Tell Me a Story: The Effects of Using the Case-Based Teaching Method in the Science Classroom

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Abstract

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Title: Tell Me a Story: The Effects of Using the Case-Based Teaching Method in the Science Classroom

Research Question: What effect does the case-based teaching method have on student learning and attitudes towards science?

Research Activities:
For years the case-based method of teaching has been prevalent in law and medical schools across the country. This method has the potential to bring real-world examples into the classroom as well as induce higher order thinking in students. In this teacher research study, I have investigated the effects that the case-based method may have on high school science students in their acquisition of scientific knowledge and development of thinking in a scientific way. A combination of student surveys, class discussion lists, student writing, and assessments were analyzed to determine the degree of effectiveness that the case-based method can provide in a high school classroom. Results indicate that employing the case method is sufficient in conveying factual scientific information and highly conducive to teaching scientific ways of thinking. Additionally, results have furthered an interest in using the case-based method throughout my teaching career and to investigating the best way to implement the method to benefit all students, including English Language Learners.

Grade Level: 9th-12th Grade Biology
Data Collection Methods: Surveys, Class discussion lists, Student writing, Assessments
Project Descriptors: Secondary, Science, Biology, Scientific thinking, Case-based learning, English Language Learners

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I Am A Teacher

The piercing ring of the alarm clock blares and I roll over in disbelief of the time lit up in red. I could swear that I just lay down after a long evening of grading papers, planning lessons, calling parents, or just plain stressing out. I crawl out of bed and gingerly head to the shower, where I wait for steam to fill the room and jump in. As the hot water meets my face, I begin to awaken. I start to go over lesson plans in my head, contemplating and tweaking when necessary. "What would be the best way to deliver this material to maximize what my students learn?" I say to myself. I go through the rest of my morning ritual thinking the same thing, taking a break only to decide what to wear. I rush out the door with bags, papers, and props in hand and hop in the car. The same question lingers in my head as I drive the 15 minutes on the freeway that my relatively short commute requires. As I turn the key to stop the engine of my car and step outside, I begin to enter a different mode of thinking. "What do I need to accomplish right now to make sure my lessons go well?" I say to myself. This question also lingers in my mind until 8:20 a.m., when the five-minute bell for second period rings.

Then we're off! The day flies by with constant "issues" to deal with, behavior to manage, and every other distraction that one could possibly conjure up. There is never a slow moment as even my lunch hour is filled with students. There are the good days and there are the not so good days, but every day feels short and I am always left wondering where the time went. On my way home, I think about all sorts of things: What's for dinner? Why did Juan act out in class today? When am I going to finish writing the final? How many papers do I have to grade tonight? It occurs to me that I am not ending my day the way I start it. I should be reflecting on what my students are and are not learning and what I can do to help them learn. As I ritually listen to National Public Radio while cruising down the freeway, a story comes on about medical schools and how students treat those that have donated their bodies to science with great respect in their anatomy classes. The announcer mentions the tradition of medical schools and their primary method of teaching, which use case-based, hands-on, semi-real situations that students must figure out. The announcer mentions that law schools are also famous for employing this method. At that moment something clicks, "Why can't I use case-based lessons in my science classroom?" I remember that I briefly explored the topic during my credential year, but had decided on investigating another method. I decide that I will need to do some research.

And so the question is posed: What exactly is case-based teaching? I struggle to find a narrowed down definition, but it seems as though it can be anything from using an actual case study to using a picture to teach a concept. I wonder if case-based teaching can help my students make some real world connections, grasp science concepts, and get students genuinely interested in science. I wonder how exactly I can employ some version of this strategy in my classroom. I make the commitment and begin to investigate.

My Job As a Science Teacher

John Dewey said, "The aim of education should be to teach us rather how to think, than what to think—rather to improve our minds, so as to enable us to think for ourselves, than to load the memory with the thoughts of other men."

Although I plan my lessons around the California State Standards and teach numerous facts of biology in a given school year, I see my job as a science teacher as something much more. I see myself using my position impart ideas, skills, concepts, and ways of thinking in addition to factual information. I fully believe in the American Association for the Advancement of Science's project 2061: Science for all Americans, which states that science education should contribute to people's knowledge of the shared values of scientists, mathematicians, and engineers. I also believe that "science education should be a reinforcement of general societal values; the inculcation in people of informed, balanced beliefs about the social values of science, mathematics, and technology; and the development in young people of positive attitudes towards learning science" (Project 2061, 1989). It is my goal that when students leave my classroom, they have gained not only knowledge in the traditional manner, but also a sense of confidence and science literacy. I hope that they see the science in their everyday lives, and that they are able to determine the difference between valid and invalid arguments. Aristotle argued that it is the mark of an educated mind to be able to entertain a thought without accepting it. It is important to me that my students gain an understanding of the natural world and the way things work. I believe that I should foster in my classroom curiosity, openness to new ideas, and skepticism so that students can use these attributes after they have graduated. Many of the goals I have for my students and those of the AAAS are intertwined. Their recommendation of goals for student to achieve in the critical-response areas of science (Figure 1) provide a guide for what I feel I should be scaffolding for my ninth and tenth grade students if I want them to be able to achieve these standards before they graduate high school. The degree to which I can support my students in achieving these goals by the time they leave high school is the measurement to which I will hold myself accountable. "The use or misuse of supporting evidence, the language used, and the logic of the argument presented are important considerations in judging how seriously to take some claim or proposition. These critical response skills can be learned and with practice can become a lifelong habit of mind" (Project 2061, 1993).

Where I Teach

Murphy, California is a small, rural town located along Interstate 80, 23 miles southwest of Sacramento and 65 miles northwest of San Francisco. Its roots are agricultural, although it is quickly becoming a bedroom community for those individuals that commute to surrounding cities with larger populations. There are currently around 16,000 residents in Murphy. According to 2000 census data, the median resident age in Murphy 31.5 years, the median household income is $54,472, and the median house value is $170,900. I am sure that these numbers have changed in the last four years, but this is the most current information available.

By the end of the 12th grade, students should:
• Notice and criticize arguments based on the faulty, incomplete, or misleading use of numbers, such as in instances when (1) average results are reported, but not the amount of variation around the average, (2) a percentage or fraction is given, but not the total sample size (as in "9 out of 10 dentists recommend..."), (3) absolute and proportional quantities are mixed (as in "3,400 more robberies in our city last year, whereas other cities had an increase of less than 1%), or (4) results are reported with overstated precision (as in representing 13 out of 19 students as 68.42%). • Check graphs to see that they do not misrepresent results by using inappropriate scales or by failing to specify the axes clearly. • Wonder how likely it is that some event of interest might have occurred just by chance. • Insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position being taken—whether one's own or that of others—can be judged. • Be aware, when considering claims, that when people try to prove a point, they may select only the data that support it and ignore any that would contradict it. • Suggest alternative ways of explaining data and criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration, with no mention of other possibilities. Similarly, suggest alternative trade-offs in decisions and designs and criticize those in which major trade-offs are not acknowledged.

Figure 1: American Association for the Advancement of Science recommendations of standards to be met by students graduating high school as determined during <u>Project 2061: Science for All Americans</u>

According to city-data.com, the Hispanic population percentage in Murphy is significantly above the state average, the median age is below the state average, the foreign-born population percentage is above state average, the house age is significantly below the state average and the percentage of the population with a bachelor's degree or higher is below the state average.

Murphy High School is located in what I would describe as the well-established part of town. The houses in the neighborhood are modest but well taken care of with the exception of some very grand, beautiful, and historic homes in the vicinity of the school. The downtown area, which has a tinge of old west charm, is within a five minute walk of the school. Most students without cars walk to it during their open-campus lunch. The high school students are the primary support of the food businesses in the downtown area. For all of its small-town western charm, there are rarely any outside visitors and only a handful of thriving local businesses, all of which seem to be restaurants. The downtown even has a general store where I have been told you can get anything from generators to cowboy boots. Dawson's, a small bar and restaurant, opens at 3:30 a.m. to serve breakfast to the many farmers that rise before the sun. Bud's across the street touts DJ's and dancing on Friday and Saturday nights. Just down the street sits Frosty's, a fast food joint that looks like it is straight out of the 1960s and from all appearances, has not been painted since. This is the part of Murphy where the high school sits, a mainly residential area within very close walking distance of what many would consider a floundering downtown.

There are other parts of Murphy that are of interest. If I were to keep moving past Frosty's, cross the railroad tracks and drive about a mile, I would enter the "new" section of town. Large, monostylistic houses are grouped together and surrounded by walls. Further past the residential area there are small strip mall shopping centers and numerous fast food chains. This is where the students with cars go for lunch to choose from an array of fast, greasy food. More houses are being built nearby. They are more of the bigger and more expensive variety. I have several new students this year that have moved from nearby bay area towns and cities because their parents can afford larger houses in Murphy, which is not in the Bay Area but also not quite part of the Sacramento sprawl.

Murphy High School started off as one building consisting of 10 classrooms. This part of the school is now known as "A wing." The school as a whole is made up of 5 permanent buildings and several portable classrooms. The buildings were added in various years to keep up with the growth of the population and were seemingly built without the foresight that additional buildings may have to be erected. This has resulted in a strange arrangement of buildings and a quad that is split into two halves. This split quad lends itself to interesting social groupings in the mornings and at break. The district has committed to building a new high school that is slated to be open in three years, which promises to be a vast improvement.

My Students

My students are a sample of all students at Murphy High (Figure 2). I have special education students, GATE students, English Language Learners, motivated freshman, middle of the road sophomores, juniors and seniors repeating biology, college bound students, non-college bound students, Hispanic students, Caucasian students, foreign exchange students, males, females, upper middle class students, students on free and reduced lunch programs, migrant students, “good” students, “bad” students, and everything in between. Each student has a different story and each student bring a different set of experiences to my classroom. It is my job to try and include each and every one of those individuals into my lesson planning and to think about how best to meet their needs.

I teach two sections of Biology at Murphy High School. Biology is technically a sophomore level class. The reason why I use the word technically is because about 70% of my students in these two sections are freshman. This indicates that these students have had success at the junior high school level in science and math, as they were recommended by their eighth grade teachers to take Biology as freshmen instead of the Physical/Earth Science class that most ninth graders take. It can be assumed that many of these freshmen in Biology are at least entertaining the idea of attending a four-year college upon completion of high school.

Figure 2: Murphy High School Demographics

Ethnicity	Murphy High
African American	32 (2.8%)
American Indian or Alaska Native	9 (0.8%)
Asian	18 (1.6%)
Filipino	8 (0.7%)
Latino	504 (44.5%)
Pacific Islander	6 (0.5%)
Caucasian	551 (48.6%)
Multiple/No Response	5 (0.4%)
Total Enrollment:	1,125

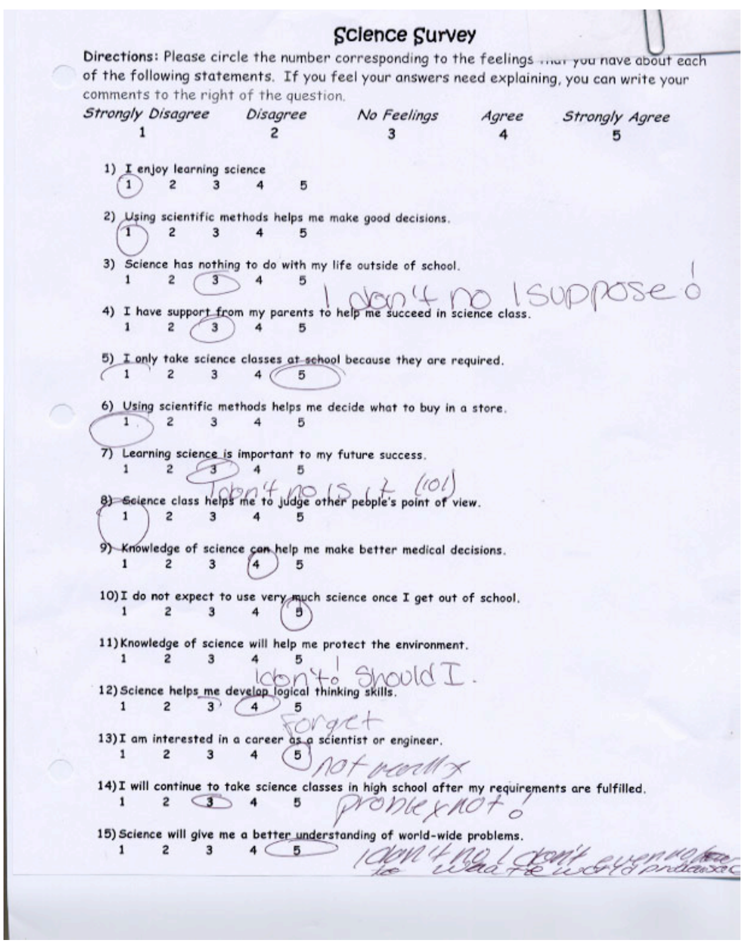
Demographic data acquired from California Department of Education for 2003-2004 school year.

