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A comparison of student learning using two teaching methods: Case study and direct instruction

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A COMPARISON OF STUDENT LEARNING USING TWO TEACHING METHODS: CASE STUDY AND DIRECT INSTRUCTION

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ABSTRACT

The purpose of this study was to investigate the effectiveness of using case studies as an instructional method. Ninth-grade students (N = 48) from two different classes were involved in the study. One class was instructed using direct instruction, while the other class was instructed using a case study. An assessment was given prior to instruction, and then following instruction. The assessments focused on concepts that were included in the case study or taught during direct instruction. These concepts focused on animal behavior of Beldings ground squirrels from an evolutionary biology perspective. Analyses of the data looked at the differences in academic performance between the group taught with a case study compared to the group taught with direct instruction. Results revealed that there were no statistically significant differences between the posttest scores of the group receiving direct instruction or the group receiving the case study.

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CHAPTER ONE

INTRODUCTION

Background

The lecture method of teaching has been used for centuries to communicate information to an audience. In science, it is an effective way of conveying the most recent scientific findings. An instructor who is lecturing can synthesize many related sources and summarize them for students. The lecture can be targeted to the interests of the students and can help students make sense of the text. The instructor who lectures and is passionate about their subject may encourage students to continue learning about the topic. However, lectures can also encourage students to be passive in their learning, since it is the teacher who chooses the topic, the pace of the lecture, and the way it is presented. Students may not remember the majority of the material from longer lectures, and students are not able to experience the subject directly (Bland, Saunders, & Frisch, 2007).

With the lecture method being in question, there is a need to look for alternatives that are capable of teaching science content, but in a way where students have greater interaction with the content, and a more active role in learning. The content needs to be interesting, comprehensible, and pertinent to students. Case studies have been suggested as an alternative to lecture, or as a supplement to lecture. Case studies are "stories with an educational message" (Herreid, 2007, p. 27). They can be formatted and used for instruction in a variety of ways, but they have certain goals in common. These goals are to promote active learning (Cliff, 2006; Kunselman & Johnson, 2004; Chaplin 2009), critical thinking, and to assist in forming connections between concepts (Yadav, Lundeberg, DeSchryver, Dirkin, Schiller, Maier, et al., 2007). Case studies can foster communication skills between students and integrate reading and writing into the curriculum (Armistead, 1984; Ribbens, 2006).

Statement of the Problem

This study focused on two instruction methods—direct instruction through lecture, and the use of a case study. The control group received instruction through lecture, while the experimental group received the case study. To measure academic performance, a pretest and posttest were given to each of the treatment group. The mean posttest scores were compared to determine whether one treatment group had significant achievements over the other. The research question to be answered was the following: Was there a difference in student academic performance when a case study was used to present course material rather than through direct instruction? The null hypothesis was as follows: There was statistically no significant difference in student academic performance between the control group which received direct instruction and the experimental group which received a case study. The alternative hypothesis states that there was a significant difference between the control group and the experimental group.

Purpose of the Study

In investigating the use of case studies for academic instruction, many journal articles were found that were written about using case studies to teach college-level science. From instructors who used cases during smaller discussion sessions, to those who used cases for hundreds in a lecture hall, the methods the instructors employ are diverse. Also diverse are the topics--from respiratory physiology (Cliff, 2006) to genetics (Coleman, 1989) to poisoning of fish by the toxins that dinoflagellates produce (Kosal, 2004). However, what did not vary was that most of these articles were written about teaching college-level science. While the search for case studies was not exhaustive, very few articles were found which described using cases at the primary or secondary level (Markowitz, DuPré, Holt, Chen, & Wischnowski, 2006; Heid, Biglan, & Ritson, 2008; Olgun & Adali, 2008). One study that was conducted focused on 5^{th}-grade students. The students comprised two classes, and one class was taught using traditional instruction (reading assignments, teacher-led discussion, and questions asked of students about the material), while the other class was taught with cases. The cases were written to include a discrepant event, and students were asked to read the case prior to the class, and to look up information on their own. In class, a student read the case aloud, unclear information was clarified, and questions were given to be answered by students working in groups. Later, a whole-class discussion took place about the findings from the case study. Finally, students completed summary questions individually. In all, four cases were used and the length of the study was six-weeks. The researchers found statistically significant differences between the two treatment groups (Olgun & Adali, 2008). Also of note was that students taught with the case study had higher attitude scores than the comparison group. The students in the experimental group responded with a more positive attitude after completing the case study as compared to the traditional instruction. These results show that case studies have promise in producing higher achievement, better attitudes toward science, and greater interest in science concepts.

While the study description above is just one event where cases were used with greater success than lecture, it seems possible that students at the high school level could benefit from receiving instruction through case studies. The science content standards stress not only that students understand science concepts, but that they understand how science is conducted, acquire and use critical thinking skills, are able to solve problems, and can communicate with their peers about science concept. Case studies may be one way to help meet these standards, and to hopefully engage students in topics that they find interesting and relevant to their lives.

In using case studies occasionally over the past several years, I had wondered how the learning outcomes from the case study work would compare to a more traditional approach. Would students perform in the same way on an assessment following each learning method? The current study will attempt to answer this question.

On a broader scale, teachers often compare best practices to determine what the most appropriate teaching method might be for a specific topic. Teachers who do not currently use case studies may find that it can serve as one more technique that they can incorporate into their teaching.

The present study aims to determine whether a traditional lecture method of instruction or a case study approach results in greater achievement by students in a biology class.

Limitations

The study was conducted on students assigned to the researcher's classes for the 2008 to 2009 school year. Therefore, the students were not randomly selected from the entire student population and assigned to treatment groups. There is the possibility that a different selection of students would have a different classroom dynamic and results could be different. These particular students were selected for the two classes based on GATE designation and/or standardized test scores, overall GPA, and teacher recommendation from the prior grade. Had a treatment group been selected from the entire student population, the following variations may have been part of the group: grade level, performance on standardized tests, and GPA.

The researcher of this study was also the classroom teacher of the students involved in the study. While any bias towards one group or the other was avoided as much as possible, there exists the possibility that this may have influence the results. To attempt to eliminate biases, both groups were told that their participation in the lesson was part of a study, but neither group was told what the research question was. When students took the pretest and post-test, they used an identification number, and not their names. When the tests were graded, only the identification numbers were visible, not student names or the treatment group from which they were collected.

Both the experimental and the control group were shown a brief video clip on Belding's ground squirrel behavior after the slide show or case study reading and prior to the post-test. There is the possibility that students watching the video learned additional information from the video, which helped them answer questions on the post-test. This leads to the possibility that the learning outcomes may not solely be a result of either the lecture or the case study. However, since both groups did see the video, this may also eliminate a variable between the two treatment groups. Therefore, any differences on the post-quiz between the two treatment groups may be a result of the respective teaching method.

While the students in both treatment groups had good attendance throughout the academic year, the possibility existed that some of the students would be absent during one or more parts of the study. Students who were absent during the pretest were given the pretest when they returned from their absence. Students in the control group who were absent during the slide presentation were given handouts of the slides that they missed. Students who were absent during sections of the case study were given those sections to read through. If a student was absent during the post-test, they were given the post-test when they returned. There were several students who due to multiple days of absences did not make up the missed test, and these students were excluded from the study.

Not all students in the class signed the youth assent form or had their parents sign the informed consent form (nine total). The data from these students was not used in the study. Two students were not given permission by their parent or guardian to participate in the study, and the data from these too were excluded from the study. There is the possibility that the students who did not return the ascent or consent forms or returned forms that did not allow participation made up a different population of the students. The limitation is that no data was collected from the non-signing or non-participating students.

The students in the experimental group were organized randomly through a computer grading program which attempts to form heterogeneous groups based on the student's grade. The possibility existed, however, that some groups had members which did more or less work on the case study questions, and therefore may have done better or more poorly on the post-test.

This study took place after the State Testing and Review (STAR) and prior to the final exam. There was approximately two weeks remaining in the school year. Student grades at that point were fairly indicative of what they would receive on the last day of school. Therefore, there may be less effort placed into testing, paying attention, and using class time effectively then there would be at a different time in the school year. Additionally, some students are restless at this time, anticipating summer vacation instead of focusing their full attention on school work. This may have impacted the results of the study.

Definition of Terms

ANCOVA: Analysis of Covariance; statistical test which removes pre-existing differences among subjects and it removes the need to test each subject with each experimental condition (Lowry, 2010).

Case study teaching: A method of teaching which involves using a story with an educational message. The way in which these stories are used varies with the topic of the case, the audience, time frame, and preference of the instructor (Herreid, 2007).

Direct instruction: A process whereby the teacher assesses prior knowledge, lets the students know what the overall objectives of the lesson are, delivers the new material, assists the students in sample problems and examples, assigns work that the students complete independently and that the teacher assesses to see if the learning objectives are being met, and finally reviews the information and provides feedback to the students when necessary (Gunter, Estes, & Schwab, 2003).

MNSQ: Mean-squared fit statistic (Linacre, 2001).

Rasch analysis: Data analysis method that uses a mathematical formula to calculate the probability of success by looking at the difference between an individual's ability and the item's difficulty (Wright & Linacre, 1987).

CHAPTER TWO

REVIEW OF THE LITERATURE

An Overview of Teaching Methods

In education, a variety of methods exist for implementing instruction. The method chosen may depend on the experiences of the teacher, the topic to be taught, and the characteristics of the learners as individuals and the class as a whole. One method of instruction commonly used in the classroom is direct instruction or teacher-centered instruction. Teacher-centered instruction is usually done through a lecture given by the teacher. The teacher plays the role of "knowledge expert" to transfer information to the student who then takes in the information (Colburn, 2003, p. 11). This teaching method is useful when there is a large amount of material to cover in a short amount of time. It is also useful for teaching step-by-step processes. With teacher-centered instruction, the teacher controls the pace of the lesson and the activities that accompany the lesson. While teacher-centered instruction refers to the overall environment in which a lesson takes place, direct instruction more specifically refers to a process whereby the teacher assesses prior knowledge, lets the students know what the overall objectives of the lesson are, delivers the new material, assists the students in sample problems and examples, assigns work that the students complete independently and that the teacher assesses to see if the learning objectives are being met, and finally reviews the information and provides feedback to the students when necessary (Gunter et al., 2003).

If a spectrum for instruction methods exists, teacher-centered instruction would be on one side, and on the opposite would lie student-centered instruction. In student-centered instruction, the responsibility of learning is given to students. Student-centered instruction is often described as "active learning" because students are participating in the course material, instead of being a passive audience. Active learning "is anything course-related that all students in a class session are called upon to do other than simply watching, listening, and taking notes" (Felder & Brent, 2009, p. 2). The idea behind active learning is that students must practice a skill in order to fully develop it, and that students cannot fully develop skills while listening to a lecture (Felder & Brent, 2003). Active learning encourages students to work together, teach each other, make sense of the information they are getting in class, and/or solve a novel problem.

