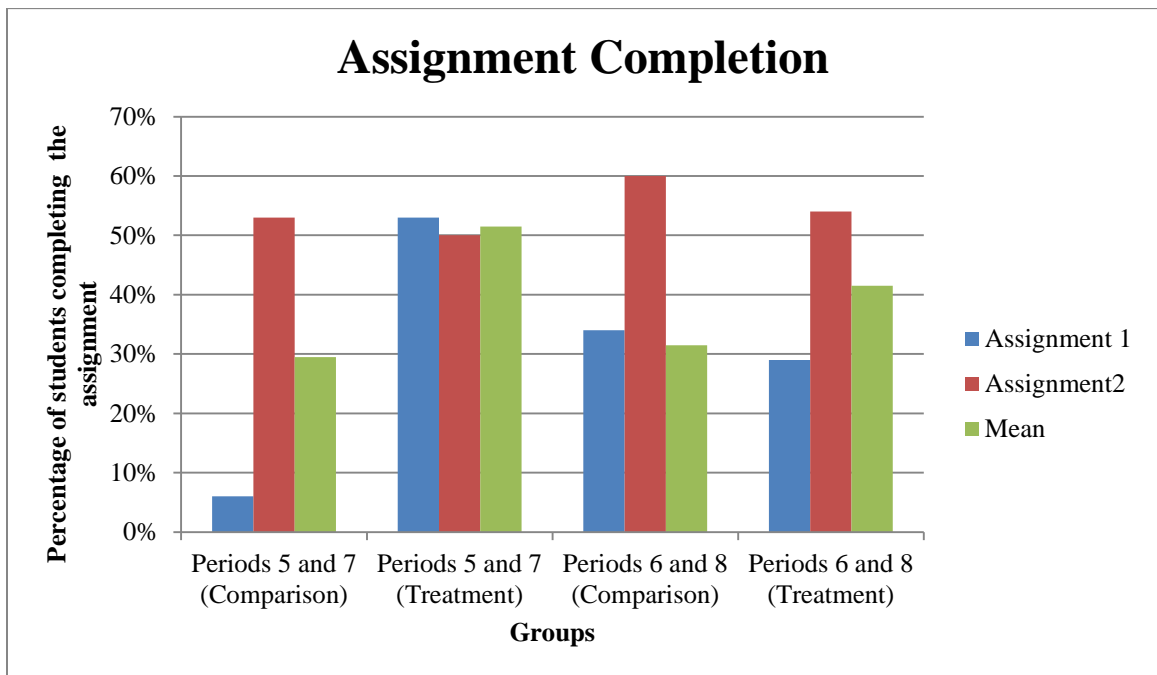


Figure 4. Bar graph of assignment completion percentage, ($N=32$ for Group 1, $N=35$ for Group 2).

Likert surveys were given after each unit. Similar questions were asked for each survey. Questions are located in Appendix D. Chi-squared tests were performed on six questions for both the heredity unit and the evolution unit.

Table 6
Summary of Likert Chi-Squared Results

Question	Group 1 Comparison	Group 1 Treatment	Group 2 Comparison	Group 2 Treatment
I paid attention in class when we were learning.	P=0.0001164	P=5.133X10 ⁻⁶	P=0.001706	P=6.785X10 ⁻⁶
If I work hard, I can understand.	P=0.001566 SD	P=0.0004398 SD	P=0.147	P=0.002905
At some point during the unit, I struggled to understand what was going on.	P=6.361X10 ⁻⁵ SD	P=0.007566 SD	P=0.5724 NSD	P=0.01299 SD
When something is hard and I have to struggle, I just give up.	P=0.002359 SD	P=0.1979 NSD	P=0.3466 NSD	P=0.0719 NSD
What we did at the beginning of class helped me engage my brain.	P=0.0001164 SD	P=0.04164 SD	P=0.01507 SD	P=0.0001308 SD
What we did at the beginning of class encouraged me to try harder.	P=0.0008626 SD	P=0.0001746 SD	P=0.005416 SD	P=0.002065 SD

All students surveyed felt like they paid attention during both the comparison unit and treatment unit. All students surveyed felt like the beginning of class helped engage their brain regardless if it was a discrepant event or not, and all students felt like the beginning of class encouraged them to try harder. The question, “If I work harder I can understand” yielded interesting results. Group 1 felt like that was true for discrepant events or regular events. Group 2 only felt that that was true for the unit with discrepant events. Their comparison unit was heredity and we did a lot of different types of Punnett squares and they struggled through that unit. Discrepant events might have helped Group 2 through the heredity unit.

Group 2 also said they would give up when something gets hard during the heredity unit and not the evolution unit. Again, discrepant events might have helped Group 2 feel more confident through that unit. Group 1 felt like they would not give up during both units.

Student interviews were conducted. The results were tallied and some trends were observed. Students were asked about their confidence in the topics they were learning. There were five major topics in both sections. Ten students in Group 1 who were interviewed reported they were confident in an average of 3.4 topics in their comparison group unit while they were confident in an average of 2.7 topics in their treatment group. For Group 2, ten students were also interviewed and they scored themselves as confident in 2.6 topics for both comparison unit and treatment unit. One possible reason for this data is that the difficulties of the topics were different in each section. Students often struggle with a lot of topics in the heredity unit. They also

struggle with embryology and putting the pieces of evidence for evolution together. More data is needed in this section to make a more confident conclusion.