Murphy High School is what I would describe as bicultural. Although small numbers of other ethnic minorities exist in the school's population, the Caucasian and Latino students are very evenly represented. I have always been impressed with the successful integration that the school has achieved between the two ethnicities. Apart from very new immigrant students, much of the student body is highly integrated both academically and socially. Many of the Latino students are second or third generation Americans, which I believe lends itself to this kind of heterogeneous mixture of Caucasian and Latino students. Morning announcements are done in both English and Spanish even though our English language learner population makes up only about 10% of the school's population. Large scale efforts are made by both the staff and the student body to account and represent all cultures in leadership activities. That said, the staff is 94% Caucasian and the students do not have very many role models of Latino heritage.

Assessing My Student's Impression of Science

I created a survey using Siegel and Ramney's CARS questionnaire as a guide, adapting the questions to my students and to what I am most interested in knowing about my students' attitudes towards science (see Figure 3). The survey consisted of fifteen statements that students were asked to respond to using a modified Likert scale. Students were asked to circle a corresponding number to how they felt about each statement. The scale was as follows: Strongly disagree (1), Disagree (2), No feelings (3), Agree (4), and Strongly Agree (5). It was important that students read each statement carefully because they were worded in such a way that students could circle an answer that they did not intend to. An example of this would be "I do not expect to use very much science when I get out of high school." A student who does not believe he/she will use science in the future will need to circle a 5 for "Strongly Agree." This is in contrast to the statement "Learning science is important to my future success." In this example, that same student would need to circle a 1 for "Strongly Disagree." Again, careful reading of each statement was crucial in order for the student to answer in their intended way. Students were given both written and verbal instructions in order to ensure accurate survey results. At the top of the survey the directions read: "Please circle the number corresponding to the feelings that you have about each of the following statements. If you feel that your answers need explaining, you can write your comments to the right of the question." The scale of feelings and their corresponding numbers were then listed in bold across the top beneath the directions. The survey was administered during class time as a starter activity. Students were asked to carefully complete it individually and silently. This was done so that students would concentrate on the survey and take the time that they needed to complete it. An example of the survey is shown in Figure 3.

Figure 3: Sample of Science Interest Survey



Science Survey

Directions: Please circle the number corresponding to the feelings that you have about each of the following statements. If you feel your answers need explaining, you can write your comments to the right of the question.

Strongly Disagree	Disagree	No Feelings	Agree	Strongly Agree
1	2	3	4	5

1) I enjoy learning science
2) Using scientific methods helps me make good decisions.
3) Science has nothing to do with my life outside of school.
4) I have support from my parents to help me succeed in science class.
5) I only take science classes at school because they are required.
6) Using scientific methods helps me decide what to buy in a store.
7) Learning science is important to my future success.
8) Science class helps me to judge other people's point of view.
9) Knowledge of science can help me make better medical decisions.
10) I do not expect to use very much science once I get out of school.
11) Knowledge of science will help me protect the environment.
12) Science helps me develop logical thinking skills.
13) I am interested in a career as a scientist or engineer.
14) I will continue to take science classes in high school after my requirements are fulfilled.
15) Science will give me a better understanding of world-wide problems.

This science interest survey is important to me because I am interested in my students' preconceived notions about science. I believe that if students have negative attitudes towards science, then they may be less likely to succeed in a high school science class. I also feel that negative attitudes towards science may be unfounded and that students may not really know what science truly *is*. I hope to clarify the definition of science that my students perceive and help them see connections between what they learn in my Biology class and the real world, particularly their own lives. The results of this survey gave me a baseline understanding of how my students think about and approach science in general.

After collecting the surveys, I created three categories of student beliefs for analysis. The three categories are as follows: "Enjoys or is interested in science," the second "Believes that science is helpful and important" and the third, "Believes that science will be relevant outside of and after high school." Students were grouped into these categories according to their answers to selected questions on the survey. That criterion for analysis follows in Figure 4.

Student Beliefs	**Characterized by the following responses:**
Enjoys and/or is interested in science	**Agrees/Strongly Agrees with 2 of the 3 following statements:** • *I enjoy learning science.* • *I am interested in a career as a scientist or engineer.* • *I will continue to take science classes in high school after my requirements are fulfilled.*
Believes that science is important and helpful to them	**Agrees/Strongly Agrees with 4 of the following 5 statements:** • *Using scientific methods helps me make good decisions.* • *Learning science is important to my future success.* • *Science helps me to judge other people's point of view.* • *Knowledge of science will help me protect the environment.* • *Science will give me a better understanding of world-wide problems.*

Believes that science will be relevant outside of and after high school	**Positive responses to 3 of the 4 following statements:** **Agrees/Strongly Agrees with:** • *I use scientific methods to decide what to buy in a store.* • *Knowledge of science can help me make better medical decisions* **Disagrees/Strongly Disagrees with:** • *Science has nothing to do with my life outside of school.* • *I do not expect to use very much science once I get out of school.*

Figure 4: Science Interest Survey Categorization

So, How do They Really Feel?

Figures 5, 6, and 7 represent the percentages of students that were found to meet each of the above criteria in order to be categorized as enjoying science, believing science is important, and believing science will be or is relevant to their lives, respectively. The low percentages that represent positive attitudes toward science are reason enough for some type of intervention.

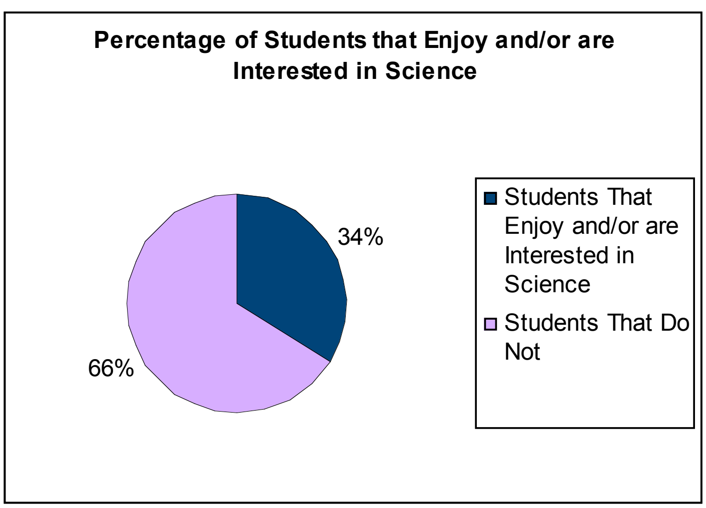


Figure 5: Percentage of Students that enjoy and/or are interested in science

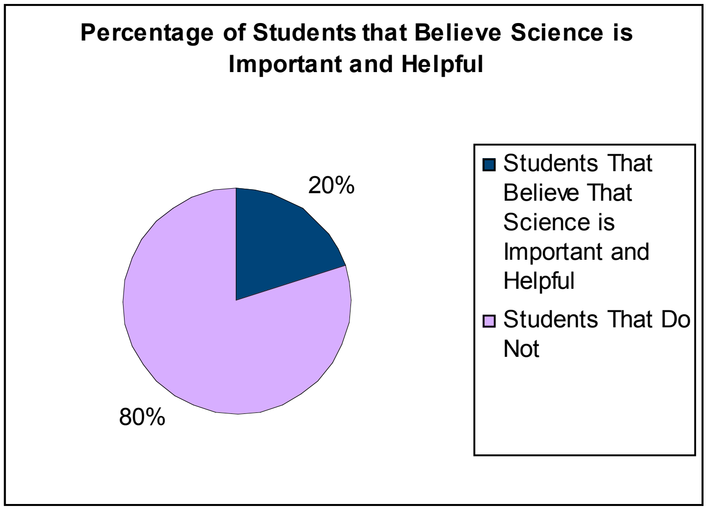


Figure 6: Percentage of Students that believe science is important and helpful to them

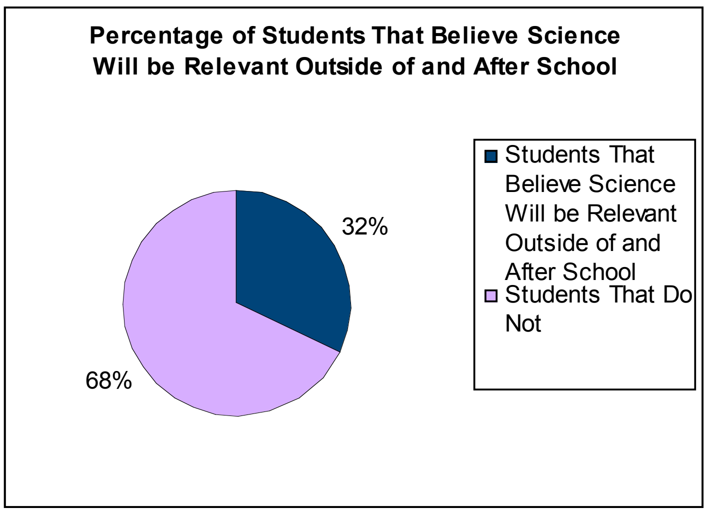


Figure 7: Percentage of students that believe science will be relevant in the future.

The data suggest that a minority, less than 1/3 of my students, have what I have defined as positive attitudes towards science. It is particularly surprising to me that the smallest percentage of students (20%) feels that science is important and/or helpful to them. The highest percentage of students (34%) enjoys learning science, but this is a very small percentage for students of this age. There could be many reasons for this, not the least of which being the way in which science has been previously presented to them. To reiterate an earlier statement, each student brings a different experience to my classroom. My own experience tells me that what my students bring to the classroom can have a profound effect on their success in learning.

The Implications of Their Attitudes

Although I have always felt that my students' attitudes and experiences could potentially affect their success in my class, the following data confirmed these ideas. I compared the results of the above survey with student achievement in my Biology classes. The following data represents the students of both my Biology classes, which total 53 students. The grading scale is as follows:

Percentage	Letter Grade Equivalent
89 - 100 %	A
79 - 88 %	B
69 - 78 %	C
60 - 68 %	D
Below 59%	F

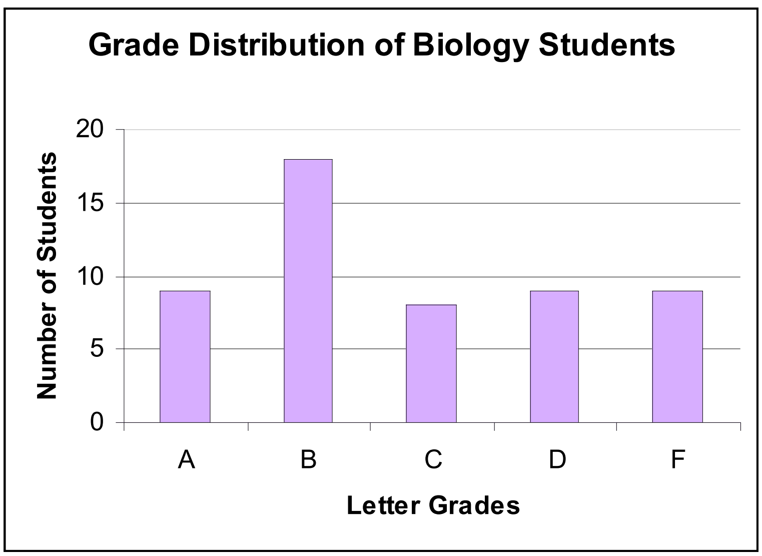


Figure 8: Grade distribution of my Biology students

As Figure 8 demonstrates, the distribution of grades is not a standard distribution. The high number of B grades is indicative of the system of grading. Students that complete all of their work are very capable of earning a B. In general, the students with D's and F's are capable of earning higher grades, but do not complete several assignments, which affects their grades severely.