Active learning can range from spending brief period of time to interrupt lecture and have students discuss an idea or problem with a partner, to having students spend entire class sessions working as groups in designated roles to try to solve a problem. Active learning can involve many different tasks in which the students are asked to take part. Students may work in pairs or groups to answer questions or collaborate on solving a problem. The problem can be one that is solved very quickly or that takes an extended amount of time to complete. A problem that takes students several class sessions in order to reach some sort of conclusions or solutions is known as Problem Based Learning, or PBL. The aim of PBL is to get students engaged in working through real-world problems. The curriculum of a unit or course is centered around the problem, and the teacher facilitates learning instead of telling students exactly what they need to know. Similar to PBL is the use of case studies, which very generally, are "stories with an educational message" (Herreid, 2007, p. 27). These *stories* range from short, open-ended questions to cases that are anywhere from several paragraphs long to a hundred pages in length. Some cases can be examined within a class session, while others may take much more time. Of the different types of cases, some are divided into several parts, and have questions following each part of the case. The questions are answered prior to moving on to the next part. Other cases can have more reading material, can involve issues that need time for research, and require the students to determine what information they need to investigate to be able to discuss the case. This type of case is really a description of problem-based learning. Additionally, some cases in science can be used to not only have students conduct literature reviews to learn more about a topic, but also to carry out laboratory investigations. Students may be asked to identify a research question, to design an experiment that would provide answers to the question, and to reach conclusions about the problem.

History of Using Case Studies for Instruction

While the use of case studies in formal education has not been around as long as the lecture method, it is not altogether new either. When someone who is experienced in a particular skill or craft assists someone who is less experienced, this can also be thought of as case teaching (Boehrer & Linsky, 1990). The use of case studies for teaching has its roots not in science, but in law. Harvard Law School began using cases in 1870 when a new dean, Christopher Columbus Langdell, was appointed. Instead of the method by which he learned law, which was by lecture, reading the textbooks, and memorization of information, he thought students should read actual cases. He argued that by understanding a few general principles, lawyers would be able to interpret individual laws. The cases he thought useful were those with clear-cut decisions and those that conformed to doctrine. He did not want to use cases that were wrongly decided as teaching tools. Although this method of teaching met with initial resistance, the use of case studies is now the prevailing method of educating those in law school. The method has been revised since it was first used by Langdell. Now, professors strive to find cases where the outcome cannot be clearly decided, and students are forced to deal with issues that are more gray than black and white (Garvin, 2003).

Following the lead of Harvard Law School, Harvard Business School began using case studies in 1920. Faculty developed casebooks from which they could assign cases to students. Similar to the cases used in law school, business school cases were based on actual events. However, less emphasis was placed on finding a correct answer at the end of the case. The written cases concluded without stating the decision made by the businessman, so the role of the student was to evaluate various possibilities. The focus was less on learning principles, as was important in law, but on practicing decision-making skills when confronted with new situations (Garvin, 2003).

Harvard Medical School did not begin using case studies until 1985. Until that time the first two years of medical school were spent hearing lectures in general science classes. In the last two years of medical school students spent time at a hospital and were involved with the patients, including gathering patient histories, carrying out physical examinations, and diagnosing. With the introduction of case studies, students in the first two years of the program spent less time in lecture, and more time analyzing and discussing cases in a small group setting where dialogue was facilitated by tutors (Garvin, 2003).

Teacher training is another area in which case studies have recently been used. In the 1920s the New Jersey State Teacher's College had a collection of cases that were studied. Various other case study books were published in the 20th century, striving to put the theories behind teaching into practice. By reading about various situations typically encountered by teachers, beginning teachers were able to role play the situation and practice decision-making (McAninch, 1991). Not only would case studies help a teacher practice useful skills prior to handling the real-life situation, but the case method more accurately determined what a teacher knew (Barnes, 1987).

History shows that using case studies in the fields of law, medicine, business, and teacher education has been an effective addition to lecture-based classes. In some situations, case studies may even replace the lecture. Therefore, it seems logical that case studies would work in science education at the undergraduate and even high school level as well. As part of his chemistry course for freshman and sophomore non-science majors, James Conant structured his lectures around great discoveries in science (Herreid, 2007). In the 1940s, as a professor at Harvard, and later Harvard's president, Conant would describe the methods scientists would use and the mistakes they would make at arriving at the incorrect or correct conclusions. The reason that he integrated case studies into his teaching was because he saw a lack of understanding among the general public for how scientific discoveries were made. Adding the case study teaching to the lecture method, however, did not catch on at Harvard, beyond Conant's lecture hall.

The Use of Case Studies in College-Level Science Education

While the use of case studies to teach science is not the most common instruction technique, there have been studies that measure its effectiveness. In a human physiology course, the case study entitled "A friend in need is a friend indeed: A case study on human respiratory physiology" was used (Cliff & Wright, 2005). The case was "designed to help students learn about how oxygen is carried in the blood" by analyzing it through the scope of carbon monoxide poisoning (Cliff, 2006, p. 215). The instructors had used information that previously identified four main misconceptions concerned with respiratory physiology that students typically have. Of these four misunderstandings, the instructors chose the one with the highest frequency and used it as the focus of the case study [this misconception was identified as the "SA/PO_2 misconception"] (Cliff, 2006, p. 215). Three case studies were used with the same students prior to respiratory physiology case, so students were accustomed to a teaching method other than lecture. Prior to a series of lectures on the respiratory system, students received the case. They worked on it outside of the class and then turned in their answers following the last respiratory physiology lecture in the series. The case was then discussed in the next class session (Cliff & Wright, 2005). The format of the case was a brief introductory paragraph, followed by ten multiple-choice questions. Students received a pretest before the first lecture on respiratory physiology (Cliff, 2006). Following the pretest, but before the start of the first respiratory physiology lecture, students were given the case study. The case study was to be read and the questions completed outside of the regular classes, and it was the students' preference as to whether they worked alone or with others. Regular class time was filled with lectures and laboratory activities. The content of the lecture and labs focused on "pulmonary ventilation, respiration, gas exchange, gas transport, and control of breathing" (Cliff, 2006, p. 216). After a week, the questions to the case study were collected, and students took a mid-test. After the mid-test, a case study review session was carried out to further clarify misunderstandings. Finally, the post-test was given to identify the misconceptions that still remained.

The authors found that more students correctly answered a particular question designed to address the SA/PO_2 misconception in the post-test as compared to the pre-test. There was a statistically significant difference between the pre-test and post-test and the authors concluded that the case study was responsible for this change. For example, 17% of the class obtained the correct answer on the pretest (concerning the SA/PO_2 misconception) prior to instruction. After the answers to the case study were submitted, and students took a midtest, 37% correctly answered the question. Following the lecture and laboratory, 40% answered the post-test question correctly (Cliff, 2006).

A significant change between pretest and posttest scores was not seen in any of the other tested areas of misconception. Students were also seen to do better on the midtest than the pretest, showing that the case study had a significant effect on correcting student misconceptions. Also important to note, is that the misconception targeted by the case study is the only one in which significant reductions in misconceptions were seen. Overall, the authors concluded that the teaching method employed to correct misconceptions can impact the repair of misconceptions by students.

In an introductory biology class at Western Illinois University, case studies are used throughout the course. While the course includes a lecture and laboratory component, case studies are integrated int the course activities and involve students working in small groups, keeping journals, and completing a major writing assignment. The case studies are used because they are an effective way to "tie the scientific method back together" (Ribbens, 2006, p. 13). Both lecture and laboratory are important in teaching about the scientific method, but neither completely explores the topic or gives the experience that working on a case study does. "The case illustrates the theory, presents the results of an experiment, or challenges students to explore a problem in search of solutions" (Ribbens 2006, p. 13). While the cases have a specific concept that they are trying to get across to students, they are important for having students experience the nature of science as well. Evaluating the real-life challenges of designing an experiment, gathering data, and interpreting results gives students more experience with how science works. It also generates discussion among students and between students and the professor. Through the discussion of a case, Ribbens was able to see where students' misconceptions lie and that his students have certain ideas about science that may have gone undetected without the use of a case study (2006).

Similar to the way in which Ribbons uses case studies, Gallucci also uses the case studies to teach about the Nature of Science and to build a foundation throughout her course about the process of science and scientific knowledge (Gallucci, 2009). For each concept that should be understood in the Nature of Science, such as "hypothesis testing" (2009, p. 18), she has a case study that complements the concept. By working through the case study, it is suggested that students acquire a better understanding of the process of science.

While the previous examples show that cases can be used throughout a course to enhance the regular topics of a course and to teach about science as a process, another use of cases is to preassess what students already know about certain concepts. Students can be given a scenario, and asked to respond to it. The responses can then be used to determine what the students already know (Gallucci, 2006). An example given by Gallucci is a scenario about a farmer who sprays his crops with a certain insecticide. While the insecticide kills most of the flies, before long the fly population is back to its beginning level. The spraying and repopulation of flies continues several times and eventually it becomes clear that the insecticide is less effective each time it is used. The responses to this prompt indicated the student's base knowledge about evolution and natural selection.

In addition to identifying misconceptions, case studies can be used to ensure that each major learning objective is taught. The big ideas of a topic are identified, and a case study allows students to practice using these ideas in a way that hearing a lecture or reading about it in the chapter cannot. Through engaging in case study analysis, students are also improving their metacognition skills, or how they think about their thinking (Gallucci, 2006). By reading a case and working as a group, students take on various roles where it is necessary that they make decisions. While the experiences that students are having with the case are done vicariously through the characters in the case, the scenarios are treated as if they are real. Students must be very involved, must be able to defend their positions, compare their positions with those of others, and discover where their own misunderstandings occur.

At the Philadelphia College of Pharmacy and Science, case studies are used in several of the science courses.

Following each unit in Mammalian Anatomy and Physiology, a case is given for students to work through, either alone or in groups. The case deals with a scenario that includes descriptive information about the patient and the symptoms. Questions follow the medical information. The case is then discussed in class to allow time for analysis. An introductory biology class includes cases that require students to gather data in the laboratory. The skills that are targeted in the laboratory case study are "detailed observations, accurate recording, experimental design, manual manipulation, data interpretation, and statistical analysis" (Smith & Murphey, 1998, p. 266). In a plant tissue culture class, students carry out various statistical tests necessary to solve the case study, but also to analyze projects that that the students design at a future date. According to the authors, "case studies teach students to make linkages and integrate material" (Smith & Murphey, 1998, p. 266). Since the cases must be solved by the students, they also give the students "a sense of accomplishment" (Smith & Murphey, 1998, p. 266).

In another example of case study use, this time for a genetics course or a general biology course that is examining the topic of genetics, short scenarios can be given that describe a particular patient. The idea behind using these short cases is to embed the goals of the lesson into the scenario, such as examining the effects of medication on a fetus, how chromosomes may break, mutations, and birth defects (Coleman, 1989). In presenting a case, instead of just telling students to look into these concepts, or lecturing about the concepts, the students take a more active role. They must pick out the important details from the case and decide what to research. By having students read cases that are based on actual events that may be controversial in nature, and role-playing a character within the scenario, students become active participants in the course. They are researching the information in the case, and making decisions based on both facts, emotions, and personal beliefs. Not only do the cases require students to learn the science of genetics, but the cases make the learning applicable to real-life situations.