Questions about discrepant events were asked. Students in both groups responded favorably to the discrepant events that were experienced. One student in Group 1 said the discrepant event with codominance using the dragon skin, “Really made me think and understand about codominance. I don’t think I would have understood with just pictures.” Another student said that the discrepant event with the Huntington’s Disease video helped me, “understand that dominant genes are not better genes.” In Group 2, two of the students reported that they felt like they already knew what was going to happen during the discrepant event. Also in Group 2, students felt positive about the discrepant event. One student said, “Looking at the actual size of the horse fossil made me curious about the other fossil horses and where they came from.”

In Group 2, there was an incident with the discrepant event where students matched pictures to see which animals were more closely related. Two students started insulting each other using the pictures, and I had to call security and have the students removed. In that case, the discrepant event made them engaged in a different way that was not positive.

Observational data from the student observation form. Data were collected on if the students were working or not working. During Group 1’s comparison unit, the average percentage tallied who were not working and needed redirection was 31% and during the treatment unit, the number fell to 17%. Group 2 also saw a decrease in the percentage who were not working and needed redirecting. For their comparison unit the

percentage not working was 29% and the percentage not working for the treatment group was 18%. Discrepant events seem to have a positive impact on the percentage of students who were not working.

Qualitative data taken from the teacher journal indicated that preparation time was longer for the discrepant events compared to the regular events. Preparing the “dragon skin” for the co-dominant discrepant event was time consuming and took about two hours. After the fourth day, a shift in the attitude of the teacher was noted. An excerpt from the journal explains the shift:

I haven't been having fun teaching this year. It's really been a struggle. I think that the last year when I got my EOC scores and nothing changed, I still had so few pass the exam, and it sent me into a depression about teaching. Also, the fact that the expectation that 71% of our students pass the exam was set schoolwide made me feel hopeless. I really don't think my students will perform well on the EOC, but that doesn't mean that they can't learn.

Today made me remember the times when I didn't have to teach to the EOC and I could do more silly and interactive stuff. We had fun in the class, learned, and I was relaxed as a teacher. I didn't worry about each student and if they had an off day, it was okay. They would get the next topic. So I think that this discrepant event was a success for me because it made me like teaching today.

Other positive influences were noted by co-workers when interviewed. One commented, “I have seen your eyes light up more when you talk about discrepant events than I have noticed this entire year.” Another commented, “I have fun talking with you about discrepant events, and I can see how you like working out what you are doing with those classes.” Overall, discrepant events were helpful in multiple ways.

INTERPRETATION AND CONCLUSION

Discrepant events appear to have a positive effect on the academic achievement of my students. Group one as a whole had more students who are experiencing success in

my class. Looking at the pretest and posttest data, I was surprised that their scores were lower during the comparison unit. I was guessing that their scores would be the same regardless as there were more students who generally are better achievers. Group 2 also surprised me with how well they did with the discrepant events. They also increased in the number of students who were working during the discrepant even unit. Pulling all of the posttest data together, the mean test score went up by 11.3%. As a teacher, I consider that a large benefit to be able to raise students' scores by that amount.

Are students willing to struggle if their brain has been engaged with a discrepant event? The students who are hard to motivate seemed to stay unwilling to struggle, but the students who are sometimes engaged, persisted more often. That tells me they are probably paying attention at the start of class, and what I do to get their brains going is more important than I realize. More assignments were completed in the discrepant events unit, a higher percentage of students were working, and students were reporting positive experiences themselves in the student interviews.

Do discrepant events affect students' confidence levels? The students were doing better academically based on the test scores, but did not rate themselves higher in the interviews. One explanation for this could be that our students have a tough time recognizing and sorting through what they know and what they do not know. Something to consider for further study would be adding metacognition. If they can recognize what they know and do not know, it might help their confidence level. The Likert surveys were interesting because it seems like for Group 2, discrepant events did help their

confidence level. Group 1 seemed confident throughout both units. This question also needed more data from more student interviews to make a better conclusion.

How did discrepant events affect me as a teacher? Overall, it was positive. When my students are scoring better and understanding the concepts better, that makes me happy. My colleagues noticed I was happier talking about discrepant events and when they went well, I felt better about my teaching. Planning and preparation was time consuming, but after the event went well, I noticed that I forgot my frustration over having to hot glue pink and purple pipe cleaners to make dragon skin.

Some limitations of the study were the number of pretest and posttest questions I was able to include; see Appendix C. My students struggle to get through the questions in one class period so I would need more questions and more data to feel more confident about this research. It was hard to make a discrepant event and not really be able to test it before I used it. People wishing to study discrepant events should think about piloting the events one year and then doing the study the following year.

It was a challenge to get students to complete the Likert surveys. I did them on the computer through Blackboard and students couldn't see how many they had to complete so I think they gave up and didn't complete or start the surveys because they thought it was too much. If I had to do it over, I would give it on paper so students could see the entirety of the survey. To feel more comfortable with the Likert data, I would have liked more participation.