Figure 9 suggests that there is a relationship between students' attitudes towards science and their performance in class. Seven of the nine "A" students responded with an "Agree" or "Strongly Agree" to the statement "I enjoy learning about science." Two "A" students responded to that same statement that they had "No feelings." None of the "A" students responded with a "Disagree" or "Strongly Disagree" to the statement and none of the "A" students declined to identify themselves.

In contrast, of the ten "F" students, only one responded with an "Agree" or "Strongly Agree" to the statement "I enjoy learning science." Three "F" students responded that they had "No Feelings" towards that statement, two "F" students responded with a "Disagree" or "Strongly Disagree" towards that statement, and three "F" students declined to identify themselves. This data is conveyed graphically in figure 9.

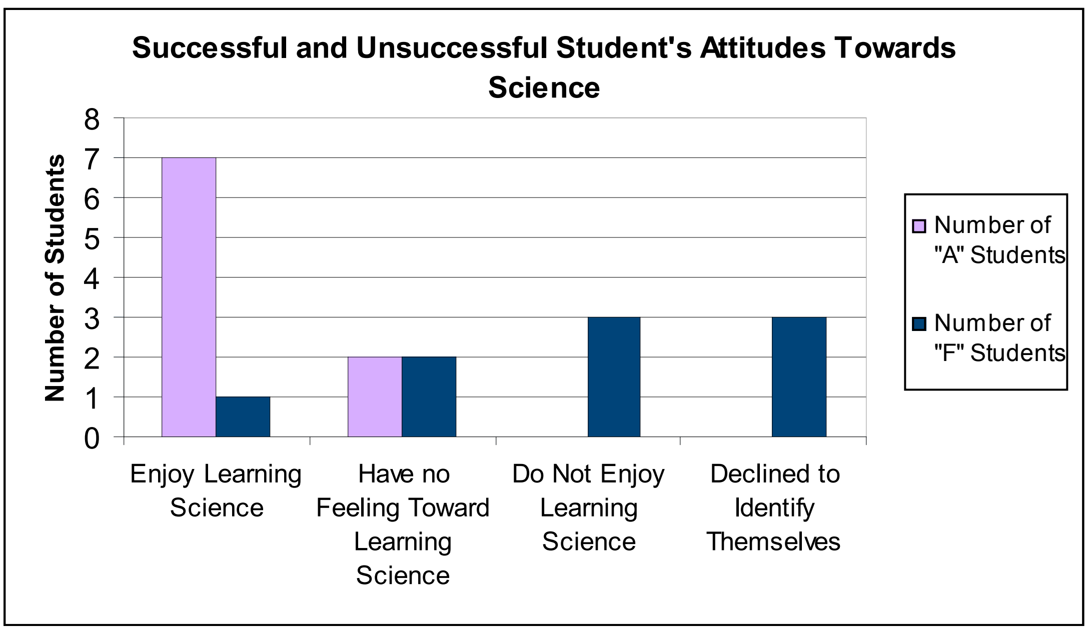


Figure 9: The correlation between student achievement in Biology and their attitudes towards science

Can the Case-Method Work for Us?

What effect does the case-based teaching method have on student learning and attitudes towards science?

Given the information I collected from the survey, I became interested in investigating whether case-method teaching could improve students' understanding of science concepts and help them to see the connections and applications that they may have outside of the classroom. I have also thought about the case method of teaching and its potential to improve students' critical thinking skills by employing such tasks as analysis of the case and decision making based on the facts presented.

In my experience as a Biology teacher, I have noticed that students seem to do one of two things with what they learn in science class. The first is that they do not think of science concepts in terms of real-world applications. They tend to think about science as a set of facts to learn and never use or think about again. The second is that they make completely incorrect comparisons to real world examples, which suggests that they actually never fully understood the science concept to begin with. I find that my students often draw conclusions that lead to more misconceptions than true knowledge, and it worries me that I am not doing enough to help them to make real connections. I would ideally like these real-world connections to be factual and appropriate ways to think about science concepts. My goal for students that leave my class is that they will understand how to examine life in a scientific fashion and to know when science concepts apply and when they do not.

After examining the results of the science interest survey, I found that many of my students believe that what they learn in Biology class does not relate to their everyday existence. I was puzzled by this, mainly because the connections come quite easily for me. The challenge is getting students to understand that they do in fact encounter science on a daily basis and will for the rest of their lives. This can be especially challenging for students that do not see themselves pursuing science after their required courses are completed. “There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole” (Project 2061, 1989). In searching for a way to bring these skills to my students and teach them science concepts, I recalled a resource that I had previously come across, the National Center for Case Study Teaching in Science, which is a joint venture between The State University of New York at Buffalo and National Science Foundation. During my previous year’s study involving academic controversy in the science classroom, I had come across this reference and was intrigued. The Center defines case studies as stories with an educational message. My students love a good story, but I wondered what would be the best way to implement these case studies in my Biology classroom. Based on what I had read, many people thought it was a great pedagogy to use case studies to teach science, but not many people were actually doing it. Although the case method of teaching is heavily relied upon in both law and medicine, it is not used enough in science education to enrich curriculum (Gabel, 1999). Even the National Center for Case Study Teaching in Science is geared mainly toward the college level, rather than high school. I became convinced that case-based teaching has the potential to affect my high school students’ ability to make correct connections to science concepts, to use analysis skills, and improve their attitudes about the usefulness of science. I just needed to come up with a way to implement case studies.

After case method teaching emerged as an exciting method for me to bring these skills and concepts to my students, I planed the intervention. During the intervention period, I attempted to use the case-based method in order to teach major concepts in each of two units of study in my Biology classes. The first unit was genetics with science principles, including patterns of inheritance, probability, formation of a pedigree, and the nature of Huntington's disease as well as bioethics. The second unit in which this method was employed was the cells and classification unit. A case study was used to explore the function of cell organelles as well as the origin of the eukaryotic cell and its organelles. In addition to the science concepts, I explored how the use of case studies can also affect my students' ability to make real-world connections to what they are learning in Biology, how case studies can affect students' ability to make scientific arguments, and how students' attitudes may change towards science after being involved in such activities.

The Specifics

The first case-based lesson was designed around a family in which the father has been diagnosed with Huntington's disease. The lesson asked students to generate justifications for both sides of an issue without involving their personal feelings and then form an opinion after a class discussion which considered the evidence on either side.

This lesson was adapted from a BSCS activity that I used to conclude a genetics unit, specifically a segment of the unit focusing on heritable disease. Both the father and mother want to have their son tested for the HD gene in order to know if he has inherited the gene or not. Since HD is an autosomal dominant disorder, there is a 50% chance that he will have received the disease-causing form of the gene from his father. The consulting geneticist has a policy that requires that a patient be 18 years old before getting tested for the HD gene. The conflict occurs with a family that would like to know immediately if their son has the HD gene.

In small groups, students were asked to generate a list of reasons why the policy should stay the same and a list explaining why it should be changed, regardless of their personal feelings about the issue. The groups were then asked to share their ideas and a class list was generated on the classroom's whiteboard. After the class discussion, students were given a homework assignment to write a letter in response to a letter that had been written by the mother of the boy to the editor of the local newspaper advocating for the testing. Since the students were able to justify reasons for both sides of the issue, they should have been able to form an opinion on the issue. This case was also used to cover concepts such as creating a pedigree and the nature of Huntington's disease. Data from this intervention include student-generated letters, class lists of reasons for and against the current policy, specific answers to exam questions. This lesson was conducted on October 20-21, 2004 during double (90 minute) periods.

The second case study introduces students to the function and structure of organelles in a eukaryotic cell and also presents the autogenic hypothesis and the endosymbiotic hypothesis of eukaryotic cell origin. The case is presented as a story of "Little Mito," who is struggling to find his roots. This case was found via The National Center for Case Study Teaching in Science Case Collection at the State University of New York at Buffalo. After reading the story, students were asked to answer a series of questions and research the evidence supporting each of the hypotheses. They were also asked to generate the comparative strengths and weaknesses of each hypothesis, much like the first intervention as well as generate letters and be assessed for content knowledge gained. Data from this intervention include student-generated letters, class lists of evidence for each theory, and specific answers to assessment questions. The lesson was conducted December 3 and 6, over two 50 minute class periods.

What Happens When…

What happens when students are given a background story to accompany their science lesson? What happens when students are asked to make decisions about real people? What follows are the results of both interventions conducted during the fall semester of 2004. There are three data sources from each intervention: results of a class discussion, student written letters, and responses to case-based questions on the respective assessments.

Data Set #1a: Class Generated List of Pros and Cons

This subset of data includes class-generated lists from both my sixth and seventh period Biology classes. Students were provided with a handout (BSCS 1997) for the activity at hand. I read the introduction as the students read along. The introduction states:

"How should you go about making good choices about important issues in life? Should you base your decisions on a whim, a coin toss, or a call to a psychic hotline? Or should you rely on well-informed, well-reasoned analysis? Scientific reasoning is a disciplined way to understand events in the natural world. Similarly, a discussion of ethical issues brings reason and discipline to decisions that involve preferences and values. We draw our values from many sources, including history, law, religion, and family. Part of the task of ethics is to identify these values clearly and to show why others should regard them as important. A discussion of ethical issues may apply to what we do as individuals or to how public policy is made. In this activity, you will use principles of sound decision making and ethics to decide whether a policy that excludes teenagers from genetic testing is good public policy."

Students were then instructed to read a letter to the editor written by a mother whose husband has been diagnosed with Huntington's disease at the age of 35. She is of the opinion that her young son should be tested immediately, since he has a 50% chance of inheriting the disease. Students were then placed in groups of three to conduct a discussion about the issue in the letter. They were instructed to work together to come up with two lists of opposing ideas about the policy. One of the two lists should state reasons supporting the current policy (disallowing testing for minors for HD regardless of parental consent). The second was to state reasons why the policy should be changed. Both lists were to be generated *regardless of personal opinion.* Groups were given twelve minutes to generate both of these lists. The students then reported their findings, one group at a time, each group contributing something new to the class list. I recorded their responses on the board. The order of reporting was changed between each list to make sure each group got a chance to contribute. The lists that were generated follow in Figures 10 and 11.

Current Policy: To withhold genetic testing for Huntington's Disease for asymptomatic teenagers	
Reasons to Maintain Policy	**Reasons to Change Policy**
▪ To protect teens from extra stress and worry ▪ So families can live life without worry about the onset of symptoms and when that will happen ▪ They can choose to get tested after they turn 18, because they still won't have symptoms ▪ Some teens may lack the maturity to understand the seriousness of the situation ▪ Teens will be able to cope better when they are older ▪ Parents may force teens to have the test ▪ Parents do not have to make that decision, they can make it on their own when they turn 18 ▪ So teens are not discriminated against or "labeled" ▪ Teens may give up and not pursue life goals	▪ Allows teen more options ▪ People can "live life to the fullest" or change their life course accordingly ▪ Teens may want to know ▪ Prevents it from being up in the air and can be dealt with ▪ Family can prepare financially ▪ Parents have a right to make decisions for their children before they turn 18 ▪ People can still choose not to have the test ▪ If a treatment becomes available, they could have it ▪ They could find out they don't have it (50/50)

Figure 10: Period 6 Class List recorded from whiteboard after discussion

Current Policy: To withhold genetic testing for Huntington's Disease for asymptomatic teenagers	
Reasons to Maintain Policy	**Reasons to Change Policy**
▪ Child will have a "normal" childhood ▪ Getting health insurance would not be an issue ▪ By not knowing, they could avoid emotional stress at a young age ▪ Teens may not want to know, but parents may force the test ▪ Prevent (put off) depression and stress ▪ Children would not be labeled ▪ Teens may not fully understand disorder/complications/death ▪ Many teens may not make fully informed decisions ▪ If teens knew they were dying, they may give up on life	▪ Teens may want to know, they have a right ▪ Teens can take advantage of their life while they have it ▪ They will be more prepared for what is to come ▪ If a treatment is developed, they will be able to get it ▪ So they do not pass it on to their children (this would assume that they have children before they are 18) ▪ So they can prepare emotionally and financially ▪ There is a 50% chance of not having it and that they are fine.