Case Study Use at the Kindergarten through Grade 12 Level

The literature regarding the use of case studies in teaching science topics in elementary, middle, or high school is not prolific. However, a study was conducted involving 5th grade students and the subject of viruses, bacteria, fungi, and protista. The research involved 88 students, divided between two different classes. In one class, the six-week study involved traditional instruction which consisted of reading assignments, explanations by students, lecture by the teacher, and note-taking by the students. Students in the other class were taught using a case study which involved very different teaching techniques. The case study was written while taking into consideration the target audiences' interests. It had situations based on real life, as well as discrepant events that would lead students to wish to learn more about the topic. Students were assigned to read the case on their own, and then in class the case was read again and clarification questions were asked by the teacher. While working on the case study, students used resource materials such as the Internet to gain background information. Students worked in groups to synthesize a report that they then presented to the class. They also answer questions that were interjected into the case study reading.

Not only was the student instruction much different between the traditional class and the case study class, but the teacher received additional training in how to instruct using case studies. The teacher was trained in assisting students in improving their critical thinking skills, and in helping students reach the answers on their own. The teacher acted more as a facilitator to help support students in understanding the topic than a provider of information.

Prior to receiving instruction, students took two pretests. One measured prior knowledge about the topic under consideration, and the other looked at attitudes towards science. Posttests were given that measured the learning that had taken place, and attitudes about science. The pretests indicated that there was no significant difference between the experimental and control groups for either knowledge base or attitudes. However, when comparing the posttests of the two groups, there was a significant difference between both achievement of learning goals, and attitudes towards science. Student reflections about the lessons mirrored the results of the posttest. Students involved in the experimental group "demonstrated positive attitudes" about science in their writings, while those in the control group "expressed their negative attitudes toward the science course" (Olgun & Adali, 2008, p. 39).

Case studies on scientific ethics were used with high school age students during a four-week summer residential enrichment program in science and engineering. The various ethics cases were written in a way that related to the students who were reading them. They related by discussing topics that described experiences students had or would likely encounter. In small groups, the students described the cases and wrote a response. The authors concluded that the "case method is an effective technique for discussing scientific ethics with high school students" (Barden, Frase, & Kovac, 1997, p. 14). Relating the cases to real experiences drew in students and helped them evaluate not just the case but their own behavior as well.

Various Methods of Case Studies Use

While the fields of law, business, medicine, teaching, and more recently science education may all use case studies for educational purposes, the type of cases used, the way the cases are written, and the presentation used will be distinctly different between these fields (Sykes & Bird 1992).

As defined by Clyde Herreid, a case is a "story with an educational message" (2007, p. 21). John Wallace breaks the case idea into three components: that a case is "based on a 'real life' situation or event focusing on the particulars of that situation", that a case is focused "around a particular phenomenon", and that a case consists of learning opportunities for both the person putting the case together and whoever may be involved with the case (2001, p. 185). Cases are constructed in a way to maximize the learning outcomes. A case can be a "document or text, a story, a vehicle for discussion, and an event" (Boehrer & Linsky, 1990, p. 44). Such broad definitions of what a case study is give it much flexibility for use in the classroom.

There are various ways in which to construct and present a case, and these range from teacher-centered to learner-centered. Conant's method was very teacher-centered, and would fall under the classification of lecture format. Herreid describes the remaining methods as "individual assignment format", "discussion format", and "small group format" (2007, p. 56, 57). The individual assignment format would include many types of assignments, such as "term papers, dissertations, and book reviews" (Herreid, 2007, p. 56), as long as they involve some sort of educational story. They are named according to who is completing the analysis of the case. In lecture, it is the instructor, while for the individual assignment it is the student. In discussion it is the large group or class as a whole, and with small group it is the group members that must analyze the case. The preferred methods for carrying out a case are the discussion format and small group format. Discussion format involves the instructor delivering questions to students. These questions aim to draw out the students' perspectives on the case. Small group format gives the group a task, roles are often chosen by the group members, and the group makes sense of the case and reaches a consensus together.

While the four formats discussed above are a general classification for who is doing the case analysis, there are a variety of ways in which cases can be used within these categories, specifically for the discussion and small group format. Several of these are discussed below.

A variation of the discussion format is the debate format. It is ideal for an issue that has two opposing views whereby teams of students research and then present their case to the other side. A public hearing format can also be used, where a panel of students hears individuals or groups of students present a specific position. The panel can ask questions of the students who are presenting, and then the panel makes a decision. Another type of format is the trial format with two opposing sides. To do this, attorneys that represent each side are needed, as are witnesses with various views. These roles are played by students, who have researched both sides, and come to the class trial prepared to take on a given role. While a decision at the end of the case is not necessarily reached, students gain experience in researching and presenting a position, and dealing with multiple perspectives on issues that have no definite right or wrong side (Herreid, 2007).

Utilizing more of a small group format is the problem-based learning (PBL) format. Of medical schools that use case studies, PBL format is the preferred method. A medical case is presented to a small group, with the goal being a diagnosis and treatment in the end. The small group discusses the main points, and target areas in which they need more information. The small group divides up the work, and when they meet next, they discuss their findings. As a group, they decide on what more they need to research. Finally, they meet again and produce a diagnosis and treatment of the problem. While this is the procedure that is often used in medical school, there is no reason why the same method would not work with a general science case. If a case is introduced that presents some sort of problem that must be solved, a small group can meet and discuss the problem in the method described above. Cases can also be in a scientific research team format where students conduct some type of scientific experiment, analyze data, discuss the results with their peers, and draw conclusions. Students can write papers using the format of a paper published in a science journal, papers are exchanged between groups for peer review, papers are revised if necessary, and turned in for grading by the instructor (Herreid, 2007).

California Science Standards and the Case Study Method

Science education in California's public schools is driven by the Science Framework for California Public Schools. The content standards for high school biology cover a wide range of topics which build upon concepts introduced in earlier grades. With the breadth of topics that range from the molecular level to the ecosystem level, a variety of learning activities can make the content more comprehensible to students. Some topics may be best presented through direct instruction, whereas other topics may suit students better if the students are involved in a more active learning process. Some types of learning activities are able to tie multiple topics together, present real-life scenarios, and have students practice skills that may not be the primary goal of the lesson, but are achieved as a result of the activity.

Although there may be many types of activities which are able to accomplish these things, such as computer simulations, role-playing, and laboratory, case studies can also contribute to these goals.

While case studies may focus on a very specific topic, such as a specific organism displaying a specific behavior, they can also be generalized to fit many scenarios. For example the case study that is the focus of this thesis is based on one specific behavior of one organism--alarm calls in the Belding's ground squirrel. The case looks at alarm calls that are made, their purpose, and their effects on the squirrel making the call and others around it. The case study presents how a female ground squirrel will be more likely to make the alarm call when she spots a predator if she can protect squirrels who are related to her in someway. By carrying out this altruistic behavior, she is helping to ensure that genetic material that she shares with her family will be passed along to future generations, even though the future generations may not be her direct descendents. While the ground squirrel's actions may attract the attention of a predator and may lead to the death of the squirrel making the alarm call, it also contributes to the survival of squirrels who are closely related to her. This deals with the broader concept of natural selection, where traits that are advantageous to the organism are passed along to future organisms.

The case study is able to tie multiple topics together by presenting information on the biology of ground squirrels, their behaviors, and natural selection. It presents real-life scenarios, by being based on actual research that was done on ground squirrels to determine how their behavior contributes to the survival of their family members. Although it is not the primary learning goals for students, the case asks students to discuss questions with a group, they must interpret a graph, form a hypothesis, and perform calculations.

The case study encompasses one of the California biology standards in which students are expected to be knowledgeable at the end of their biology course. This evolution standard, which states "students know how natural selection determines the differential survival of groups of organisms" is presented thoroughly in the case study (California Department of Education [CDE], 2003, p. 238). The case study also deals with standards that fall under the Investigation and Experimentation section of the Science Standards for high school. One of these, that students "formulate explanations by using logic and evidence" is asked of students during the case study (CDE, 2003, p. 279). Students must use the information presented to form hypothesis. They must also look at data (evidence) and use it to draw conclusions about the concepts. The other standard asks students to "recognize the cumulative nature of scientific evidence" (Science Framwork, 2003, p. 279). By presenting information in piecemeal fashion, students have time to process a small amount of information at a time. They must also connect one part of the information with other parts in order to reach the correct conclusions. The case study may also lead to further discussion between students and the instructor as to how the research was conducted on the ground squirrels. Students could be asked to propose how they would study alarm calls and altruistic behavior in ground squirrels. This could lead into a discussion about experimental procedures, such as sample size, variables, and controls. With case studies, the topic may be expanded to deal with student interests, and should not be limited to just what is presented in the case.

Summary

In conducting the review of relevant literature, there were few studies which examined the use of case studies at the high school level. This review looked at the attributes of two teaching methods, the history of case study use, various ways in which case studies are used in a college science setting, the use of cases at the elementary, middle, and high school level, diverse methods for using case studies, and finally, how the California science standards may be met through the use of case studies. While case study use has been suggested as a way of improve critical thinking skills, engage students in the content, enhance communication between students, and get students to become active participants in their learning, more research needs to be conducted to determine the appropriateness of case studies for high school students.

CHAPTER THREE

METHODOLOGY

School Background and Demographics

The school in which this study took place is in the High Desert within San Bernardino County in Southern California. It is a public, suburban high school, which had a student population of 3,544 students during the 2008 to 2009 school year. Of these students, 1,064 were in the 9th grade, 1,007 made up the 10th grade, 795 were in 11th grade, and 678 were in 12th grade. The ethnicity of the student population is as follows: Hispanic or Latino (58%), White (not Hispanic) (27%), African American (9.6%), and Filipino, Pacific Islander, and Asian collectively make up 2.9% (California Department of Education [CDE], 2009). English Learners compose 17.7% of students. Students receiving free and reduced price meals make up 51.1% of the population. The majority of students attend six periods per day, and class length ranges from 50 to 55 minutes.

This study took place in a public high school among two classes of students enrolled in general biology. The students in the two classes were in the same grade and were taught by the same biology teacher. They also had similar overall class percentages, which were based on the students test and quiz scores, homework, classwork, laboratory, and participation grade. Both classes focused on the same topics, regardless of whether they were in the experimental group (case study), or the control group (lecture). The biology topic focused upon for this study was evolutionary biology. More specifically, the content looked at the role that altruism plays in evolutionary biology by examining Belding's Ground Squirrels and the alarm calls that they make. The students in the experimental group worked in groups to read a case study that consisted of multiple parts. Each part was followed by questions, which were answered together by the group. The control group listened to a lecture and viewed a computer slide presentation. This group was responsible for taking notes. Both the lecture and the case study contained the same information. Both groups took a pretest prior to the beginning of the study, and took a posttest once the case study and lecture were complete. The assessments were based on the academic content of the lesson.