VALUE

Based on the results of this project, I am consciously incorporating discrepant events in my classroom as part of my lessons. Even though it is difficult sometimes to plan discrepant events in biology class, I try to plan an experience that is unexpected. My co-workers have also noticed the positive effect this project has had on me, and we are talking more about discrepant events. Next year, I am planning to incorporate discrepant events into our science department collaboration. As the department chair, I set the agenda for our collaborative planning. I plan to have discussions about discrepant events early in the year, starting in October so we can have a month to get settled. Teams of teachers break into small groups and plan based on their content area such as chemistry, biology, environmental science. Teachers can plan discrepant events for their classes and then we can meet back and share what happened in their classroom. We can search periodicals for discrepant events and also ask in the NSTA resource center. Hopefully, we can put together a list of discrepant events that work by the end of the year. If all works well, we can share the information with other schools in our district or possibly present at a conference such as the Florida Association of Science Teachers.

Comparing the pretests with each other, and combining all of the data, I think discrepant events did have the effect on higher test scores. Overall, I think the positive effect on me as a teacher and the positive effect on the majority of the students in the class make discrepant events a powerful tool that should be used regularly. The reduced number of students not working makes me want to continue using discrepant events in the future. The co-workers that I interviewed were excited with me so discrepant events

are something that can make my colleagues excited as well. Anything students respond positively to, is something worth repeating. It did take time to come up with the discrepant events, but I have two units' worth and I can refine and revise those. By continuing discrepant events, I can also see if the results contained in this paper were valid.

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APPENDICES

APPENDIX A
STUDENT OBSERVATION FORM

Date _____ Period _____

Lesson Topic _____

Parts of the 5E lesson plan used in the lesson _____

Student	Working W=working NW = not working	Redirected	Clarified I = instructions C = content	Observations
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
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19				
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21				
22				

APPENDIX B
IRB EXEMPTION LETTER



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
 c/o Microbiology & Immunology
 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
 FAX: 406-994-4303
 E-mail: cherylj@montana.edu

Chair: Mark Quinn
 406-994-4707
 mquinn@montana.edu
Administrator:
 Cheryl Johnson
 406-994-4706
 cherylj@montana.edu

MEMORANDUM

TO: Lisa Rouwenhorst and Walter Woolbaugh
FROM: Mark Quinn *Mark Quinn Cj*
DATE: November 28, 2016
SUBJECT: "The Impact of Discrepant Events on a 10th Grade Biology Classroom" [LR112816-EX]

The above research, described in your submission of November 28, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX C
PRETESTS AND POSTTESTS

Name: _____ Class: _____ Date: _____
ID: A

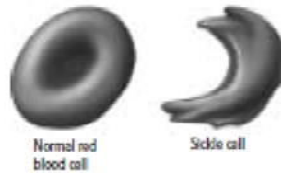
Heredity pre-test

Multiple Choice

Identify the choice that best completes the statement or answers the question.

- _____ 1. A man carrying the allele for Huntington's disease marries a woman who is homozygous recessive for the allele. What is the probability that their offspring will develop Huntington's disease?
- 25 percent
 - 50 percent
 - 75 percent
 - 100 percent
- _____ 2. The gene for brown eyes (B) is dominant over the gene for blue eyes (b). Two brown-eyed people have a blue-eyed child. Which genotypes make this possible?
- The mother and father are both homozygous brown-eyed (BB).
 - The mother is homozygous brown-eyed (BB) and the father is heterozygous brown-eyed (Bb).
 - The mother is heterozygous brown-eyed (Bb) and the father is homozygous brown-eyed (BB).
 - The mother and the father are both heterozygous brown-eyed (Bb).
- _____ 3. An individual has type AB blood. His father has type A blood and his mother has type B blood. What is the individual's phenotype an example of?
- simple recessive heredity
 - simple dominant heredity
 - incomplete dominance
 - codominance

_____ 4. Study the blood cells in the picture below. Describe the genotype for the individual with these types of cells.



- homozygous recessive
- heterozygous
- homozygous dominant
- codominant

_____ 5. A woman who is not colorblind is married to a man who is not colorblind. They have, however, a son who is red-green colorblind. What is the mother's genotype?

- $X^B X^B$
- $X^B X^b$
- $X^b X^b$
- $X^B X$

Name: _____

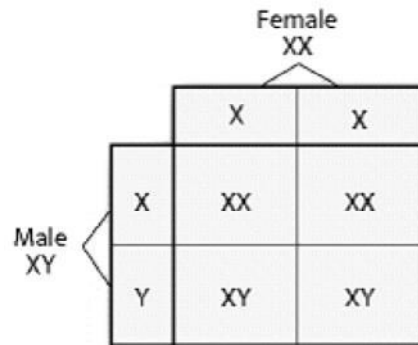
ID: A

- _____ 6. Many traits, such as stem length in plants and skin color and height in humans, are controlled by two or more genes. What is this called?
- a. simple dominant inheritance
 - b. monogenic inheritance
 - c. polygenic inheritance
 - d. codominance
- _____ 7. White-flowered plants crossed with red-flowered plants to produce pink-flowered offspring is an example of _____.
- a. codominance.
 - b. complete dominance.
 - c. dominance.
 - d. incomplete dominance.