Figure 11: Period 7 Class List recorded form whiteboard after discussion

This data set at first seemed small, manageable, and straightforward. My initial interpretation of the class discussion was that it was very successful. Even after reading and contemplating the students' reasons to change the geneticist's policy as well as the converse several times, I am still impressed with the level of thought that students put into the activity. It is not often that I am able to directly observe critical thinking by my students and this lesson proved to be an excellent way to do so. After carefully looking at the reactions of the students, I realized that there were three basic types. The first I titled “Emotional/Mental,” which consisted of reasons such as, “Teens will be able to cope better when they are older” and “So teens are not discriminated against or labeled.” The second group of responses I labeled “Legal/Financial” in which typical responses are “Parent has a right to make decisions for their child before they turn 18” and “The family will be able to prepare better financially”. The third student response category was the “Medical/Science” category. An example from this category is “The teen may test negative, he only has a 50% chance of inheriting the disorder.” I did not group the responses according to which side of the issue the students were on. This is important because students were supposed to generate these reasons regardless of their personal beliefs. The results of the data analysis are demonstrated in Figure 12.

Type of Reason	Number of Responses
Emotional/Mental	20
Legal/Financial	11
Medical/Science	5
Total Number of Reasons Generated	34*

Figure 12: Number of types of reasoning given to support an opinion
* Two responses were placed in two categories, as parts of them fit into each.

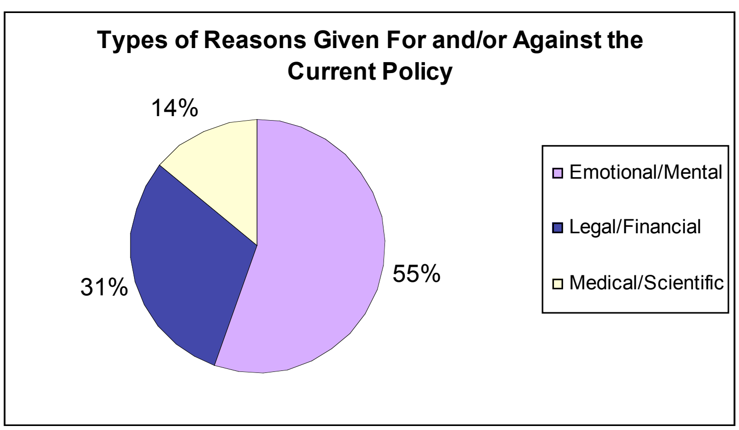


Figure 13: Graphic representation of the types of reasoning given to support an opinion

Since the situation that students were confronted with is a very emotional situation, I am not surprised that the majority of the reasons that students gave were related to emotion. I am, however, surprised by the number of legal and financial responses. I had assumed that high school students may not see the legal and financial implications, as they do not have many of these concerns at this point in their life. Although the medical and scientific reasons were the fewest, this does not concern me as the reasons that the students did give were medically correct and included some background information that I provided prior to the lesson. From a science standpoint, students were able to understand that Huntington's disease is a dominant disorder and that there was a 50% chance that the child in this case would inherit the disorder. This is explicitly stated as a reason to change the policy on both the sixth and seventh period lists. In addition, the students understood that the disorder could be passed unknowingly to children due to the late onset of symptoms. This is stated as a reason to change policy on the seventh period class list. Also, students were able to understand that a treatment is not currently available, but one may become available. This could possibly be due to a short conversation on gene therapy that took place in both classes a couple of days earlier. Again, this was also given as a reason to change the policy in both classes. Interestingly, all of the medical/scientific reasons were on the side of changing the policy to allow minors to get the genetic test with parental permission.

Data Set #1b: Class Generated List of Evidence

This subset of data also includes lists generated by both my sixth and seventh period Biology classes. Students were given a handout containing the story of "Little Mito," the role that he played in his "family," the roles that his other family members played. The story also presented two competing ideas about where Mito came from. Students were then placed in groups of three to conduct a discussion about the dilemma facing Mito. They were instructed to work together to come up with two lists of evidence for each of the two theories that Mito's family had about his origins. One of the two lists should state reasons supporting the Endosymbiotic theory with the second list to state evidence for the Autogenic Hypothesis. Students were given background information packets to facilitate a further understanding of each theory and the evidence to support it. Groups were given twelve minutes to generate reasons to support either theory. Students then reported out, one group at a time, each group needing to contribute something new to the list. I recorded their justifications on the board. The order of reporting out was changed between each list to make sure each group got a chance to contribute.

Evidence for Autogenic Hypothesis	Evidence for Endosymbiotic Hypothesis
• Advantages to being bigger • The endoplasmic reticulum is connected to the cell membrane • Seems like it could happen • No other way to explain certain organelles (ER, Golgi, vesicles, lysosomes, and vacuoles)	• Bacteria, chloroplast, and mitochondria are all around the same size • Mitochondria and chloroplasts have their own DNA • Mitochondria and chloroplasts have double membranes around the outside • Mitochondria and chloroplasts divide independently of the nucleus • There are other examples of symbiosis in nature

Figure 14: Period 6 Class Generated List Recorded from Whiteboard after Discussion

Evidence for Autogenic Hypothesis	Evidence for Endosymbiotic Hypothesis
• The endoplasmic reticulum is connected to the cell membrane • Endosymbiotic hypothesis only talks about mitochondria, chloroplast, and cilia/flagella evolution • Makes sense	• Things like this happen all the time (symbiotic relationships) • Chloroplasts and mitochondria can make proteins on their own like bacteria • They divide by themselves by mitosis • Bacteria, chloroplast, and mitochondria are all around the same size • Mitochondria and chloroplasts have double membranes around the outside

Figure 15: Period 7 Class Generated List Recorded from Whiteboard after Discussion

Due to the nature of the subject matter and lack of emotion involved in presenting evidence, this data was not able to be analyzed in the same way as data set #1a. The evidence given by students should be completely science-based and not emotional or financial, as was the case with the HD lesson. After careful consideration, I decided to analyze the data according to the number of correct science principles used and the number of misconceptions used as evidence. The results of the data analysis are demonstrated in Figures 16 and 17.

Type of Evidence	Number of Responses
Correct Science Principals Used	14
Incorrect Science Principals Used	3
Total Pieces of Evidence Given	17

Figure 16: Number of types of reasoning given to support an opinion

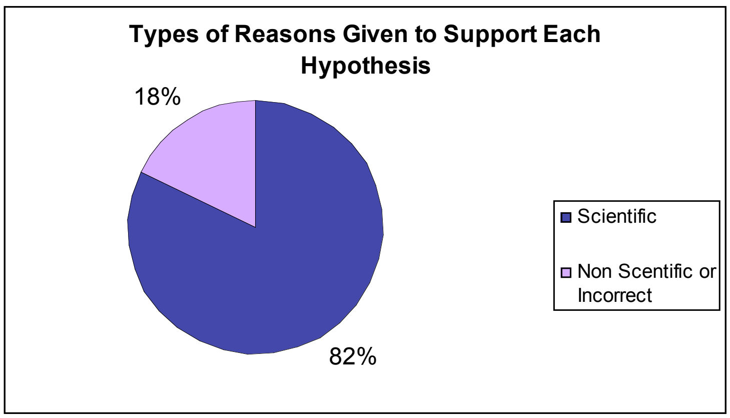
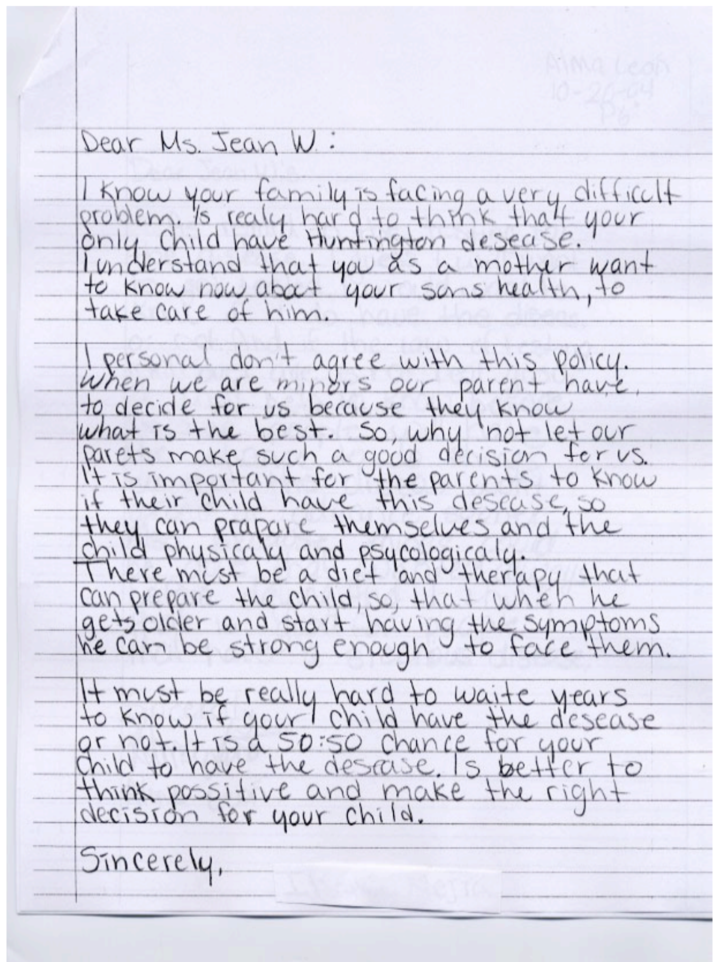


Figure 17: Graphic representation of the types of reasoning given to support a theory.

Only 3 of the 17 pieces of evidence suggested by the class groups were non-scientific in nature. They included responses like "Seems like it could happen" and "Makes sense." Regardless of what students actually thought when they came up with these responses, they do not demonstrate any use of science principles or the ability to gather the facts from the literature provided. Fourteen of the pieces of evidence were scientific and correct. These pieces of evidence to support each theory were found in the provided literature and applied in the appropriate way by students.

Data Set #2: Individual Student's Letters

As a follow up to both intervention lessons, students were given a homework assignment. The assignment from the first intervention required students to write a response letter to the family of the boy in question expressing their opinion on the matter of genetic testing for minors. They were also asked to provide reasons for their opinions. The response letter assigned as a follow up to the Mito lesson required students to write to Mito telling him where they thought he may have come from, using evidence to back up the opinions that they had formed. It is important to mention that 24 of my 51 students involved in this intervention completed and turned in these assignments. This is a 47% completion rate for homework. This level of homework completion is not atypical for my students, even though they have homework assigned on a regular basis. The average rate of homework completion for both classes has been about 56% so far this year.



Dear Ms. Jean W.:

I know your family is facing a very difficult problem. Is realy hard to think that your only Child have Huntington desease. I understand that you as a mother want to know now about your sons health, to take care of him.

I personal don't agree with this policy. When we are minors our parent have, to decide for us because they know what is the best. So, why not let our parets make such a good decision for us. It is important for the parents to know if their child have this desease, so they can prapare themselves and the child physicaly and psycologicaly. There must be a diet and therapy that can prepare the child, so, that when he gets older and start having the symptoms he can be strong enough to face them.

It must be really hard to waite years to know if your child have the desease or not. It is a 50:50 chance for your Child to have the desease. Is better to think possitive and make the right decision for your child.