While this study focuses on a specific topic of study (altruism in Belding's ground squirrels) and a specific group of students, it is the hope that the results can be generalized for a broader range of academic subjects and students.

Research Question and Hypothesis

Is there a difference in student academic performance when a case study is used to present course material rather than through direct instruction?

The null hypothesis: There is no statistically significant difference in student academic performance between the control group which receives direct instruction and the experimental group which receives a case study.

The alternative hypothesis: There is a statistically significant difference in student academic performance between the control group which receives direct instruction and the experimental group which receives a case study.

An Institutional Review Board application for California State University at San Bernardino was submitted and approved for the study in this thesis. The collection of student data was confidential and any specific identifiable information present in the student data was eliminated prior to inclusion in this study. An identification number was assigned to each student prior to them taking the pretest, and they used this number on both the pretest and post test. Prior to being presented in this thesis, the student data was placed in a randomized order.

Once the IRB had been approved, it was explained to students that they would have the opportunity to participate in a study only if they chose to do so. It was explained to the students that any information that they provided would be confidential, and that their participation or lack of participation in the study would in no way affect their grade. All students were given the youth assent form and parental consent form. After the forms were reviewed with the students in class, students were advised to discuss their participation in the study with their parents. Parental consent and youth assent forms were collected over the next several days. Students who declined to participate took part in the lesson, but had their results removed from the data prior to analysis. Any student who did not turn in one or both of the forms also took part in the lesson, but their results were not included in the study.

Population of the Experimental and Control Groups

The students who participated in the study were in 9th grade and in biology classes during the 2008-2009 school year. These students were part of the Academic Curriculum Enrichment (ACE) program at the school in which the study was conducted. This program is available to students who have been 1) designated GATE (Gifted and Talented Education) in a previous grade; and/or 2) have obtained high test scores on the STAR (Standardized Testing and Review); and/or 3) have achieved high grades in core classes in junior high or middle school and have a teacher recommendation. Therefore, not all students in the ACE class are GATE designated, but they must have shown some type of academic achievement to be placed in the program. The two biology classes in which the study took place were composed entirely of 9th grade students, as the ACE program is open only to freshmen.

As part of the program, these students were enrolled in four core classes: Biology, Honors English, Geometry, and World History. While some 9th graders may take biology, honors English, and Geometry, the ACE classes are the only ones that also have students enrolled in World History. The remaining two periods are usually filled with a foreign language and physical education. Additionally, the students in each ACE class moved through their four core classes as a group. Because of this grouping, the students in each class were very familiar and comfortable with their classmates. These classes would be certain to engage in conversation and discussion, on both a social and academic level. The ACE classes were much more similar to each other than to a non-ACE class. For example, the overall class means for the second semester was (87.4%) for period 3 and (87.9%) for period 4. However, the overall class mean for the non-ACE class was (70.7%). When unpaired t tests were conducted for periods 3 and 4, there showed no statistically significant difference. However, there was extreme statistical significance between period 3 and the non-ACE class.

Prior to the study, the students in both classes were presented with a variety of teaching methods throughout the year. These methods included whole class instruction, group work, partner work, and individual work. The activities included readings with follow-up questions, laboratory work, computer-based virtual labs and Internet searches, lecture and note-taking, and simulations.

Overview of the Study

Due to the similarity of the two groups involved in the study, period 3 was assigned as the control group, while period 4 was assigned as the experimental group. The total number of students in period 3 was 32. Of these 32 students, 25 participated in the study. The enrollment in period 4 was 30, and of these, 23 participated.

To assess students' prior knowledge, a pre-test was given. The pre-test consisted of twelve questions. The first three questions were open-ended questions, while questions four through twelve were multiple choice with four answer choices. Following the lesson, the same questions were given as a post-test. The post-test had an additional question which addressed the attitudes of the students towards the topic they learned about. The questions were written by the researcher, and were based on the information presented in the case study and lecture.

The Control Group

Prior to instruction, a Powerpoint presentation was created using the information contained in the literature for the selected case study. The presentation contained the important details of the case study, summarized into 19 slides. The slides included text, pictures, a graph, a mathematical equation, and a video. The slides are shown in Appendix C.

Students were instructed to take notes during the presentation, as they would at any time when a presentation was shown. Note-taking was carried out by students on an individual basis. Since the teacher was doing the instructing, students were not encouraged to discuss the slides with each other. Questions were asked of students as the presentation was given, but this limited the discussion by the whole class. Any questions asked by the students were addressed.

<u>The Experimental Group</u>

Prior to the day of the case study, students were assigned to random groups using the grouping feature on a computer grade book program. The program grouped the students so that the average grades between groups is equal. This method of grouping was used in previous activities where groups were used. After a brief introduction about the activity, the groups were announced. Students met with their group in a specific location in the classroom.

The case study itself was taken from The National Center for Case Study Teaching in Science Case Collection through the State University of New York at Buffalo. The title of the case study was "My Brother's Keeper: A Case Study in Evolutionary Biology and Animal Behavior" (Benson, 2004). It consisted of eight sections. Each section had information, followed by one to six questions. There were several terms that may not have been recognized by students. To make the reading more comprehensible, substitutions for these words were placed in parenthesis following the challenging term. For example, the term "diurnal" was explained in parenthesis as "active during the day".

To help with organization of the parts and to ensure that each group completed all parts, a different colored piece of paper was used for each section of the case study. Once the groups had finished one part of the case study, they could move on to the next part. The first part of the case study was read together as a group, but in the remainder, groups worked at their own pace. Each group worked through the entire case, one part at a time. Students would either read each part individually and then answer the questions as a group, or one student would read while the others listened, and then they would answer as a group. The decision of how to do this was left to the group to decide. The group's answers to the questions were recorded on one sheet of paper, which was collected at the end of the case. The teacher circulated around the room to ensure that students stayed on task, and to clarify the questions accompanying each part. If the teacher was asked the same question repeatedly by different groups, the teacher would get the students' attention and clarify misunderstandings. The questions for parts one through three were discussed following the completion of part three, while the questions for parts four through eight were discussed after the completion of part eight.

The topics of each part of the case study were as follows:

Part I: Background information on Belding's ground squirrels, including life strategies of males and females, and alarm calls made by the ground squirrels. Students are asked to generate hypothesis as to why the Belding's ground squirrels make alarm calls.

Part II: Students are asked to generate several alternative hypotheses and predictions about alarm calls, including why the squirrels call, who benefits from the call, when do they benefit, should all individuals call, the group or predator response to the call, and the immediate effect on the caller.

Part III: Graphs showing the response of male and female ground squirrels to a predatory animal, subdivided by age (adult, 1-year, and juvenile). Students are asked to draw conclusions from the graphs.

Part IV: A summary of conclusions drawn from the graph, followed by questions to students. The questions included why females would call more than males, how the proximity of relatives influenced whether it was cost-effective to call, and why females called more readily when they were closer to other related individuals.

Part V: Information on kin recognition mechanisms and kin selection. Students are asked to suggest ways in which individuals recognize kin, and ways of testing whether the suggested ways are important in kin recognition.

Part VI: Information about another species of ground squirrel where the males will make alarm calls prior to emigrating from his birth place, but once they move away, they no longer call. Students are asked whether this data supports the hypothesis they generated in Parts I and II. They are asked to make predictions about what would happen if females left their birth place, but males stayed behind. Students are asked to predict what would happen regarding alarm calls if neither sex left the birth place, and why students think one sex leaves the birth place at all.

Part VII: The idea of kin selection is explained in terms of economics, which says that for one Belding's ground squirrel to risk its life for another, they must be related. There also has to be a benefit to helping, and this benefit must outweigh the cost. Benefits are seen as the number of offspring that the kin can have because a squirrel helped, and the costs are the number of offspring that the helping squirrel will not have because it helped. The equation that represents the idea of kin selection is shown, and students are asked questions that require them to understand and use the equation. The case study is shown in Appendix D.

Data Analysis

The class means of the control and experimental group were compared to determine whether there was a statistically significant difference between the two treatment groups. This was done using an unpaired t-test. The data that was collected consisted of the pretest and the posttest from each class. To determine whether the two treatment groups showed statistically significant differences in their posttest scores, Analysis of Covariance (ANCOVA) was conducted. ANCOVA was chosen as the analysis tool because it makes it possible to examine different experimental conditions independently, without having to have the various treatment groups experience all of the experimental conditions. It also removes differences that exist among the individuals in the two treatment groups. While the groups chosen for this study have many characteristics in common: same grade, all students were selected for participation in the class, and no statistically significant difference between overall class means for the two groups, there may still be differences between the two groups that would affect the results. ANCOVA is able to measure the differences between two samples, and remove these differences so that comparisons can be made. Finally Rasch analysis was carried out to examine the relationship between student ability and test item difficulty. Rasch analysis makes it possible to see the distribution of students and test items so that discrepancies between the item difficulty and the student ability can be determined (Lowry, 2010). Test items and students who did not fit the model were examined in more depth to determine possible causes for the outliers.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The purpose of this thesis was to investigate the effects of the use of a case study for instruction as compared to direct instruction though lecture in a high school biology class. Specifically, this study focused on student performance on pretest and posttests concerning the topic of evolutionary biology and animal behavior. The findings based on analysis of the data, as described in Chapter 3, are presented in this chapter.

The following research question was examined: Was there a difference in student academic performance when a case study was used to present course material rather than direct instruction? The null hypotheses states that there is no statistically significant difference in student academic performance between the control group which received direct instruction and the experimental group which received a case study. The alternative hypothesis states that there is a statistically significant difference between the experimental and control group means. The alpha level was set at 0.05.

$$H_o : \mu_{control} = \mu_{experimental}$$
$$H_1 : \mu_{control} \neq \mu_{experimental}$$

The means were taken from all work that was done either in the first semester or the second semester by the students involved in this study. The descriptive statistics for the students are presented in Table 1. Unpaired t-tests were performed on the data to compare the class means for the control group and experimental group. Therefore, in semester one, the mean of the control group was compared to the mean of the experimental group. The same comparison was made for the second semester. In both semester one and semester two, there was no statistically significant difference between the two treatment groups ($t = 0.2400$, $p > 0.05$ and $t = 0.6623$, $p > 0.05$, respectively). This shows that these two treatment groups can be compared when examining the two different teaching methods.

Table 1. Semester 1 and Semester 2 Descriptive Statistics

		Semester 1		Semester 2	
	N	Mean	s.d.	Mean	s.d.
Control group	25	87.6	6.5	87.4	7.4
Experimental group	23	86.3	7.1	87.9	7.0

Number of students in the study (N), mean, and standard deviations (s.d.) of the semester 1 and semester 2 overall grades for the control and experimental group.