Name: _____ Class: _____ Date: _____

Genetics Quiz**Multiple Choice**

Identify the choice that best completes the statement or answers the question.

**Figure 14–1**

- _____ 1. According to Figure 14–1, what is the approximate probability that a human offspring will be female? a. 10%
- b. 25%
- c. 50%
- d. 75%
- _____ 2. Which of the following pairs of genotypes result in the same phenotype? a. $I^A I^A$ and $I^A I^B$
- b. $I^B I^B$ and $I^B i$
- c. $I^B I^B$ and $I^A I^B$
- d. $I^B i$ and ii

Blood Types	
Blood Type	Combination of Alleles
A	$I^A I^A$ or $I^A i$
B	$I^B I^B$ or $I^B i$
AB	$I^A I^B$
O	ii

Figure 14–2

_____ 3. If a heterozygous man with blood type A and a heterozygous woman with blood type B produce an offspring, what might be the offspring's blood type? (Draw a Punnett square.)

- AB or O
- A, B, or O
- A, B, AB, or O
- AB only

_____ 4. The tall allele, T, is dominant to the short allele, t, in pea plants. You examine a pea plant that exhibits the tall phenotype. What is its genotype?

- Tt
- short
- tall
- tt

_____ 5. A researcher crosses two pink snapdragon plants. According to this information and the diagram below, what is the ratio of their offspring?

	R	r									
R	RR	Rr	<table border="1"> <thead> <tr> <th>Genotype</th> <th>Phenotype</th> </tr> </thead> <tbody> <tr> <td>RR</td> <td>red</td> </tr> <tr> <td>Rr</td> <td>pink</td> </tr> <tr> <td>rr</td> <td>white</td> </tr> </tbody> </table>	Genotype	Phenotype	RR	red	Rr	pink	rr	white
Genotype	Phenotype										
RR	red										
Rr	pink										
rr	white										
r	Rr	rr									

- 0 red; 4 pink; 0 white
- 1 red; 2 pink; 1 white
- 3 red; 0 pink; 1 white
- 4 red; 0 pink; 0 white

_____ 6. Roger wants to do a dihybrid cross of a male guinea pig with a genotype YyRr. What should Roger put down the side of the Punnett Square? a. YR, YR, YR, and YR

- Yr, Yr, Yr, and Yr
- YR, Yr, yR, and yr
- YR, YR, yr, and yr

_____ 7. Huntington's disease is a dominant gene. A man who is heterozygous for Huntington's disease marries a woman who is homozygous recessive for the

allele. What is the probability that their offspring will develop Huntington's disease? (Draw a Punnett square.) a. 25 percent

- b. 50 percent
- c. 75 percent
- d. 100 percent

_____ 8. The gene for brown eyes (B) is dominant over the gene for blue eyes (b). Two brown-eyed people have a blue-eyed child. Which genotypes make this possible? (Draw a Punnett Square if needed.) a. The mother and father are both homozygous brown-eyed (BB).

- b. The mother is homozygous brown-eyed (BB) and the father is heterozygous brown-eyed (Bb).
- c. The mother is heterozygous brown-eyed (Bb) and the father is homozygous brown-eyed (BB).
- d. The mother and the father are both heterozygous brown-eyed (Bb).

_____ 9. An individual has type AB blood. His father has type A blood and his mother has type B blood. What is the individual's phenotype an example of? a. simple recessive heredity

- b. simple dominant heredity
- c. incomplete dominance
- d. codominance

_____ 10. Colorblindness is linked to the x chromosome. Normal vision is dominant over being colorblind. A woman who is not colorblind is married to a man who is not colorblind. They have, however, a son who is colorblind. What is the mother's genotype? (Hint. Work backwards.) a. colorblind

- b. $X^B X^b$
- c. $X^b X^b$
- d. normal

_____ 11. Many traits, such as stem length in plants and skin color and height in humans, are controlled by two or more genes. What is this called?

- a. simple dominant inheritance
- b. monogenic inheritance
- c. polygenic inheritance
- d. codominance

- ___ 12. In mink, brown fur color (B) is dominant to silver-blue fur color (b). If a homozygous brown mink is mated with a silver-blue mink, what is the most common genotype?
- a. Bb c. brown fur
b. bb d. silver-blue

Use figure 10-7 to answer the question below.

	MX	Mx	mX	mx
MX				
Mx				
mX				
mx				

Figure 10-7

- ___ 13. How many offspring will be recessive for both traits?
- a. 9 c. 9:3:3:1
b. 3 d. 1
- ___ 14. If two heterozygous individuals are crossed, what percent of their offspring are also expected to be heterozygous? (Draw a Punnett Square.)
- a. 0 c. 75
b. 50 d. 100
- ___ 15. If a female fruit fly heterozygous for red eyes ($X^R X^r$) crossed with a white-eyed male ($X^r Y$), what percent of their offspring would have white eyes? (Draw a Punnett Square.)
- a. 0% c. 50%
b. 25% d. 75%
- ___ 16. When roan cattle are mated, 25% of the offspring are red, 50% are roan, and 25% are white. Upon examination, it can be seen that the coat of a roan cow consists of both red and white hairs. This trait is one controlled by ____.
- a. multiple alleles c. sex-linked genes
b. codominant alleles d. polygenic inheritance

- ____ 17. A cross between a white rooster (W) and a black hen (w) results in blue Andalusian offspring (Ww). When two of these blue offspring are mated, the probable phenotypic ratio seen in their offspring would be ____.