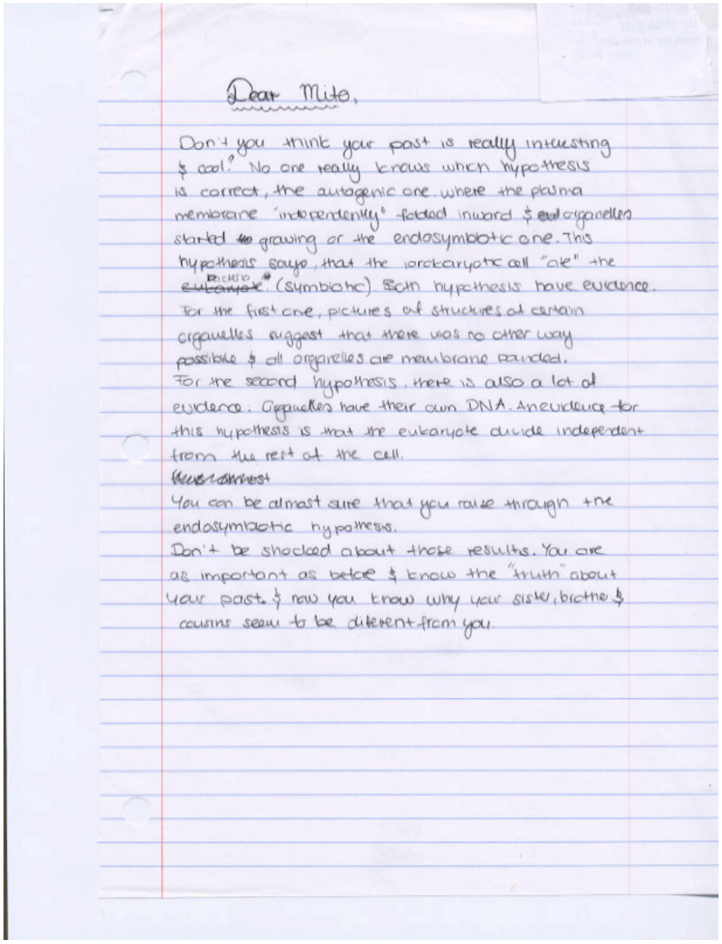
Sincerely,

After reading through the letters from the first intervention carefully and noting trends, I decided to analyze the letters on two levels. The first level was whether or not the letter contained some reasons given for the student's opinion on the matter. These reasons could be generated in class, or reasons that the student came up with after digesting the discussion that we had in class. The importance of these letters relates back to the introduction of the BSCS activity that stated "*Scientific reasoning is a disciplined way to understand events in the natural world. Similarly, a discussion of ethical issues brings reason and discipline to decisions that* *involve preferences and values."* If students are able to generate convincing arguments supported by evidence, then they are thinking scientifically. Of a total of 24 letters that were turned in, I was able to identify 60 valid reasons why the policy concerning the testing should change and/or remain the same. That is an average of 2.5 reasons per response letter. Considering the fact that no length or number of reasons requirement was given to the students, I consider that a successful outcome. Three of the 24 letters contained no reasoning to back up the opinion stated. This is 12% of the sample and indicates that 88% of the students that turned in a letter were able to use scientific skills by supporting their opinions with evidence. It is important to note that only half of the students completed this homework assignment. It is entirely possible that I am analyzing a select sample of students. Although I feel that this data set is important, it cannot solely provide evidence that the case-based method of teaching encourages critical thinking skills.

The second level of analysis dealt with students including any of the science and/or medical reasons for either position. This could include any of the reasons stated as a part of the class discussion and mentioned in data source #2, or **correct** medical and/or scientific reasons that students came up with independently. I found that 14 of the 60 reasons given throughout 24 letters (23%) were related to the science or medicine aspect of the genetic testing issue. Again, because the case is mainly an ethical issue based on policy, I am not surprised by the lack of specific scientific reasons stated. The point of this exercise is not that scientific or medical reasoning was used; the point is that reasoning was used at all. Although this case is an ethical issue, it could be argued that the ability to formulate and articulate an opinion using solid reasons or evidence for that opinion is in itself scientific.

The set of letters from the second intervention were analyzed in an almost identical fashion. Due to the nature of the cell organelle lesson, there was less emotional opinion involved

Figure 19: Sample Letter from Mito Lesson



Dear Mito,

Don't you think your past is really intuesting $ cool? No one really knows which hypothesis is correct, the autogenic one, where the plasma membrane "independently" folded inward $ ~~and~~ organelles started ~~to~~ growing or the endosymbiotic one. This hypothesis says, that the pokaryotic cell "ate" the ~~eukaryote~~ bacteria* (symbiotic). Both hypothesis have evidence. For the first one, pictures of structures of certain organelles suggest that there was no other way possible $ all organelles are membrane bounded. For the second hypothesis, there is also a lot of evidence: Organelles have their own DNA. An evidence for this hypothesis is that the eukaryote divide independent from the rest of the cell.

~~[illegible]~~

You can be almost sure that you raise through the endosymbiotic hypothesis.

Don't be shocked about those results. You are as important as before $ know the "truth" about your past. $ now you know why your sister, brothe $ cousins seem to be diferent from you.

in these response letters. The letters were still categorized as to whether or not they contained supportive reasoning and secondarily, whether or not they contained scientifically factual reasoning. Again, I received 24 letters, the exact number of letters received from the earlier assignment, yielding a homework completion rate at 47%. It is interesting to note that they were not from all of the same students, as three students who completed the assignment earlier did not this time around, but three new students did. Of the 24 letters received, 23 of them contained supportive reasoning for their explanation. This means that 96% of the students used some sort of reasoning to support their statements. This is an increase over the original 88% of students that were able to support their statements during the first intervention.

The second level of analysis had to do with whether students included scientific reasons for either position. This could include any of the reasons stated as a part of the class discussion and mentioned in data source #2, or **correct** scientific reasons that students came up with on their own after class. Again, there was an increase over the first set of letters. Seventeen of the 23 letters containing supportive reasoning contained scientific supportive reasoning. This is 74% of the sample, a vast improvement over the 57% of letters containing scientific reasoning displayed in the first set of letters. As I argued earlier, using solid reasons or evidence for an opinion is in itself scientific. The results of the data analysis are represented in Figures 20 and 21.

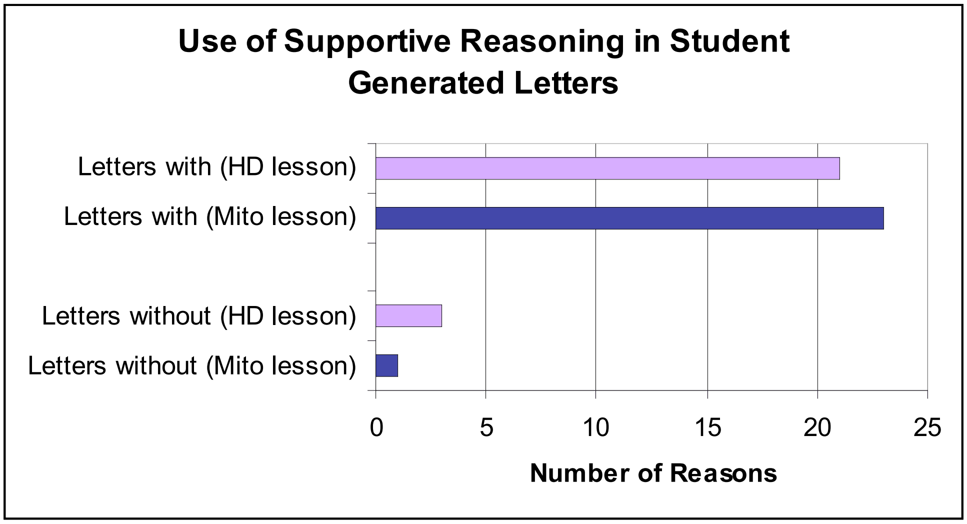


Figure 20: Number of supportive reasons given by students in letters

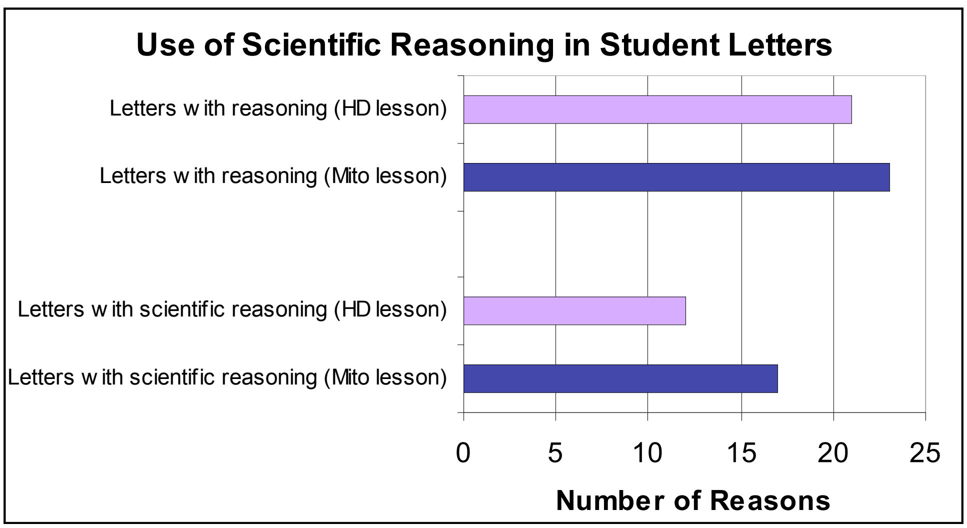
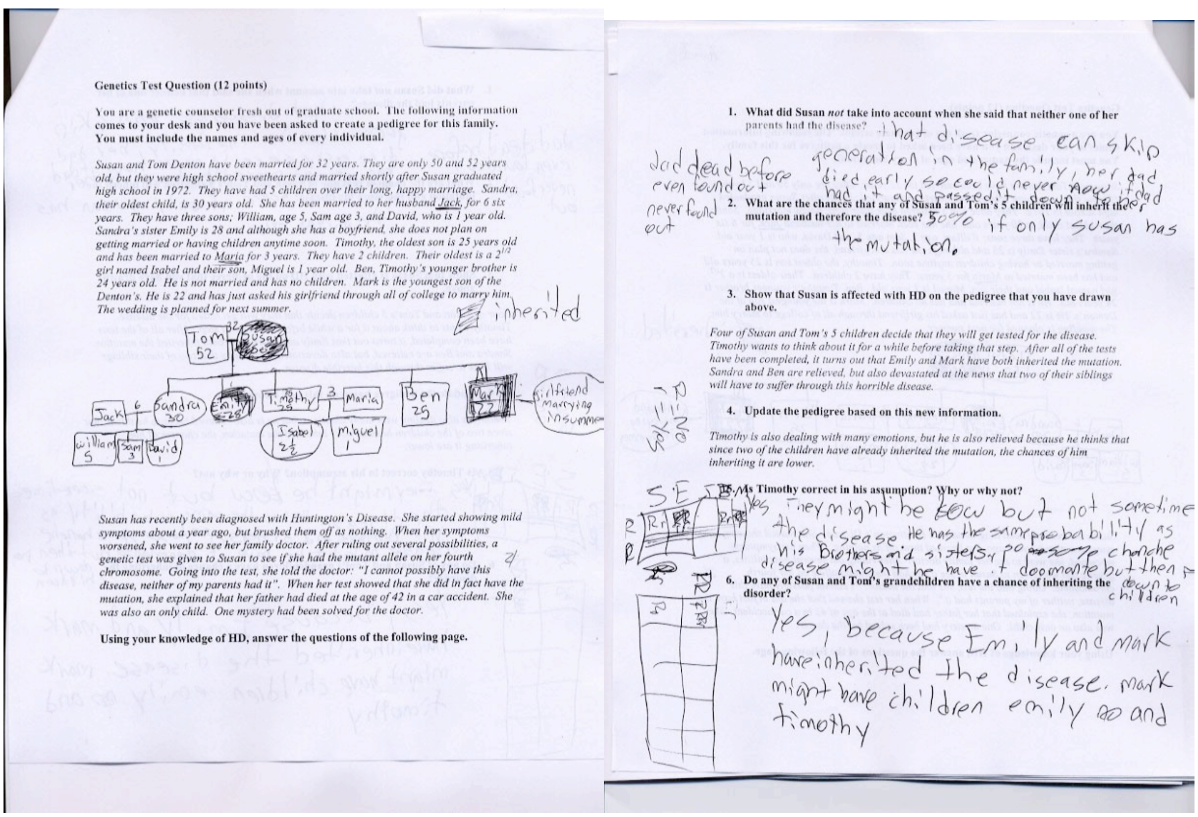


Figure 21: Number of scientific supportive reasons given in student letters as compared to total number of supportive reasons

I attribute the increase in scientific reasoning associated with the second case to two properties unique to this lesson: the nature of the subject in the "Little Mito" case which did not involve an ethical dilemma as did the Huntington's disease case. I feel that it was probably more apparent to students that their reasons should contain scientific evidence. Secondly, the process of case-based teaching and letter writing was no longer a new phenomenon, and students better understood the assignment and expectations due to experience. I do feel that these data sets suggest that the case-based method of teaching can provide an adequate forum in which students can learn how to make a scientific argument and support their argument with evidence. As I have stated earlier, I believe that the fact that they are using supportive reasoning at all is in itself scientific.