Presentation of the Findings for the Analysis of Covarience

It was necessary to look at whether there was a statistically significant difference between the control group that received direct instruction, and the experimental group that received the case study. This was carried out by conducting an Analysis of Covariance (ANCOVA). There are several reasons why this statistical test was chosen for this particular study. ANCOVA makes it possible to examine different experimental conditions independently, without having to have the various treatment groups experience all of the experimental conditions (Lowry, 2010). It also removes differences that exist among the individuals in the two treatment groups (Lowry, 2010). While the groups chosen for this study have many characteristics in common: grade in school, criteria for selection into the program, and overall class means, there may still be differences between the two groups that would affect the results. An ANCOVA was able to measure the differences in posttest group means between the control and experimental groups, after adjusting for initial differences in the groups. The ANCOVA summary is presented in Table 2. The F-ratio was 3.14 with a p-value of 0.08 which was greater than the alpha level of the pre-set .05 level of significance. Therefore, there was no statistically significant difference, as measured by the adjusted posttest scores, between the case study group and the direct instruction group.

Table 2. ANCOVA Summary

Source	SS	df	MS	F	P
adjusted means	3.73	1	3.73	3.14	0.083
adjusted error	53.45	45	1.27		
adjusted total	57.19	46			

Sum of squared deviates (SS), degrees of freedom (df), mean square (MS), F ratio, and P value.

Discussion of the Findings for the Analysis of Covariance

While no statistically significant difference was seen between the two treatment groups in this study, other studies that used case studies at either an undergraduate level or a kindergarten through grade twelve level did show significant differences. When a case study curriculum was used in a fifth grade classroom over a six-week period, there were significant gains in both a positive attitude towards science and in the science concepts that were tested (Olgun & Adali, 2008). There were differences between the current study and the Olgun and Adali study, the greatest being the amount of time devoted to the treatment in the study. A six-week period gives more time for the students to become comfortable using case studies, and it allows repeated exposure to teaching methods. Similarly, Cliff (2006) obtained results which showed a 36 percent reduction in the occurrence in one of the identified misconceptions. The Cliff study used a case study focusing on respiratory physiology to help bring about conceptual changes regarding some common misconceptions. The participants in the study were sophomores in college, and they had worked with case studies prior to this study, throughout their semester in the class. Again, the details of the participants of the study were different than in the present study, but statistically significant results were uncovered. The current study was conducted over a shorter period of time, which may not have allowed students to become confident in the use of the method. The one-week treatment with a single unit of study was not adequate time in building students' proficiency with case studies.

In the literature written about case studies, a reoccurring idea is that the cases must match the interests of the students (Herreid, 2007). Students should be engaged in the learning activity if the treatment is to be effective. Interesting cases are often those that are controversial in nature, where an ethical dilemma exists. They focus on the "messy nature of science" and allow students to sort through both the facts and moral issues to reach a conclusion (Herreid, 2007, p. 85). The current study's topic may not have been of interest to the students, which may have led to the lack of statistical significance. The importance of student engagement was shown in a study conducted by Dori and Tal (2003). This study involved students in grades 10 to 12 who were not planning on studying the sciences. Case studies were used to teach biotechnology. Significant gains were found in what students knew and understood at the end of the case study, and low performing students were able to reduce the disparity between themselves and high performing students. The students participating in the case study also thought the case studies were interesting and applicable to real life (Dori & Tal, 2003).

Perhaps it was the content of the case study that contributed to the results shown by this study. For students to achieve set learning goals, they should be interested in the topic, but perhaps for many students involved in this study, this was not the case. Case studies are a way of engaging students in science topics that may be controversial. This case was not controversial and perhaps it failed to grab students' attention, which could lead to the absence of statistically significant difference between the two treatment groups.

Presentation of the Findings for the Rasch Analysis

The raw data were further analyzed to obtain item calibrations and person ability measures along a common scale. The analysis was produced using the Winsteps program (Linacre, 2009) that uses the Rasch simple logistic measurement model to evaluate an individual's response to test items by summing the correct responses to all items. Individuals with a greater score of correct responses is said to have a higher ability. The Rasch model simultaneously examines the difficulty of test items and the ability of the persons. When an individual has a higher ability, they are more likely to get a more difficult question correct than an individual that has a lower ability. If the data fit the model, the model can be used to determine how well test items are able to measure an individual's ability. Data that do not fit the model are a result of probabilities that do not match what is actually found. These data can be examined to determine which test items have a greater level of difficulty.

The equations that are used to determine the item measures and student abilities are shown below. If $X_{ni} = 1$, it indicates a correct response, while $X_{ni} = 0$ indicates an incorrect response to a given assessment item.

The probability that the person n will obtain a score of 1 on item i is shown in the following equation:

$$P\{X_{ni} = 1\} = \frac{e^{(\beta_n - \delta_i)}}{1 + e^{(\beta_n - \delta_i)}}$$

The symbol β_n denotes the ability of person n and δ_i is the difficulty of item i (Rasch Model, n.d.). If there is a large difference between $\beta_n - \delta_i$ there is a greater probability of a correct response (The Formula of the Rasch Model, 1999). If a person's ability is higher than the item difficulty, there is a greater chance of the person getting the correct response. According to the model, the log odds, expressed in logitt units, of a correct response by a person to an item is equal to $\beta_n - \delta_i$.

$$\log_e \frac{P\{X_{ni} = 1\}}{1 - P\{X_{ni} = 1\}} = \beta_n - \delta_i$$

The assessments (pretest and posttest) were examined to determine if they were an appropriate evaluation of student learning. This would be based on whether there was an adequate range of difficulty in the questions, so that a full range of student abilities could be determined. By organizing the student's ability and the item difficulty into a item map, the results of the assessment can be visually observed. The distribution map is presented in Table 3. The more able students and the test items with greater difficulty appear at the top of the distribution map, while the less able students and the test items with less difficulty appear toward the bottom of the map. Students who are more able should answer the questions with more difficulty at a greater frequency than students who are less able. Theoretically, the map scale ranges from $-\infty$ to $+\infty$. In the current study, the scores were rescaled to reflect the number of questions answered correctly. The minimum score was 0 and the maximum score was 12. Based on this scale, the item mean (i.e. UMEAN) was set at 6.22 logits and each unit on the scale (i.e., USCALE) was 1.3 logits. The majority of students were clustered between 5 and 9 on the map, which means that most were able to answer between 5 and 9 questions correctly. The person ability had a mean of 7.5. In looking at the distribution of scores for the pretest and posttest, it appears that there were some questions on the test which were too easy. By having questions that are too easy, the test did not allow one to discriminate between more able students and less able students. Although there is a range in the difficulty of the test questions, there could be more questions with a higher level of difficulty. Including moderate to difficult items would help discriminate among student who had greater proficiency in the area of study. On the distribution map, there were test items that were clustered together, such as items 6 and 9, items 3, 4, 12, and 8, and items 1, 5, and 7 (Table 3). There should be an even spread of items along the Y-axis, and the questions should line up with the students on the left-hand side of the map. It is preferred that there not be large gaps between the test items, which indicates that these are not targeted areas of the test. The pretest and posttest used in this study could have benefited from having a wider range of questions, as well as a larger number of questions. If there were a greater number of questions, it would be easier to determine whether a student had gotten a question correct because they really knew the material, or because they guessed and got it correct.

Table 3. Distribution Map of Person Ability and Item Difficulty

```
Scale                                               PERSONS - MAP - ITEMS
                                                         <more> <rare>
11                                          18 21 39 41 45 +    The highlighted
                                                          T     areas denote test
                                                                items that are
                                   06 10 13 22 23 35 43 47      clustered together
                                                            T   (i.e. questions 3,
10                                                         +    12, 4, and 8).
                                                                Test items should
                                                                have an even
                                                                spread along the
                                                                Y-axis.
    01 03 05 07 08 09 11 15 19 24 25 32 33 34 38 40 48
9                                                         S+  Q11


                                                              Q10
                             02 04 17 26 28 29 30 37 42 44 46
                                                            S    Person ability
8                                                          +       mean (7.5)

                                  12 14 20 27 31 36 39 41 45  Q3
                                                              Q12    Q4

                                                          M — Q8
7                                     06 08 13 16 32 38 48+


                       10 18 20 21 22 23 28 29 30 35 37 40 47  Q6     Q9
                                                            M
6                                                          +

                                      03 15 26 27 34 43 46      Item difficulty
                                                                  mean (6.22)
                                                          S
5                    01 02 07 12 14 16 17 24 25 31 33 36 42 44+


                                                              Q7

                                                    05 11 19  S Q1
4                                                          +  Q5


                                                          T
                                                       04 09
3                                                          +



                                                            T
                                                              Q2
2                                                          +
                                                         <less> <frequ>
```

Discussion of the Findings for the Rasch Analysis

In using Rasch analysis to look at how well the items function, it is possible to determine the specific test items that did not adequately differentiate whether students knew the information or not. These test items are said to be "misfitting" because either the student should not have gotten the answer correct, but did, or the student should have gotten the item correct, but did not.

The Rasch model ranks students in terms of ability, which is based upon their responses to various items with different degrees of difficulty. Items that fit the model have the expected mean square (MNSQ) value of 1. However, items may vary from the expected mean squared value of 1 and still fit the model, but with less predictability. There are various ranges that are acceptable (Linacre & Wright, 1994). The data in this study used a range of 0.7 to 1.5 as being acceptable. Values lower than 0.7 showed data that was more predictable than the model expects (Linacre & Wright, 1994). This could be due to the students' prior knowledge about the test item, or possibly even cheating. Values above 1.5 show too much error to be evaluated. When values are outside of the acceptable range, they must be examined.

Several test items showed MNSQ scores outside the range of acceptable values, indicating that those items were misfitting. Test question six (Which trophic level (or position the organism occupies in the food chain) most accurately describes the Belding's ground squirrel?) and seven (What does the term *territorial* mean?) both had outfit MNSQ values above the acceptable 1.5 value (i.e., 2.05 and 2.12 respectively). On examining the distribution map, questions six appears just above the mean item difficulty, while question seven appears below the mean item difficulty. However, the students who missed these easy questions had an ability measures that were well above the item difficulty. This means that the students should have gotten the questions correct. Since the students missed questions they should have gotten correct, their responses are unexpected and contribute to misfit as indicated by the mean squares.

Certain test items also showed MNSQ values below the 0.7 range. Questions one (What purpose does the alarm call serve?) and two (What do you think the other Belding's ground squirrels will do if they hear the alarm call?) had Outfit MNSQ values of 0.42 and 0.67, respectively, which indicate that the data were more predictable than expected. As stated above, this could be due to factors such as guessing, special knowledge, or cheating. In the test, these two questions were prefaced by the following information "A species of squirrel, called Belding's ground squirrel, live in the Western United States. Sometimes, if they spot a predator, such as a coyote, they will stand on their hind feet and call out an alarm." It is possible that these sentences gave away too much information towards answering the test questions.