(Draw a Punnett Square.)

- a. 100% blue c. 75% blue, 25% white
b. 75% black, 25% white d. 25% black, 50% blue, 25% white

- ____ 18. Examine the graph in Figure 11-3, which illustrates the frequency in types of skin pigmentation in humans. Another human trait that would show a similar inheritance pattern and frequency of distribution is ____.

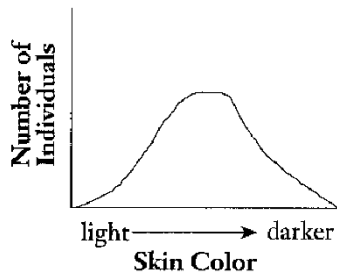


Figure 11-3

- a. height
b. blood type
c. number of fingers and toes
d. incidence of cystic fibrosis

- ____ 19. A man heterozygous for blood type A marries a woman heterozygous for blood type B. The chance that their first child will have type O blood is _____. (Draw a Punnett Square.)

- a. 0% c. 50%
b. 25% d. 75%

- ____ 20. White-flowered plants crossed with red-flowered plants to produce pink-flowered offspring is an example of _____.

- a. codominance.
b. complete dominance.
c. dominance.
d. incomplete dominance.

Name: _____ Class: _____ Date: _____

Primate Evolution

Multiple Choice

Identify the choice that best completes the statement or answers the question.

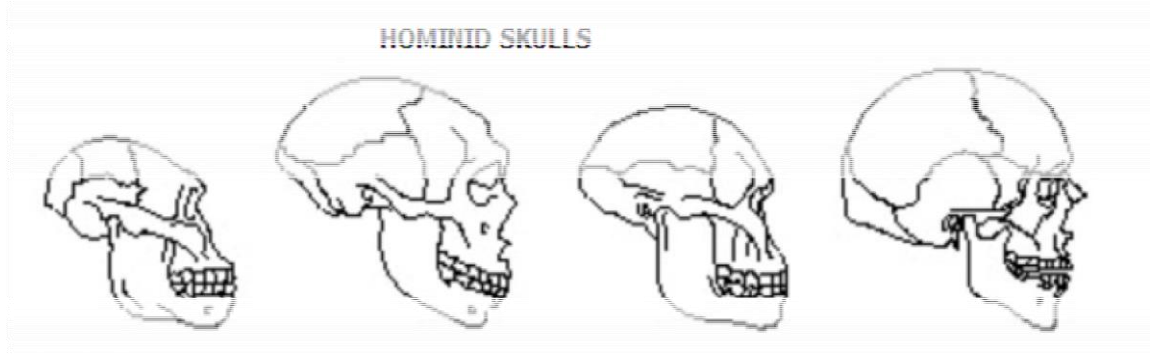
_____ 1. Fossils of hominid skulls reveal that as hominids evolved, the size and shapes of their skulls changed. The drawings show four skulls that represent different species of hominids.

1.

2.

3.

4.



Based upon the trends in hominid evolution, what is the proper sequence of the skulls shown from earliest to most recent hominid species?

a. 3,1,4,2

c. 2,3,4,1,

b. 1,3,2,4

d. 1,2,3,4

Chimpanzee
Pan Troglodytes

Ancient Hominid
Australopithecus afarensis

Human
Homo Sapiens

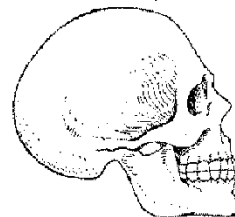
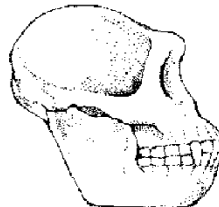
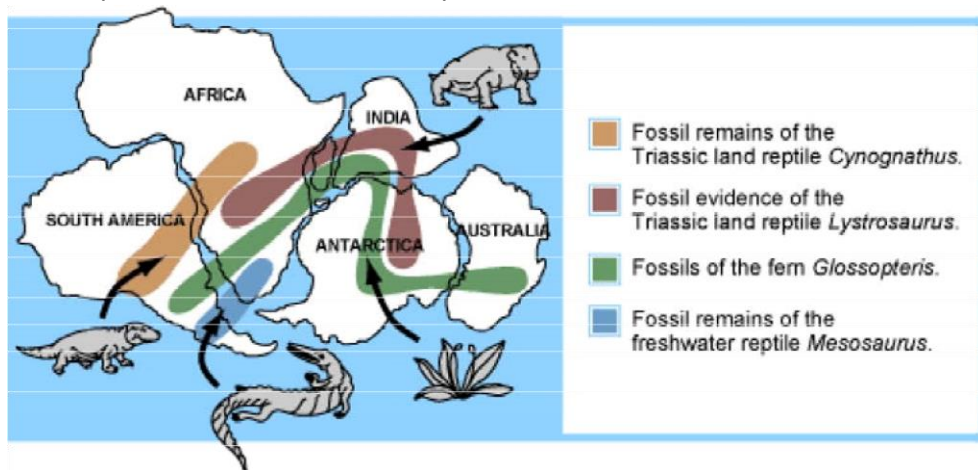