Data Set #3: Assessment of Student Learning Outcomes

This data set includes a case-based exam question that was included in the genetics unit related to the Huntington's case as well as an assessment given to the students that was based on the "Little Mito" case.



Genetics Test Question (12 points)

You are a genetic counselor fresh out of graduate school. The following information comes to your desk and you have been asked to create a pedigree for this family. You must include the names and ages of every individual.

Susan and Tom Denton have been married for 32 years. They are only 50 and 52 years old, but they were high school sweethearts and married shortly after Susan graduated high school in 1972. They have had 5 children over their long, happy marriage. Sandra, their oldest child, is 30 years old. She has been married to her husband Jack, for 6 six years. They have three sons; William, age 5, Sam age 3, and David, who is 1 year old. Sandra's sister Emily is 28 and although she has a boyfriend, she does not plan on getting married or having children anytime soon. Timothy, the oldest son is 25 years old and has been married to Maria for 3 years. They have 2 children. Their oldest is a 2 1/2 girl named Isabel and their son, Miguel is 1 year old. Ben, Timothy's younger brother is 24 years old. He is not married and has no children. Mark is the youngest son of the Denton's. He is 22 and has just asked his girlfriend through all of college to marry him. The wedding is planned for next summer.

Susan has recently been diagnosed with Huntington's Disease. She started showing mild symptoms about a year ago, but brushed them off as nothing. When her symptoms worsened, she went to see her family doctor. After ruling out several possibilities, a genetic test was given to Susan to see if she had the mutant allele on her fourth chromosome. Going into the test, she told the doctor: "I cannot possibly have this disease, neither of my parents had it". When her test showed that she did in fact have the mutation, she explained that her father had died at the age of 42 in a car accident. She was also an only child. One mystery had been solved for the doctor.

Using your knowledge of HD, answer the questions of the following page.

1. **What did Susan *not* take into account when she said that neither one of her parents had the disease?** that disease can skip generation in the family, her dad died early so could never know if dad had it and passed it down to her

2. **What are the chances that any of Susan and Tom's 5 children will inherit the mutation and therefore the disease?** 50% if only Susan has the mutation.

3. **Show that Susan is affected with HD on the pedigree that you have drawn above.**

Four of Susan and Tom's 5 children decide that they will get tested for the disease. Timothy wants to think about it for a while before taking that step. After all of the tests have been completed, it turns out that Emily and Mark have both inherited the mutation. Sandra and Ben are relieved, but also devastated at the news that two of their siblings will have to suffer through this horrible disease.

4. **Update the pedigree based on this new information.**

Timothy is also dealing with many emotions, but he is also relieved because he thinks that since two of the children have already inherited the mutation, the chances of him inheriting it are lower.

5. **Is Timothy correct in his assumption? Why or why not?** Yes they might be low but not sometime the disease He has the same probability as his brothers and sisters

6. **Do any of Susan and Tom's grandchildren have a chance of inheriting the disorder?** Yes, because Emily and mark have inherited the disease. mark might have children emily and timothy

Figure 22: Student sample of pedigree assessment question

The case-based genetics exam question was created by me and it is centered on a family and their situation with Huntington's disease. The assessment question was worth 12 of the 41 available points on the exam, which is roughly 30% of the total available points. The entire question required students to construct a pedigree based on the story, adding to it as the story progresses, and to use their knowledge of HD to answer five questions. A sample can be seen in Figure 22.

The “Little Mito” assessment consists of a chart that students were required to complete with information learned from reading the story presented to them. Students were required to know the full names of the cell organelles, and be able to translate what each character (organelle) in the case did for the family in the story but also what the actual organelle does for a eukaryotic cell. This section of the assessment was also worth 30% of the total available points. A sample of student work can be seen in Figure 23.

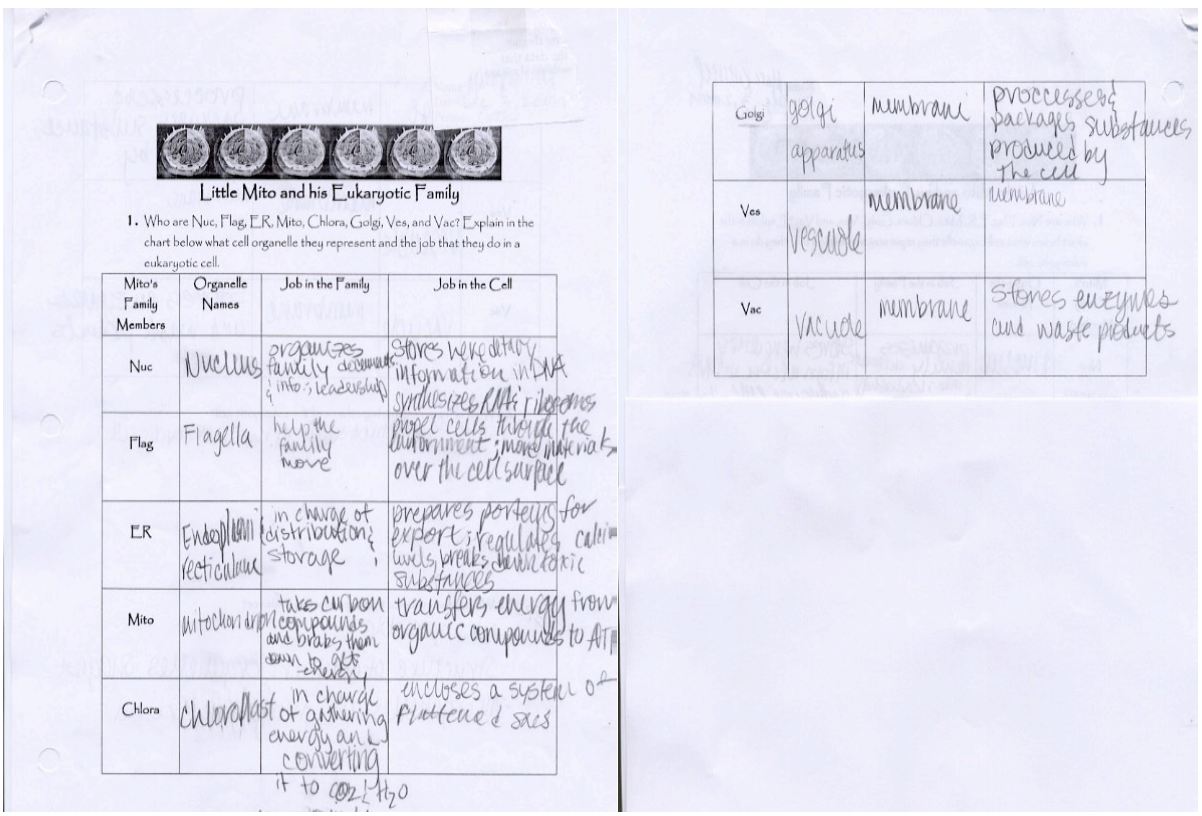


Figure 23: Sample of assessment associated with “Little Mito” case

For the first case presented to the class, there were specific learning outcomes that I set for students regarding Huntington’s disease, the application of creating a pedigree, probability, and dominant inheritance patterns before beginning the lesson. These were to be achieved through both the case-based lesson about one family's struggle with Huntington's and the case-based approach that I took to teach students how to create pedigrees. In analyzing this data source, I have examined the answers to 4 questions on the assessment as well as the student's ability to create a pedigree from the story. The analysis criteria for each are explained in Figure 24.

Question/Skill	Indicators that the student has learned the desired concept or skill
Skill: The ability to create a pedigree given the necessary information	Student is able to use correct symbols and a correct representation of the affected family.
Question (#1): What did Susan not take into account when she said that neither one of her parents had the disease? *This question is related to the nature of Huntington's disease. Susan's father died at the age of 42 in a car accident.*	Student indicates that the father died before the onset of symptoms. This demonstrates the knowledge that HD does not develop until middle age.
Question (#2): What are the chances that any of Susan and Tom's children will inherit the disease? *This question also deals with the nature of Huntington's disease as well as probability. Students must know that HD is a dominant disorder and that when a trait is dominant and carried by one parent, there is a 50% chance of inheriting it.*	Student gives the answer "50%."
Question (#5): Is Timothy correct in his assumption? Why or why not? *This question assesses the students' understanding of the laws of probability.*	Student answers that Timothy is not correct in his assumption and explains that a 50% chance of inheriting the disorder means that each child has a 50% chance, not that 50% of the children will have it.
Question (#6): Do any of Susan and Tom's grandchildren have a chance of inheriting the disorder? *This question assesses students' understanding of the dominant pattern of inheritance.*	Student may answer yes, but with the justification that this will be true only if the two diagnosed children have their own children, or if the untested Timothy ends up having the disorder. Student my also answer no, with the justification that the two children with disorder do not have children and nor does Timothy, who does not know if he has HD.

Figure 24: Analysis criteria of exam questions to determine level of student learning

I have analyzed this data source according to whether or not students were able to meet the four learning outcomes that I had set for them for the case-based lessons during the genetics unit. I have categorized a positive learning outcome for each category as shown in Figure 25.

Learning Outcomes	Correct Answers to the Following Questions
Ability to create a pedigree	Drawing of the pedigree on page 1
Understanding Laws of Probability	Questions 2 and 5
Understanding Dominant Inheritance Patterns	Questions 2 and 6
Knowledge of Huntington's disease	Questions 2 and 1

Figure 25: Definitions of positive learning outcomes

Learning Outcomes	Number of Students Meeting the Outcome (n=52)
Ability to create a perfect pedigree	29
Understanding Laws of Probability	35
Understanding Dominant Inheritance Patterns	25
Knowledge of Huntington's disease	27

Figure 26: Number of students able to achieve a positive learning outcome

In measuring the success of the students in achieving the desired learning outcomes, I found that 58% of my students were able to create a completely correct pedigree, half of them gained a full understanding of the dominant inheritance pattern, 70% of them fully understood the laws of probability, and 54% gained a full understanding of the nature of Huntington's disease. It should also be mentioned that 92% of the students created a pedigree with only one mistake. In all of the 18 exams that contained one mistake, the same mistake was repeated. This mistake was the age order of the family members. This informs me greatly on which aspect of the pedigree making the students struggled with conceptually or that I did not do an outstanding job of explaining.

Additional analysis was conducted to determine the degree to which students met the desired learning outcomes in the first exam. Categories of full, partial and no understanding were created.

Learning Outcomes	**Full Achievement**	**Partial Achievement**	**No Achievement**
	Correct answers to both the following questions	**Correct answers to one of these two questions**	**Incorrect answers to both questions**
Ability to create a perfect pedigree	Completely correct pedigree	Pedigree with one mistake	Pedigree with more than one mistake
Understanding Laws of Probability	2 and 5	2 and 5	2 and 5
Understanding Dominant Inheritance Patterns	2 and 6	2 and 6	2 and 6
Knowledge of Huntington's disease	2 and 1	2 and 1	2 and 1

Figure 27: Degrees of understanding categories as determined by the researcher

The original categories created to determine successful learning outcomes are listed in Figure 25, but those categories assumed complete understanding of the learning outcome. The more specific categories that monitor degrees of understanding are further explained in Figure 27.

The number of students achieving at least a partial understanding of each of the four concepts is a more convincing argument that students learned something from this intervention. Ninety-two percent of students partially understood the creation of pedigrees, 86% came away with some understanding of the dominant inheritance pattern, 92% gained some understanding of the laws of probability, and 90% expanded their understanding of the nature of Huntington's disease. These results are represented in Figure 28. This analysis does not address misconceptions or misunderstandings. The partial understanding conveys that students demonstrate that they may be able to answer an assessment question about the topic in one capacity, but not in another. This does not necessarily imply that the student has gained a misunderstanding. Further research would need to be conducted in order to investigate the propagation of misunderstandings when using the case-based method.