In addition to looking at how well the test determined the ability of the students, it is also necessary to look at the consistency of the results. This was done by looking at the person reliability. The higher the person reliability, the greater the consistency of item responses to person measures. This is determined by the proportion of true variance in measures to the total variance. The person reliability was 0.64. Higher person reliabilities would likely be obtained by increasing the number of students tested. Cronbach Alpha (KR-20) was also obtained, and the value was 0.74. In general, a Cronbach's Alpha score of 0.7 or greater indicates a reliable test. The value of 0.74 indicates that it would be possible to repeat the test results if the test were given again to another group of students.

In summary, there was no statistically significant difference between the treatment and control groups in terms of performance on the posttests. There may be variety of reasons as to why this study produced this result. The most apparent being the inadequate length of time for which the treatment was implemented and the fact that the topic chosen for the case study was standard course material and not controversial or in any other way of substantive interest to the students.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

As an educator, it is important that I find the best possible way of teaching science concepts to my students. Their comprehension of the material, interest in the topic, and ability to retain the information are all factors in how successful they are in biology, and may indicate how likely they are to pursue other classes in this subject area. While research has shown that there is not just one best way of teaching, it is clear that students must be actively participating in their learning in order for it to be meaningful. Active learning involves such tasks as reading, writing, interpreting graphs and charts, discussing, and solving problems (Bland et al., 2007). Higher order thinking skills are used, such as applying what has been learned, analyzing an idea or concept, evaluating claims, and creating a novel approach to a situation (Krathwohl, 2002). Some instructional strategies are more likely to produce active learning, such as investigative laboratory or research assignments, collaborative group work, student debates, concept mapping, reflective journals, and case studies (McKinney, 2010). Case studies can be used to link the ideas presented in lecture with a real-life situation, thereby making the content relevant. They can also be used to make laboratory assignments more meaningful by incorporating a real problem that needs to be solved, and requiring laboratory skills to solve it. In addition, case studies can serve as a substitution for laboratory assignments when time is limited, or when a laboratory assignment is not available for a particular topic (Smith & Murphey, 1998). Perhaps case studies cannot replace the need for lecture completely, but they can complement it by diversifying teaching styles. A wide selection of teaching styles is not only important because of the various learning styles of students, but also because each of these teaching styles is likely to focus in on different skills important for students to master (Camill, 2006).

With an interest in case study teaching in mind, an investigation was conducted to determine whether the use of a case study to teach a biological concept would be effective in achieving set learning outcomes. The research question to be examined was: Is there a difference in student academic performance when a case study is used to present course material rather than through direct instruction? The null hypotheses was: There is statistically no significant difference in student academic performance between the control group which receives direct instruction and the experimental group which receives a case study.

Limitations and Weaknesses

After carrying out this study, collecting and analyzing the data, it is apparent that a larger sample size of students would have given more conclusive information. With few individuals making up each treatment group, any response on the pretest had a large effect. Having additional individuals answering the questions would have also provided more information about the item difficulty and whether there was an adequate amount of distribution of easy and difficult test items.

Twelve test items were given in the pretest to try to determine what students already knew about animal behavior of the Belding ground squirrels, and then what they had learned after the lesson though the posttest. It is possible that there were not enough questions to fully determine whether students had learned the information presented in the case study or lecture. With a limited number of questions, each correct or incorrect answer made a large contribution to the overall scores that made up the control and experimental group. The correct and incorrect answers given by students also contributed to determining the student ability measures, which obtained the mean of 7.22. A broader range of questions, and a greater number of questions may have altered the student ability measures.

Utilizing case studies requires students to be familiar with the process. While students in both classes had worked in groups often throughout the year, it was the first time a case study had been used. Had case studies been used on a regular basis throughout the year, and clearer expectations been set, the outcome of the study may have been different.

The implementation of the study was done in the last two weeks of the school year. The students had already taken the Standardized Testing and Review for biology, the major concepts for the year had been taught, and students were fairly secure in the grades they were receiving for the course. The timing of the study may have affected the results of both the case study and direct instruction groups.

Other studies which used case studies in teaching provided more than one incidence of case study to their students. One occurrence of case study or direct instruction may not be enough to base a study upon. In the study which focused on elementary age students learning about various pathogens, the study was conducted over a six week period (Olgun & Adali, 2008). Being able to repeat the process of pretest, then lecture or case study, and then posttest more than once would have been a better test of whether case studies were effective in teaching science concepts.

Finally, the researcher of this study was also the classroom teacher of the students involved in the study. While any bias towards one group or the other was avoided as much as possible, there exists the possibility that this may have influence the results. To attempt to eliminate biases, both groups were told that their participation in the lesson was part of a study, but neither group was told what the research question was. When students took the pretest and post-test, they used an identification number, and not their names. When the tests were graded, only the identification numbers were visible, not student names or the treatment group from which they were collected.

Significance of the Study

Despite the fact that there were no statistically significant differences between the two treatment groups, both groups did show a statistically significant difference between their pretest scores and their posttest scores; the control group performed significantly better on the posttest than on the pretest, and the experimental group also performed better on their posttest than on their pretest. This shows that in this case, both types of instruction are equally effective in obtaining the learning goals. One method cannot be recommended over the other when just considering posttest scores. However, there may be reasons why an instructor may decide to choose one research method over the other.

Direct instruction may be a good teaching method when there is a large amount of information to be communicated, when there are steps that must be followed by the students to carry out a certain learning goal, and when an instructor would like to communicate to students precisely what the learning expectations are of the students. A useful application of direct instruction may be in teaching skills, facts, and knowledge type of information. If a teacher would like to ensure that higher cognitive levels are reached, such as applying, analyzing, evaluating, and creating, direct instruction may not be the optimal choice. Even with direction instruction, there is a protocol for ensuring that students have met the learning goals designated by the instructor. It includes a series where prior learning is assessed and new material is presented. Students then engage in some type of practice where the instructor can give feedback. Following this, students receive practice they must do on their own, and in which the instructor will give feedback. Finally, these concepts should be reviewed from time to time as new material is presented (Gunter et al., 2003).

Case studies may be chosen as a teaching method when there is less information that needs to be learned by students, but when they need to have a greater understanding and in-depth knowledge of that information. Case studies may require students to analyze a topic and make a decision based on the information that is given. More than teaching science concepts, case studies "teach how the process of science works and [aim to] develop higher-order skills of learning" (Herreid, 2007, p. 31). Case studies usually require students to work in groups, whereby they will develop skill in communicating with their peers and seeing ideas from different perspectives (Herreid, 2007). However, case studies may require more time, more flexibility by the instructor and students, and need to be used more than once in order to get students to feel at ease with the method.

Teachers must look at the students that make up the classroom in which they teach in deciding whether case studies would be appropriate. Case studies often emphasize reading and comprehension, which would require students to be comfortable reading and interpreting what is written. Prior to giving a case study, the teacher should assess the reading level of students, and choose an appropriate case study in terms of the length of the reading assignment, content, and reading difficulty level. It may be necessary to divide the reading into shorter sections, provide explanation following the reading, or provide side notes within the reading that would help students deduce the meaning of difficult concepts.

Future Research

Although no differences were found between the two treatment groups, further research should be done to examine the most effective way of teaching science concepts. Other studies have shown success in using case studies (Olgun & Adali, 2008; Cliff, 2006), therefore it seems possible that students in a high school science classroom could also benefit from the use of case studies. Perhaps a study focusing on the most effective way of presenting case studies would be valuable. There are a variety of different ways that cases can be used, from public hearing format to trial format (Herreid, 2007). These various methods could be compared to see which produces the greatest improvements in student achievement. Case studies should also be used routinely with students, so that they become comfortable with the method. As case study use becomes more commonplace, students will understand their responsibilities towards learning. By using case studies for an entire unit of study, or even over a semester, studying the effects of case study use on student performance may be better determined. The topic of the case could also be an important motivator of student learning. Perhaps students were not very interested in Belding's ground squirrels, but they would be in a topic that was more controversial, or one that they heard mentioned on the news. If introduced correctly, cases with controversial topics, such as stem cell research or global climate change could motivate students to want to learn more about the specific topic, and in science in general (Brickman, Glynn, & Graybeal, 2008). An assortment of topics could be chosen to see which leads to greater achievement by students. By focusing in on the method of case study presentation, the length of time in which case studies are used, and the topic of the case, further gains can be made in understanding how case studies can best be used with high school students.

APPENDIX A

HUMAN SUBJECT FORMS

Youth Assent Form

Title of Study: ____A Comparison of Student Learning Using Two Teaching Methods: Direct Instruction and Case Study

Researcher: Laura Elmer

The purpose of this letter ask you to be in a research study that will help me discover what method of teaching will be best for helping students learn. The purpose of the study is to determine whether direct instruction (lecture presented by the teacher with some student participation) or case study (a short story with questions and data that the students evaluate) will be more effective for students learning about animal behavior. This study will involve approximately a week of class time. You will take a short pre-test to see what you already know about the topic. You will then learn about the topic. Finally, you will take another short post-test to see what you learned that you didn't already know.

This study has no more risk than you would encounter in daily life.

The topic that you will be learning about is evolution, which is a normal part of the biology curriculum. However, this particular lesson will go into more depth than usual when learning about evolutionary biology. A benefit from being in this study is that you will learn about animal behavior and how it is affected by evolution. You will have the opportunity to learn about this aspect of evolution to a greater extent than you would regularly. The information that you provide may help to determine how students will be instructed in the future.

There is no compensation (money, gifts, etc.) for being in the study.

You do not have to be in this study if you do not want. If you do not wish to be in the study, you will be given the same work as others who are in the study, but your results will not be used in the study. If you want to be in the study, you may choose to leave some questions blank or not do parts of this study. If you want to be in the study, you can stop being in this study at any time without any penalty to you. If at any time you want to stop being in this study, you should tell the researcher, Mrs. Elmer.

The score that you get on the pre-test and post-test will be kept private. While the information that you provide will be used in the paper that describes the study, your name will not be used, and no one will be able to tell that you were in the study.

You should talk with your parents or the person who takes care of you about this study before you sign this form. We will also ask your parents to give permission for you to be in this study.

If you have questions now about this study, ask before you sign this form. You can ask me before or after class, send me an Email (Laura.Elmer@Hesperia.org), or call (760.244.9898, ext. 453).

If you have any questions later, you may talk with me at any time.

If this study raised some issues that you would like to discuss with a professional, you may contact Dr. Herb Brunkhorst at California State University, San Bernardino. His office telephone number is (909) 537-5613 and his Email is hkbrunkh@csusb.edu.

If you have questions or concerns about your rights as a research subject, you should contact the Institutional Review Board at (909) 537-7588 or Email at mgillesp@csusb.edu.

If you have had all of your questions answered and you want to be in this study, then please sign below.

Date	Signature	Printed Name
Date	Witness's Signature	Witness's Printed Name

I have explained the study to the youth, have allowed an opportunity for questions, and have answered all of his/her questions. I believe that the youth understands this information.

Date	Signature of Researcher	Printed Name

Note: A signed copy of this form will be given to the subject and parents or guardian.

This assent form was approved by the Institutional Review Board at California State University, San Bernardino on May 6, 2009.