Figure 16-2

- _____ 2. Which characteristic of the skulls in figure 16-2 shows an increase in intelligence? a. decreased teeth size
- b. smaller eye sockets
- c. rounder jaw
- d. increased brain cavity size
- _____ 3. Which characteristic of the skulls in Figure 16-2 most impacts the food a species eats?
- a. increased brain cavity size
- b. smaller eye sockets
- c. decreased teeth size
- d. rounder jaw
- _____ 4. Use the picture below to answer the question:



Which evidence for evolution is pictured?

- a. Comparative embryology c. Fossil record
- b. Comparative anatomy d. Biogeography
- _____ 5. How do fossils demonstrate evidence of evolution?
- a. Fossils reveal that many species have remained unchanged for millions of years.
- b. They show that ancient species share similarities with species now on Earth.
- c. They show evidence of species that are now extinct.
- d. They are the primary source of evidence for natural selection.

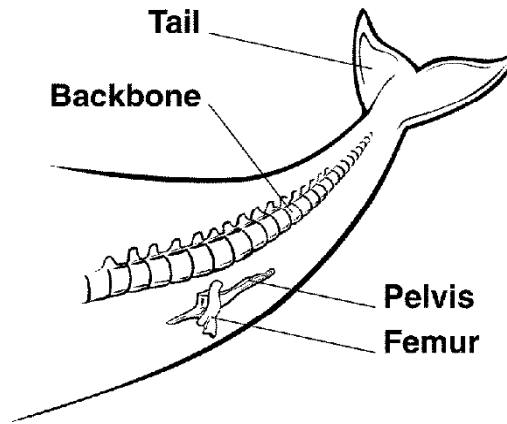
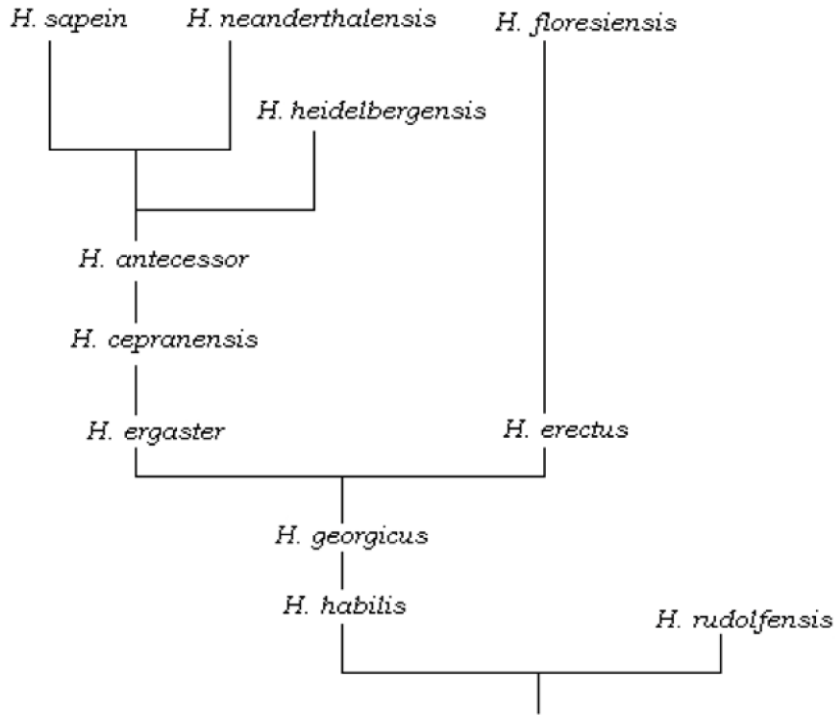


Figure 16-1

- _____ 6. In humans, the pelvis and femur, or thigh bone, are involved in walking. In whales, the pelvis and femur shown in Figure 16-1 are a.
- examples of fossils.
 - vestigial structures.
 - acquired traits.
 - examples of natural variation.
- _____ 7. Which species are believed to have overlapped in time?
- Homo ergaster* and *Homo neanderthalensis*
 - Homo erectus* and *Homo floresiensis*
 - Homo sapiens* and *Homo erectus*
 - Homo sapiens* and *Homo neanderthalensis*
- _____ 8. What distinguishes fully modern humans (*Homo sapiens sapiens*) from their most recent family members?
- | | |
|------------------------------|--------------------|
| a. development of bipedalism | c. use of tools |
| b. development of culture | d. use of shelters |
- _____ 9. Use the picture below to answer the question.