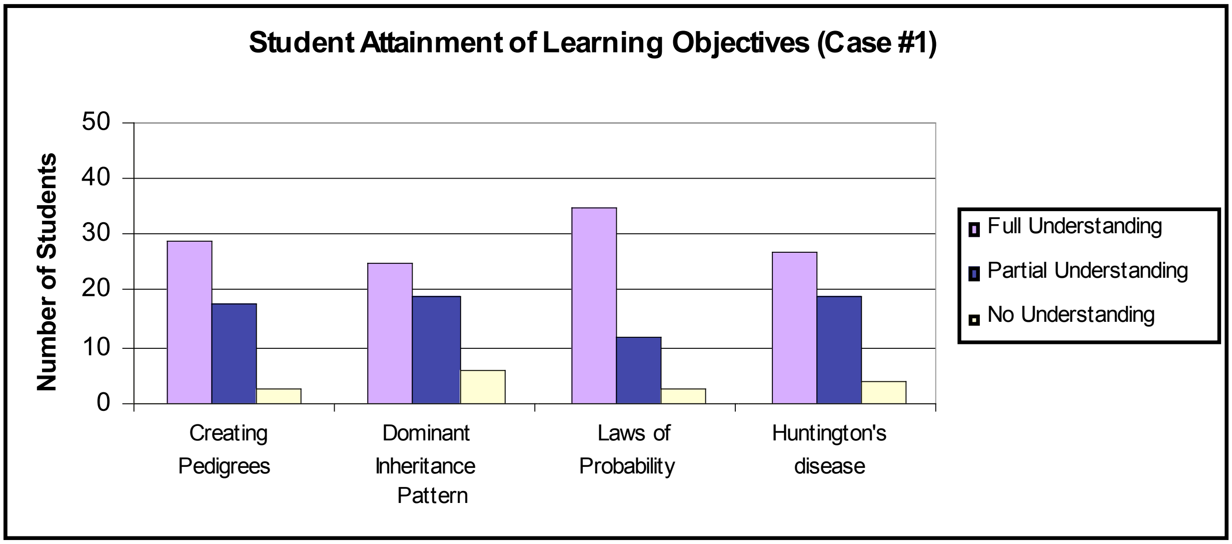


Figure 28: Number of students that gained knowledge and the degree of that knowledge for each of the four stated learning objectives

I also established learning outcomes for my students prior to introducing the assessment related to the "Little Mito" case. These learning objectives are related to being able to identify all of the major eukaryotic cell organelles and to understand what they do in a cell. The criteria for analysis are further explained in Figure 29.

Learning Outcomes	**Indicators that the student has learned the desired concept or skill**
Student is able to identify the eight major eukaryotic organelles with prompting.	Student fills in correct organelles in blank spaces provided.
Student is able to identify the major functions of each of the organelles.	Student fills in correct answer for the blank left for "job in the cell" column.
Student is able to understand the metaphor of the story of "Little Mito" and the eukaryotic cell.	Student not only fills in correct job in the family from the story, but also in the cell as well.

Figure 29: Analysis Criteria of Assessment questions to determine level of student learning

As shown in Figure 29, there were three major learning outcomes that were set for the lessons surrounding the "Little Mito" case. While the analysis of what constitutes a positive learning outcome is slightly different from that of the Huntington's case, the premise of being able to learn science concepts from the lesson is still the same. Using these criteria of analysis, 92% of my students were able to identify the eight major organelles of a eukaryotic cell, 61% of them were able to fully understand the function of each one of those organelles, and 73% of them fully understand the metaphor that was presented to them in the case. These results can be seen in Figure 30 below.

Learning Outcomes	**Number of Students Meeting the Outcome (n=52)**
Identification of the eight major organelles in the eukaryotic cell	48
Identification of the function of each of those organelles	32
Understanding of the metaphor between the "Little Mito" case and a eukaryotic cell	38

Figure 30: Number of students able to achieve a positive learning outcome

Learning Outcomes	**Full Achievement**	**Partial Achievement**	**No Achievement**
	Complete tasks associated with each with this degree of accuracy	**Complete tasks associated with each with this degree of accuracy**	**Complete tasks associated with each with this degree of accuracy**
Identification of the eight major organelles in the eukaryotic cell	100%	> 70%	50% or below
Identification of the function of each of those organelles	100%	> 70%	50% or below
Understanding of the metaphor between the "Little Mito" case and a eukaryotic cell	100%	> 70%	50% or below

Figure 31: Degrees of understanding categories as determined by the researcher

Additionally, the data were analyzed to reflect whether students grasped a full or partial understanding of the desired learning outcome, or if they did not achieve the learning outcome at all. The criteria for these degrees of understanding are explained in Figure 31.

The partial understanding outcomes were very high in terms of percentage of students that gained *some* (at least 70% accuracy) understanding of the concepts at hand. Ninety-eight percent of my students were able to partially name the organelles of a eukaryotic cell, 98% of them were able to identify the function of those organelles with 70% accuracy, and 90% of them partially understood the metaphor used in the case to describe those organelles as members of a family working together to keep a household running (Figure 32).

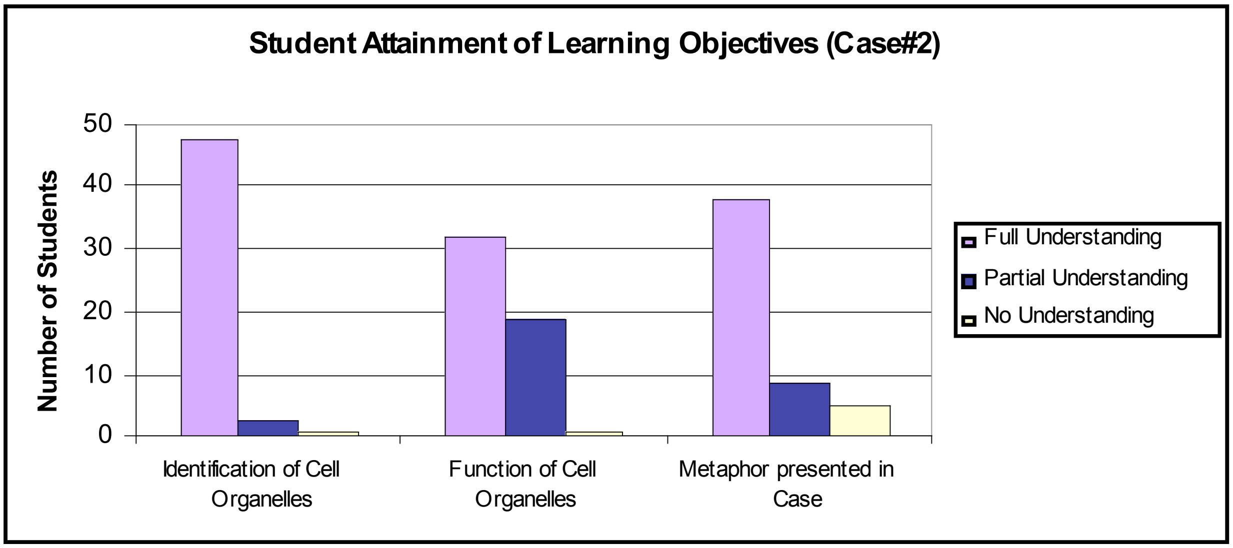


Figure 32: Number of students that gained knowledge and the degree of that knowledge for each of the three stated learning objectives

Did Their Attitudes Change?

I administered the same science interest survey as in the very beginning of this study following the implementation of both interventions. The same analysis criteria were used to organize and classify student responses (Figure 4). In terms of enjoyment and/or interest in science, the case-based method seemed to have little to no effect on my students. Almost the exact same percentage of students reported an interest or general liking of science at 36% as opposed to the 34% of students that originally did. This does not mean that the case method cannot foster an interest in science. These results could be due to the specific questions asked in the survey or related to the particular cases that were used in both of the interventions. The student responses in the categories of importance of science and relevance of science are strikingly different. The results follow in Figures 33, 34, and 35.

When students' responses were analyzed early in the school year as to whether they thought science was important and helpful, only 20% of the surveys indicated that they believed it was. Following the intervention, a surprising 45% of students now believe that science is important and helpful. This pattern of increase is seen in regards to student beliefs about the relevance of science outside of and after high school.

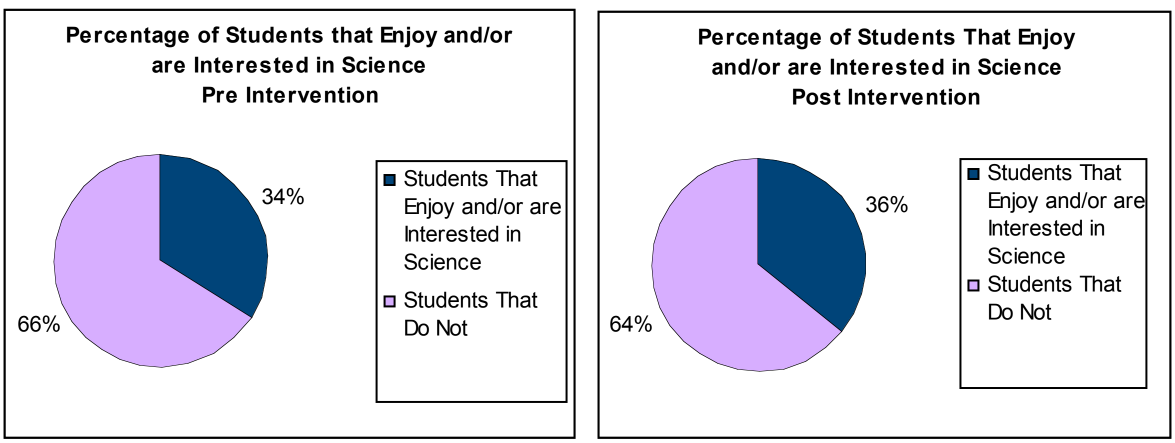


Figure 33: Pre and post assessment of student enjoyment and interest in science

In September 2004, 32% of students felt that science was indeed relevant in their lives or would be in the future. At the completion of this study, 62% of the students felt this to be true. This increase of 30% speaks volumes of the potential of the case-based method in encouraging students to make real-world connections to the concepts they learn in science class. As this connection with the real-world was one of my original goals of the intervention, I am excited by the prospects of utilizing the case-based method in the future to facilitate this aim.

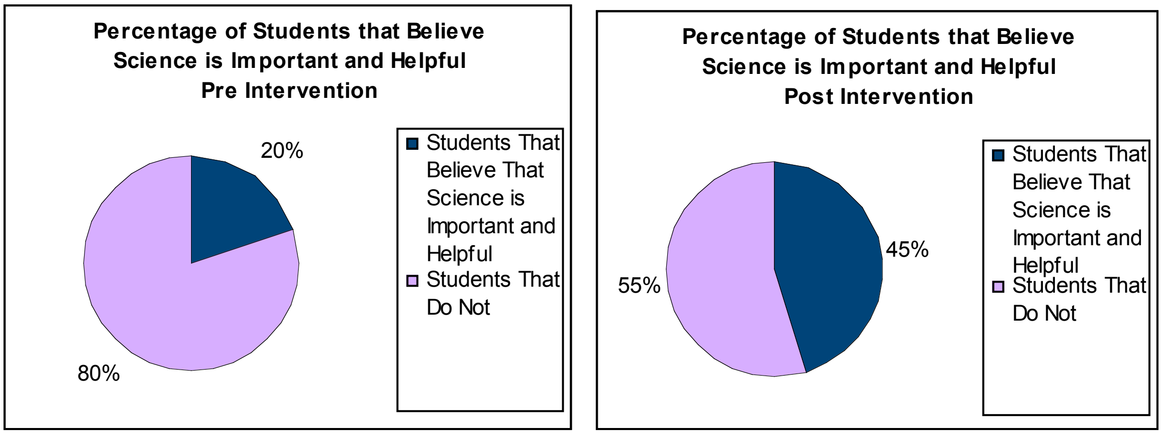


Figure 34: Pre and post assessment of student beliefs of importance and helpfulness of science