Consent to Participate in Research

Title of Study: A Comparison of Student Learning Using Two Teaching Methods: Direct Instruction and Case Study

Researcher: Laura Elmer

Dear Parents/Caretakers,
Your child is invited to be in a research study about the effectiveness of teaching methods on student learning. Your child will be taught either through lecture (direct instruction) or a short story (case study) to see which results in greater learning about the topic of animal behavior. Your child was selected as a possible participant because your child is in the G.A.T.E. biology class taught by Mrs. Elmer. I ask that you read this form and ask any questions you may have before agreeing to allow your child to participate in this study.

The study: The purpose of this study is to evaluate the effectiveness of two teaching methods that will be used to teach the same topic. If you agree to allow your child to participate, your child will be asked to take a short pre-test to see what he or she already knows about a topic. Students will then be presented with the lesson. Written work from this lesson will be collected. Students will then take a post-test to see what they have learned after being presented with the lesson. The pre- and post- test will each take approximately 30 minutes. The lesson will take approximately three days.

Risks and benefits: This study has no more risk to your child than those involved in everyday classroom practices and assessment. The topic of animal behavior is part of a larger unit on Evolutionary Biology. Evolution is a topic normally taught in biology, however, this lesson will allow students to receive more in-depth instruction in how an animal's behavior is influenced by evolution. They will also be able to get feedback about what they learned after engaging in the lesson. Your child's participation will also help the teacher determine how students will be instructed in the future.

Confidentiality: The records of this study will be kept private. Your child will receive a random number, known only to the researcher and to your child. This number will be placed on any work that is collected and will be used in the study.

Voluntary nature of participation: Participation in this study is voluntary, and your child may withdraw from the study at any time without any effect on their academic standing. If your child does not participate in this study, his/her performance and grades at school will not be affected in any way. Students who do not participate in the study will still carry out the lesson in class, however, their work will not be used in the study. In order to participate in this study, your child will also read and sign a statement similar to this.

The researcher conducting this study is Laura Elmer. You may reach her at by phone at 760-244-9898, extension 453 or by Email at Laura.Elmer@Hesperia.org. Please feel free to ask any questions you have now, or at any point in the future. If you have any questions or concerns about your child's rights as a research subject, you may contact the Institutional Review Board at California State University, San Bernardino at 909.537.7588 or by Email at mgillesp@csusb.edu.

Check one:
______ Yes, my child may participate in this research study.
______ No, I would prefer my child not participate in this research study.

Child's name: ______________________________

Signature of Parent ___________________________ Date__________________

Researcher's Signature___________________________

This consent form was approved by the Institutional Review Board at California State University, San Bernardino on May 6, 2009.

APPENDIX B

INSTRUMENTS

Identification Number: ____________

Evolutionary Biology and Animal Behavior Pre-Test

A species of squirrel, called Belding's ground squirrel, live in the Western United States. Sometimes, if they spot a predator, such as a coyote, they will stand on their hind feet and call out an alarm.

1. What purpose does the alarm call serve?

2. What do you think the other Belding's ground squirrels will do if they hear the alarm call?

3. Explain what is meant by the term fitness?

4. Do all Belding's ground squirrels have an equal chance of making an alarm call? Which of the following would be most likely to make a call?
   A. Adult females.
   B. Adult males.
   C. Young females.
   D. Young males.
   E. All ages and sexes have an equal chance of calling.

5. Which of the following most accurately describes the Belding's ground squirrel?
   A. Carnivore
   B. Omnivore
   C. Herbivore
   D. Detritivore

6. Which trophic level (or position the organism occupies in the food chain) most accurately describes the Belding's ground squirrel?
   A. Producer.
   B. Primary consumer.
   C. Secondary consumer.
   D. Tertiary consumer.

7. What does the term territorial mean?
   A. Finding and eating food.
   B. Moving long distances seasonally to new locations.
   C. Protecting a certain area from other animals.
   D. A threatening interaction between two individuals of the same species.

8. What is kin recognition in Belding's ground squirrels?
   A. Squirrels recognize other members of their species.
   B. Squirrels recognize other types of squirrel species.
   C. Squirrels recognize the predators they should avoid.
   D. Squirrels recognize the squirrels they are related to.

9. What happens when male and female Belding's ground squirrels reach adulthood.
   A. Females leave to find a new home, but males stay in the same area.
   B. Females stay in the same area, but males leave to find a new home.
   C. Females and males both stay in the same area in which they were born.
   D. Females and males both leave the area in which they were born.

10. How do Belding's ground squirrels spend most of their year?
   A. Hibernating.
   B. Looking for food.
   C. Looking for mates.
   D. Looking for a new home area.

11. What does the term altruism mean?
   A. To be selfish.
   B. To be unselfish.
   C. To be aware of what is going on around you.
   D. To be unkind.

12. If given the equation $\frac{B}{C} > \frac{r_{offspring}}{r_{recipient}}$ what does $\frac{B}{C}$ represent?
   A. How likely an animal is to find food.
   B. The chances of a male finding and mating with a female.
   C. The chances of an animal living until a certain age or dying at a certain age.
   D. The advantage and disadvantage of one animal helping another.

Identification Number:_______________

Evolutionary Biology and Animal Behavior Post-Test

A species of squirrel, called Belding's ground squirrel, live in the Western United States. Sometimes, if they spot a predator, such as a coyote, they will stand on their hind feet and call out an alarm.

1. What purpose does the alarm call serve?

2. What do you think the other Belding's ground squirrels will do if they hear the alarm call?

3. Explain what is meant by the term fitness?

4. Do all Belding's ground squirrels have an equal chance of making an alarm call? Which of the following would be most likely to make a call?
   A. Adult females.
   B. Adult males.
   C. Young females.
   D. Young males.
   E. All ages and sexes have an equal chance of calling.

5. Which of the following most accurately describes the Belding's ground squirrel?
   A. Carnivore
   B. Omnivore
   C. Herbivore
   D. Detritivore

6. Which trophic level (or position the organism occupies in the food chain) most accurately describes the Belding's ground squirrel?
   A. Producer.
   B. Primary consumer.
   C. Secondary consumer.
   D. Tertiary consumer.

7. What does the term territorial mean?
   A. Finding and eating food.
   B. Moving long distances seasonally to new locations.
   C. Protecting a certain area from other animals.
   D. A threatening interaction between two individuals of the same species.

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   C. Squirrels recognize the predators they should avoid.
   D. Squirrels recognize the squirrels they are related to.

9. What happens when male and female Belding's ground squirrels reach adulthood.
   A. Females leave to find a new home, but males stay in the same area.
   B. Females stay in the same area, but males leave to find a new home.
   C. Females and males both stay in the same area in which they were born.
   D. Females and males both leave the area in which they were born.

10. How do Belding's ground squirrels spend most of their year?
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   B. Looking for food.
   C. Looking for mates.
   D. Looking for a new home area.

11. What does the term altruism mean?
   A. To be selfish.
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   C. To be aware of what is going on around you.
   D. To be unkind.

12. If given the equation $\frac{B}{C} > \frac{r_{offspring}}{r_{recipient}}$ what does $\frac{B}{C}$ represent?
   A. How likely an animal is to find food.
   B. The chances of a male finding and mating with a female.
   C. The chances of an animal living until a certain age or dying at a certain age.
   D. The advantage and disadvantage of one animal helping another.

13. After leaning about Belding's ground squirrels, how likely would you be to look up more information on your own?
   A. Very likely.
   B. Somewhat likely.
   C. Somewhat unlikely.
   D. Very unlikely.

APPENDIX C

RESOURCES FOR THE CONTROL GROUP

Belding's Ground Squirrels

Evolutionary Biology and Animal Behavior

The following information was adapted from Benson, K (2004) My Brother's Keeper: A Case Study in Evolutionary Biology and Animal Behavior, *National Center for Case Study Teaching in Science*, University of Buffalo, State University of New York.

Background Information

- Diurnal animals (active during the day, like humans).
- Live in the far western United States.
- Live in sub-alpine meadows

Background Information

- Hibernate for 7 to 8 months.
- The rest of the year is spent mating and eating.
- Squirrels must eat large amounts of food so that they have enough fat stores to hibernate.
- Herbivores--Diet is seeds, flowers, and vegetation (leaves, grass).

Background Information

- After hibernation, females mate.
- They create territories near others of their family, and have between 3 and 6 pups.
- Pups exit burrow when 3 to 6 weeks old.
- Young males (juveniles) leave and join a new group.
- Females stay where they were born, for life.

When Predators Attack...

- Predators include coyotes, weasels, and raptors.
- If a squirrel sees a predator, it will stand on its hind feet and call out an alarm.
- Other squirrels hear the alarm, and go to their burrows.
- Only some squirrels call.

Why do the squirrels call?

- Questions to consider:
  - Who benefits?
  - When do they benefit?
  - Should all individuals call?
  - What is the group or predator response to the call?
  - Is there an immediate effect on the caller?

Positives and Negatives of Calling

Positive Effects

- Other squirrels will hear the call and be able to protect themselves.

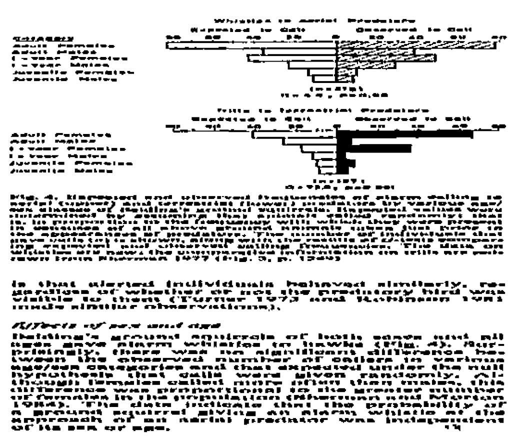
Negative Effects

- The predator will know where the squirrel is that is making the call, and will attack the squirrel.

When an animal acts in a way that increases the fitness of other individuals in the population, but reduces their own fitness, it is called ***altruism***.

Who does the calling?

- Females call more often than males.
- Adults females call more often than female juveniles.



Graph: Benson, K (2004)

Why do adult female squirrels call most often?

- Females stay in the place in which they were born for their entire life.
- Staying near home means they live near family.
- Members of their family are called "kin".
- Squirrels are able to recognize kin, and are more likely to call when kin are nearby.

Other Squirrels

- In another species of ground squirrel, males make an alarm-call before they leave the area in which they were born.
- After they leave, they stop making calls.

Kin Selection

- There is a mathematical formula to determine whether individuals should help kin.
- We each share half of our DNA with our mom and half with our dad = relatedness (*r*) or $r_{recipient}$.
- So, *r* for mom = 0.5 and *r* for dad = 0.5. What is *r* for your sibling?
- We have a relatedness of 0.25 with a grandmother, and 0.125 with a cousin.
- $r_{offspring}$ is the relationship between parent and offspring (usually 0.5).

Kin Selection

- Need to also know the costs and benefits of helping.
- Costs = number of offspring the donor will not have.
- Benefits = number of offspring your kin will have because the donor did help.
- If $\frac{B}{C} > \frac{r_{offspring}}{r_{recipient}}$ it is adaptive to help.