According to the cladogram (family tree) humans are least related to

- a. *H. rudolfensis* c. *H. neanderthalensis*
- b. *H. habilis* d. *H. floresiensis*

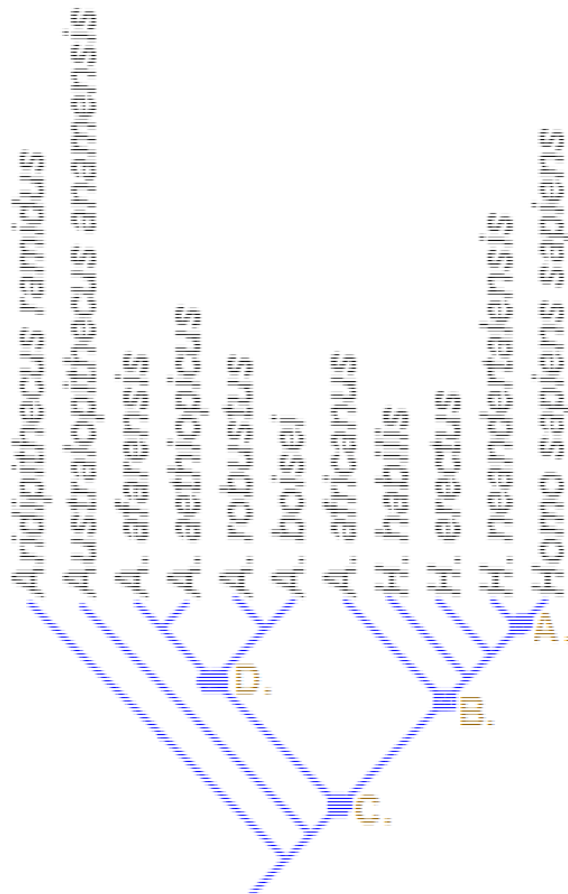
___ 10. Which of the following evidence for evolution is used to tell how many traits species have in common with each other and how related they are to each other?

- a. Biogeography c. Fossil record
- b. DNA evidence d. Comparative anatomy

___ 11. You found a hominid skeleton and wanted to figure out if it walked on two legs. What is the best way for you to gather information?

- a. Measure the brain size. c. Measure the tail bone and compare with a modern human.
- b. Measure and compare the pelvis bone to d. Measure how big the feet are and the pelvis of a modern human. compare with a modern human.

___ 12. Use the picture to answer the following question:



Where is the most recent common ancestor of *A. afarensis* and *A. boisei*?

- a. Point B
- b. Point C
- c. Point D
- d. Point A

13. Use the table below to answer the question.

LOCATIONS OF MAJOR HOMINID FOSSIL FINDS

Species	Dates	Locations of Fossils
<i>Australopithecus afarensis</i> (<i>A. afarensis</i>)	4–3 million years ago	Africa
<i>Australopithecus africanus</i> (<i>A. africanus</i>)	2.7–1.9 million years ago	Africa
<i>Australopithecus robustus</i> (<i>A. robustus</i>)	2.1–1.4 million years ago	Africa
<i>Homo habilis</i> (<i>H. habilis</i>)	2.4–1.5 million years ago	Africa
<i>Homo erectus</i> (<i>H. erectus</i>)	1.6 million–200,000 years ago	Asia
<i>Homo neanderthalensis</i> (<i>H. neanderthalensis</i>)	300,000 years ago– 30,000 years ago	Europe

Which conclusion is supported by the data presented in the table?

- a. Hominids first evolved in Europe and then migrated to Asia and Africa. The human family tree begins with hominids that first appeared in Africa.
- b. Hominids that evolved in Asia and Europe are not related to those that first appeared in Asia. evolved in Africa.
- c. The human family tree begins with Europe are not related to those that first appeared in Asia.
- d. The human family tree begins with Africa. evolved in Africa.

___ 14. Which term best describes the structures shown in Figure 15-3?

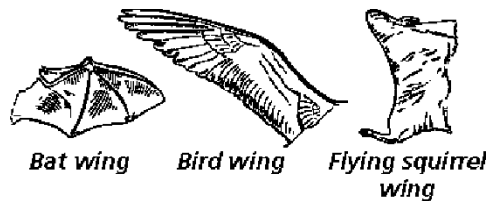


Figure 15-3

- a. homologous c. analogous
- b. heterologous d. vestigial
- ___ 15. Which of the following is an accurate comparison of derived traits and ancestral traits?
- a. Derived traits result from artificial selection; ancestral traits result from natural selection.
- b. Derived traits appear in species; ancestral traits appear in genera or higher taxa.
- c. Derived traits are primitive; ancestral traits are contemporary.
- d. Derived traits are recent features; ancestral traits are more primitive features.

Name: _____ Class: _____ Date: _____

Evidence of Evolution

Multiple Choice

Identify the choice that best completes the statement or answers the question.

____ 1. Which term best describes the structures shown in Figure 15-3?

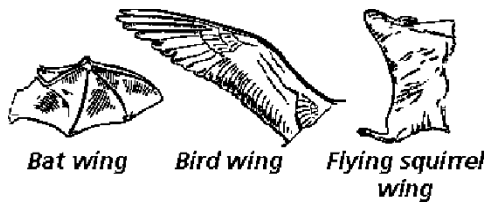


Figure 15-3

- a. heterologous
- b. homologous
- c. vestigial
- d. analogous

____ 2. Compare the DNA sequences below.

Mouse	TGCAGCTTCTCCGC
Dog	TGCAGCTTCTCCGC
Horse	TGCCACTTCTCCGC
Opossum	TCGA ACTTCTGGGTG
Platypus	TCCAGCTTCTCCGG

According to the DNA sequences, which animal listed is the closest relative to the **horse**?

- a. Dog
- b. Platypus
- c. Opossum
- d. Mouse

____ 3. Which is true because of comparative embryology?

- a. Turtle and human embryos have a tail because they have similar genes.
- b. A frog embryo resembles an adult frog.
- c. Male and female eagle embryos have wings.
- d. The embryos of all animals appear different.

____ 4. Which of the following is a difference between derived traits and ancestral traits?

- a. Derived traits are new to a species; ancestral traits are left from an ancestor.
- b. Derived traits result from human breeding; ancestral traits result from natural breeding.
- c. Derived traits appear in species; ancestral traits appear in groups or families.
- d. Derived traits are left from an ancestor; ancestral traits are new to a species.

_____ 5. Which of the following evidence for evolution is used to tell how many genetic traits species have in common with each other and how related they are to each other?

- a. Fossil record c. Comparative anatomy
- b. Biogeography d. DNA evidence

Name: _____

Use the picture below to answer the next question.

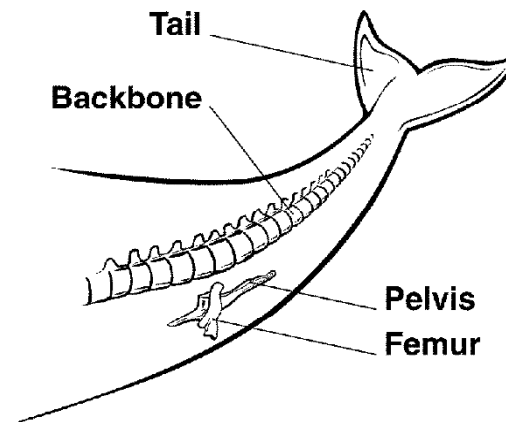


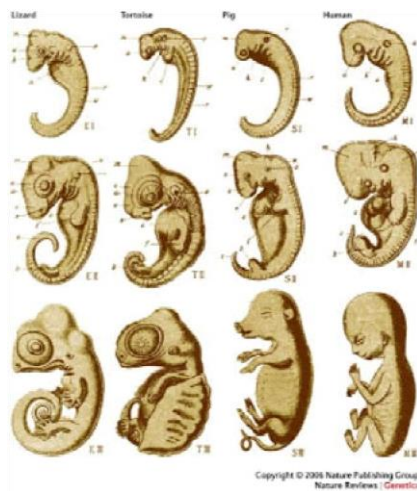
Figure 16-1

- _____ 6. In humans, the pelvis and femur, or thigh bone, are involved in walking. In whales, the pelvis and femur shown in Figure 16-1 are a.
- a. vestigial structures.
 - b. acquired traits.
 - c. examples of fossils.
 - d. examples of natural variation.

_____ 7. Which is the definition of evolution?

- a. the change of species over time
- b. the appearance of new species
- c. parents passing traits to offspring
- d. genetic differences in a species

_____ 8. Use the picture to answer the following question:
Which evidence for evolution is pictured?

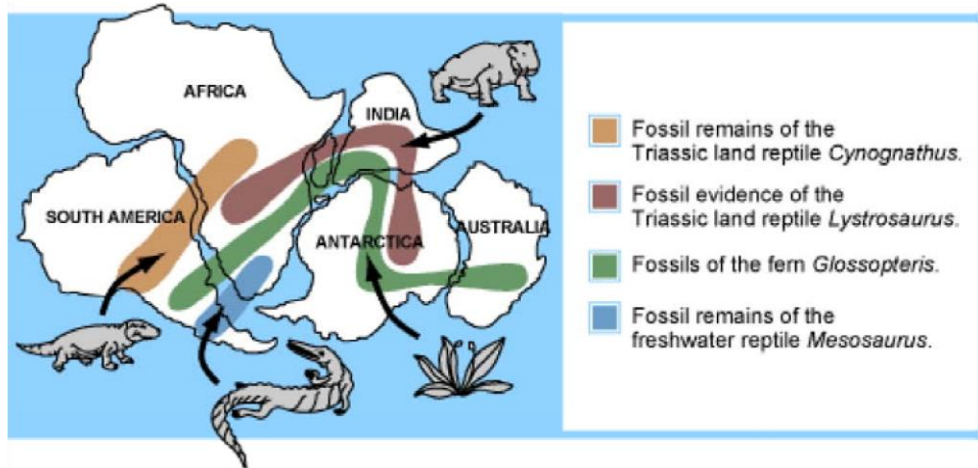


- a. Embryology
- b. Comparative DNA
- c. Fossil Record
- d. Comparative anatomy

Name: _____

- _____ 9. How do fossils demonstrate evidence of evolution?
- a. Fossils are the best source of evidence for evolution.
 - b. Fossils show that ancient species share similarities with related species now on Earth.
 - c. Fossils show evidence of species that are now extinct.
 - d. Fossils reveal that many species have remained unchanged for millions of years.

_____ 10. Use the picture below to answer the question:



Which evidence for evolution is pictured?

- a. Fossil record c. Comparative embryology
 b. Comparative anatomy d. Biogeography