Kin Selection

- $\frac{B}{C} > \frac{r_{offspring}}{r_{recipient}}$

Calculate the following:

- You share a relatedness of 0.5 with your offspring.
- You can help your nephews and nieces, and your relatedness to them is 0.25. $r_{recipient}$
- For the equation to be true, the benefits must be more than twice the cost to your offspring.
- If B = 2.5 and C = 1, the equation would be true, and it would be adaptive to help your kin.

A Question to Think About...

- Suppose there were a car accident and you could only save one person—your best friend or your sibling. Who would you save? Why?
- Does your answer change if you consider kin selection?

APPENDIX D

RESOURCES FOR THE EXPERIMENTAL GROUP

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp
National Center for Case Study Teaching in Science, University at Buffalo, State University of New York

My Brother's Keeper: A Case Study in Evolutionary Biology and Animal Behavior

Written by Kari Benson
School of Sciences
Lynchburg College, Lynchburg, VA

Part I—Hypothesis Development

Belding's ground squirrels (*Spermophilus beldingi*) are diurnal (active during the day) rodents that live in sub-alpine meadows in the far western United States. Due to the extreme weather, the squirrels hibernate for seven or eight months of the year. They must enter hibernation with sufficient fat stores to survive this long hibernation. The squirrels spend their short active period by initially mating, then eating large quantities of food. They are primarily herbivorous, eating mostly seeds, flowers, and vegetation.

Adult females mate shortly after they emerge from hibernation. After mating, some males disperse (move away) to new groups; the others often return to hibernation before the young are born. The females establish territories within the social group and have between three and six pups. The pups emerge from their burrows when three to six weeks old, and the juvenile males disperse (leave to join new groups) shortly thereafter. The females typically remain in their natal (birth) group for life.

Paul Sherman (1977; 1981) studied Belding's ground squirrel behavior. The squirrels are subject to many dangers, including predation by coyotes, weasels, and raptors. Often, if a squirrel spots a predator, it will stand up on its hind feet and call out an alarm. When others hear the alarm, they quickly retreat to their burrows. Not all squirrels are equally likely to call.

Question

1. Generate some hypotheses to explain why the squirrels call.

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part II—Alternative Hypotheses and Predictions

What predictions do you have about the frequency of alarm calling for the hypotheses you generated in Part I? Use the table below to record your predictions.

Hypotheses	Predictions				
Why do the squirrels call?	**Who benefits?**	**When do they benefit?**	**Should all individuals call?**	**Group/predator response to call?**	**Immediate effect on caller?**

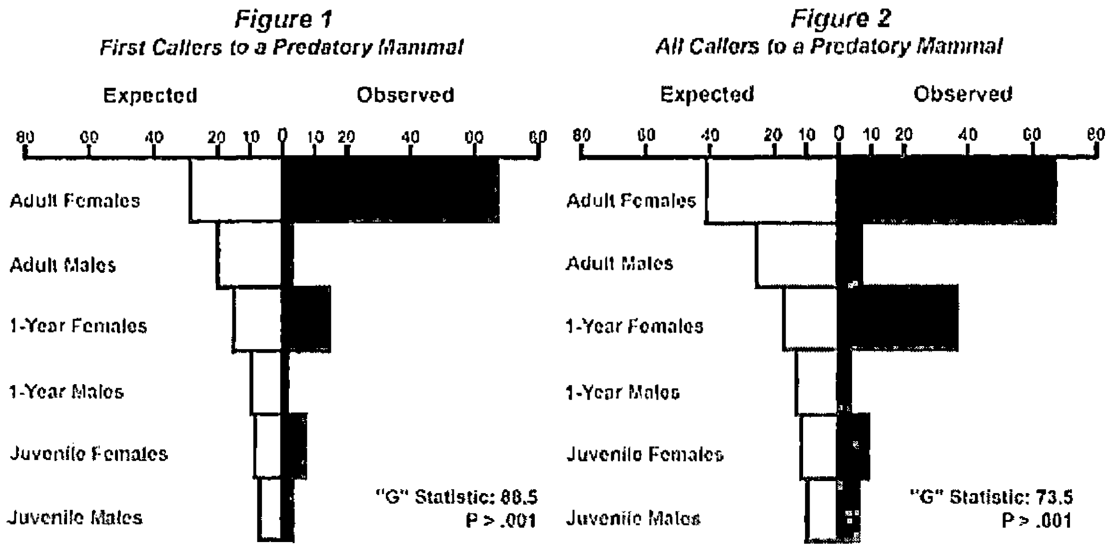
Question

1. How can we discriminate among these competing hypotheses?

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part III—Experimental Results

Not all squirrels call equally. Examine the following figures and then answer the question.



Figures represent expected vs. observed frequencies of alarm calls across classes of Belding's ground squirrels drawn from 102 interactions with predators. Adapted from Sherman 1977.

Question

1. What conclusions can you draw from the data shown in the above figures?

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part IV—Sherman's Conclusions

Females call disproportionately more often than predicted by their abundance. Adult females call more often than one-year-olds or juveniles. Males call disproportionately less than predicted by their abundance.

Questions

1. Why might this be?

2. How do these data compare to your predictions?

3. Why would females call more than males?

4. How should the proximity (nearness) of relatives influence whether it is cost-effective to call?

5. Consider the following: Females call more readily when they are close to other related individuals.

6. What is the kin selection hypothesis? (Hint: You may have to use another source to find out more about the kin selection hypothesis). Does the data support the kin selection hypothesis?

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part V—Kin Recognition Mechanism

Kin recognition mechanisms are the mechanisms squirrels might use to recognize that an individual is kin. Kin selection, by contrast, favors related individuals evolutionarily. The kin selection hypothesis requires that individuals can recognize kin. Sherman's data demonstrate that females are more likely to call when their kin are nearby.

Questions

1. How might individuals recognize kin?

2. Can you think of ways to test whether a particular modality (call, smell, taste, and so forth) is important in kin recognition?

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part VI—Other Squirrels

There is another species of ground squirrel (Spermophilus tereticaudus) whose males behave differently (Dunford 1977). In this species, males are likely to alarm-call before they leave their natal site, but they remain silent after they disperse. A natal site is the site in which they were born.

Questions

1. Do these data support your current hypotheses about calling?

2. What predictions would you make if females dispersed and males remained in natal groups?

3. What predictions would you make if neither sex dispersed?

4. Why is it that one sex disperses from each of these groups?

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part VII—Economics of Kin Selection

Hamilton (1964) proposed a mathematical means of interpreting whether individuals should help kin. The decision to help kin requires that you can recognize (in some way) who is related to you, and (ideally) by how much. To determine this, Hamilton measured the percent of DNA that you would share with someone by common descent, which he calls relatedness (r). For example, you would share half of your genes with a parent by common descent. Thus, you would have a relatedness of 0.5 with either parent or with a full sibling, a relatedness of 0.25 with a half sibling or a grandchild, and a relatedness of 0.125 with a cousin. You also need to know the relatedness between the donor and the recipient (rrecipient) and the relatedness between the donor and its offspring (roffspring). Note that roffspring = 0.5 in typical diploid organisms.

Second, you have to know what it will cost you to help. For simplicity, Hamilton measured cost as the number of offspring (corrected for the relatedness) that you won't have because you helped someone else. This is the cost of helping (C).

Third, you have to know how many more offspring your kin can have because you helped; this is the benefit of helping (B). It is adaptive to help if the following equation is true:

$$\frac{B}{C} > \frac{r_{offpsring}}{r_{recipient}}$$

Thus, you can determine for a number of circumstances whether you should help your relative or not. For example, you share a relatedness of 0.5 with your offspring and the same (roffspring = 0.5) with a full sibling (one with whom you share a father and mother). If you can help some nephews or nieces, then rrecipient = 0.25. The benefit in the form of nephews or nieces must be greater than twice the cost to your own offspring to be adaptive. That is, for every offspring you cannot have because of helping (this is the cost, or C), anything more than an additional two nephews or nieces (this is the benefit, or B) would satisfy the inequality. This condition would be satisfied if B = 2.5 and C = 1. Written mathematically, this would look like the following:

$$\frac{2.5}{1} > \frac{0.5}{0.25}$$

This expression is correct. The left-hand part of the equation equals 2.5. The right-hand part of the equation equals 2. The left exceeds the right, so helping is adaptive through kin selection.

The original case study can be found at:
http://www.sciencecases.org/kin_selection/kin_selection.asp

Part VII Questions

Questions

1. Suppose there were a car wreck and you could only save one person—your best friend or your sibling. Who would you save?

2. How many siblings would you have to save if helping forced you to give up one of your own children?

3. How many nephews or nieces would you have to help if helping forced you to give up three of your own children?

"My Brother's Keeper" by Kari Benson

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CASE TEACHING NOTES
for
"My Brother's Keeper: A Case Study in Evolutionary Biology and Animal Behavior"

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INTRODUCTION / BACKGROUND

This is an interrupted case where students work in small groups on behavioral data they are given in a piecemeal fashion and interpret the data with respect to evolutionary biology. [Editor's Note: For a description of the interrupted case method, see the prologue to "Mom Always Liked You Best," another case on our website.]

This case is suitable for courses in behavior, evolution, and ecology. Sections of it could be used in an introductory biology course if evolution and ecology get sufficient coverage. I have used the case in both an introductory biology course and an upper-level animal behavior course to reinforce an understanding of kin selection and to encourage students to consider the levels-of-selection controversy.

The case was inspired by work done by Paul Sherman (1977). Sherman discovered that the apparently altruistic behavior of alarm calling in Belding's ground squirrels is, in fact, nepotism. That is, it is not evolutionarily stable to assist non-related individuals at a cost to yourself (without sufficient opportunity for reciprocation or group selection); rather, evolutionarily speaking, it is beneficial to aid those individuals that share your genes by common descent, even if they are not your direct offspring.

The case requires that students understand the basic principles of natural selection. Students should recognize that selection requires fitness benefits to some heritable trait. Thus, natural selection results in differential success of specific alleles in a population. Students must recognize that there are fitness benefits to certain alleles if they are to conclude that genes shared by common descent can confer a fitness advantage to an individual. It may also be helpful to emphasize that natural selection acts on phenotypes but results in changes in allele frequencies in a population.

Objectives

Upon completion of the case, students will have developed testable hypotheses and interpreted graphical information. In addition, they will understand that:

- Natural selection does not (necessarily) act for the good of the species.
- Natural selection can favor traits that do not directly enhance individual fitness.
- Kin selection can explain many behaviors that seem otherwise maladaptive.
- Humans are animals, and evolutionary strategies may be revealed in human behavior.

DETAILED CASE ANALYSIS

Detailed case analysis is provided in a separate file that is password-protected. To access this information, go to the detailed case analysis. You will be prompted for a username and password. If you have not yet registered with us, you can see whether you are eligible for an account by reviewing our password policy and then apply online or write to answerkey@sciencecases.org.

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