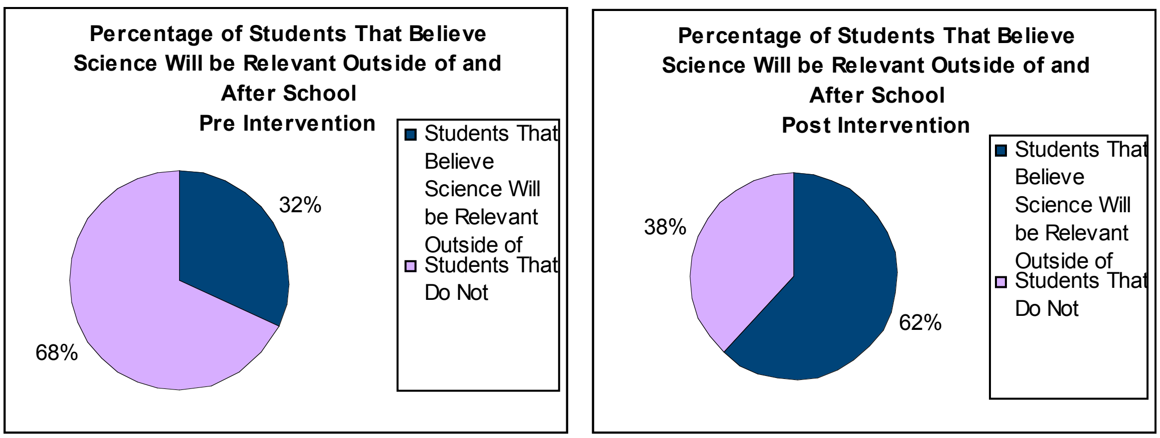
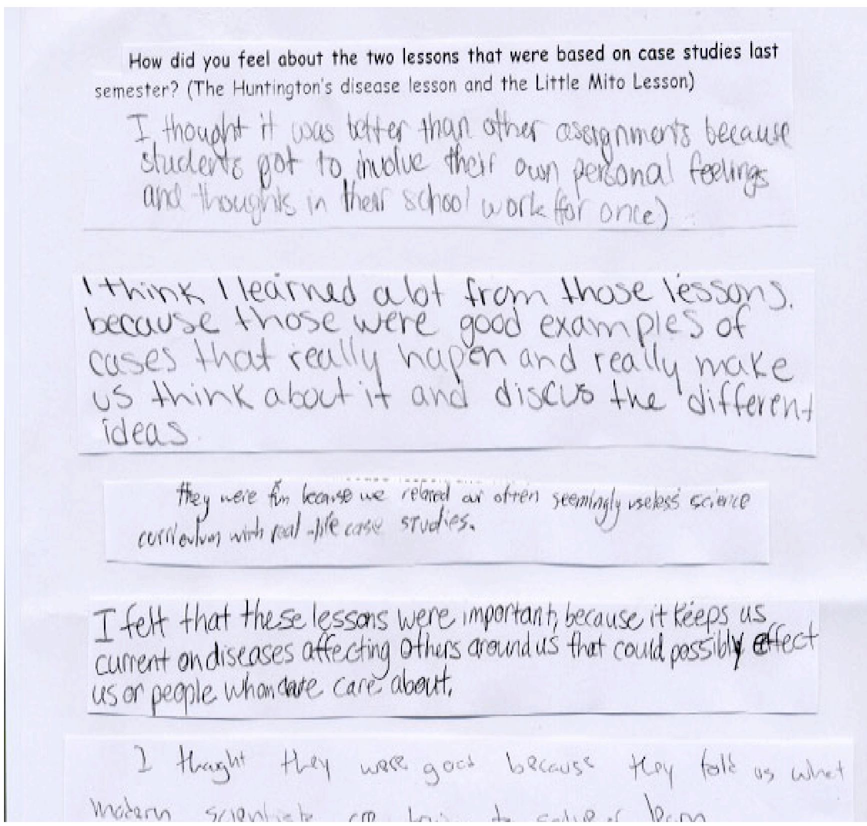


Figure 35: Pre and post assessment of student beliefs of relevance of science to their lives

Tell Me More!

Due to the changes in student attitudes that I found in my survey analysis, I became motivated to ask students more about their experience with the case-based method in my classroom. The surveys that I had administered contained a modified Likert scale. Students only needed to circle a number to answer the questions. To get a better idea of what the students thought in their own words, I passed out a piece of paper as a starter in class one day with the following question posed, "How did you feel about the two lessons that were based on case studies last semester? (The Huntington's disease lesson and the "Little Mito" lesson)." Answers varied greatly, but most were informative. Many students judged the lesson on whether they "liked" it or not, which does not say much about what they learned from it. Of course students prefer many activities that they do not learn from but that are enjoyable. I would argue that if students "like" something, they will be more open and receptive when it comes to the educational aspect of the situation. Other students gave well-thought out answers that addressed the applications of the cases to real life as well as how the stories helped them remember certain things. I have included a representative sample of responses below in Figure 36.


How did you feel about the two lessons that were based on case studies last semester? (The Huntington's disease lesson and the Little Mito Lesson)

I thought it was better than other assignments because students got to involve their own personal feelings and thoughts in their school work (for once)

I think I learned a lot from those lessons. because those were good examples of cases that really hapen and really make us think about it and discus the different ideas.

They were fun because we related our often seemingly useless science curriculum with real-life case studies.

I felt that these lessons were important, because it keeps us current on diseases affecting others around us that could possibly effect us or people whom we care about.

I thought they were good because they told us what modern scientists

Figure 36: Sample of student responses given when asked their opinion about the case-based lessons conducted in class

Implications for English Language Learners

Between the two Biology classes, five of my students are English Language Learners. They vary in English proficiency and motivation. They are all upperclassmen in a much younger class trying to pass Biology for their science credit. Of the three students who speak Spanish as their primary language, two have already taken and failed a year of Biology. My other two English Language Learners are unique in that they are foreign exchange students. One is from Switzerland and her English is exceptional. The other is from Japan and arrived speaking almost no English at all. She did have the ability to read and write proficiently, but struggled with speaking and listening. I have found that her English has improved tremendously over this school year.

While one may intuitively question the effectiveness of this strategy for English language learners, I believe that the results were positive with these students. Although two of my Spanish-speaking students were not able to fully achieve any of the learning outcomes, they did show that they gained some understanding of the concepts at hand. The third Spanish-speaking student was able to achieve the majority of the learning objectives (4 of 7) and partially achieve the rest. My Swiss student was able to successfully achieve the four learning outcomes associated with the HD lesson as well as the three learning objectives associated with the "Little Mito" lesson. My Japanese student successfully achieved 5 of the 7 learning goals. All five of the EL students indicated that they enjoyed these lessons, especially the Huntington's disease case. The main struggle that they reported was the large amount of reading and the use of metaphors in the "Little Mito" case. I do feel that case-based instruction can be successfully used for English Language learners. I believe that it is a matter of choosing reading level appropriate material and scaffolding the process of reading for information for those ELL students.

I will be teaching a sheltered Biology class next year. This will be a new offering on our campus. The need is great, but no one has been qualified or wanted to teach it the past several years. Conducting this teacher research study has given me several great ideas about how to use the case method in a sheltered setting. Many times, EL students can be intimidated by long paragraphs of reading. As I mentioned earlier, cases can be anything from pictures to long and involved scientific research. The case method has the potential to put science concepts into context for EL students. I believe that with carefully chosen, reading level appropriate cases, this context can help transcend the language and cultural barrier that can exist between EL students and their English only peers as well as their English only teacher.

Implications for Teaching Practice

After conducting this teacher research study, I have set the goal for myself of finding and/or developing a case-based lesson or project for each unit of the high school Biology curriculum. This is a goal that I hope to complete for the next academic year. Hopefully, after more experience with the method I will begin to write my own cases and ultimately, I would like to involve students in writing and creating cases. Not only do I feel that my students can benefit in several ways from case-based lessons; I personally enjoyed presenting them to my students. I enjoyed my students' enthusiasm during discussions as well as their thoughtful response letters. The data suggest that the students also enjoyed the lessons. My students' insightful comments about why they liked the lessons were the single most convincing piece of evidence that I gathered throughout this process. My students were able to come up with good reasons to use the case-based lessons that I had not even thought of.

This is not to say that improvements and adjustments cannot be made to improve my method of delivery. The letters that I had students write will be an in-class assignment in the future so as to get a higher completion rate. For the purposes of this study, I used one case that involved an ethical dilemma and one that was told as a story that contained metaphors that students needed to understand to learn science concepts. As I mentioned earlier, cases can come in many different forms. The National Center for Case Study Teaching in Science suggests that even a photograph can serve as the basis of a case. I would like to further investigate which types of case works best for which units. This will probably take several years of testing and changing, but that is how I see my job as a teacher. I hope that I never stop being willing to change when it seems the best thing to do for my students. I also hope to get students more proactive throughout the process. My goal of having the students write their own cases for units is a lofty one, but I believe it can be achieved.

Conclusions

What effect does the case-based teaching method have on student learning and attitudes towards science?

The case method of teaching has long been used in institutes of higher education such as medical and law schools. It has even begun to infiltrate the curriculums of four-year universities as there are many resources that point to how the case method can improve learning as part of a college curriculum. One such article, written by Kim Bilica of the State University of New York at Buffalo, offers advice on the potential of the case method in science and engineering courses held at the university. Bilica argues that although much of the evidence to support the case method comes from anecdote, it is an adaptable instructional method that can engage students and involve them in higher order thinking skills. While I too can give anecdotal evidence that the case method has the potential to be successful in the high school classroom, I have also collected a substantial amount of data that leads to the same conclusion.

In terms of learning scientific facts and concepts, the case method is one successful way in which to impart this knowledge. My first intervention, which involved the case of a family and their trouble with Huntington's disease, resulted in at least 50% of my students being able to *fully* understand each of the four science concepts that I outlined earlier. Additionally, at the very least, 88% of my students were able to gain *some* understanding of those four concepts. While 50% is not a stellar number in terms of success, the concepts are ones with which I am told students struggle on a year-to-year basis. Additionally, the data from the second intervention reinforces the idea that the case method can be used to teach science concepts. Almost every student was able to name the organelles of a eukaryotic cell when prompted (92%). In addition, 62 % of my students were also able to name their function, and 73% showed a clear understanding of the metaphor of "Little Mito" and his family to a eukaryotic cell.

While one may argue that attainment of factual science knowledge is the most important information that students should get out of a lesson, I would argue that it is the larger picture that is more critical. To refer again to the AAAS project 2061: Science for All Americans, "The values, attitude, and skills (associated with science) can be thought of as habits of mind because they all relate directly to a person's outlook on knowledge and learning and ways of thinking in general." It is these "habits of mind" that I am trying to foster as a science educator. Based on the data that I have collected, it can be concluded that the case method certainly does not deter from student opportunities to learn factual information. Some may argue that integrating these case-based lessons in to the curriculum may take away for the instructional time needed to teach the California State Standards. My argument is that, if fully integrated, the case method can not only be sufficient in conveying scientific facts, but also be extremely efficient in facilitating the larger picture "habits of mind" that I discussed earlier.

When students were asked to write response letters as a follow-up assignment to the two cases, they were required to state a point of view and support that view with evidence. This in and of itself is a scientific skill and is one that is essential to meeting the goal of producing scientifically literate high school graduates. The response letters proved successful with 88% of the students that turned in a letter able to use scientific skills by supporting their opinions with evidence. It is important to note that only half of the students completed this out of class assignment. Thus, it is quite possible that I am analyzing a select sample of students. The same trend of non-completion was true for the letters written in response to the second intervention. It is interesting to note that they were not from all of the same students, as three students who completed the assignment earlier did not this time around, but three new students did. Of the 24 letters received, 23 of them contained supportive reasoning for their explanation. This means that 96% of the students used some sort of reasoning to support their statements. This is an increase over the original 88% of students that were able to support their statements during the first intervention. The letters were also analyzed on a second level. For the first intervention, 88% of the students used supportive reasoning in their letters. Of the 88% of students that gave reasons for their opinion, 54% gave reasons that were related to the science or medicine aspect of the issue. Because this was mainly an ethical issue based on policy, I am not surprised by the lack of specific scientific reasons stated. The point of the exercise is not that scientific or medical reasoning was used; the point is that reasoning was used at all. Although this is an ethical issue, the ability to formulate and articulate an opinion using solid reasons or evidence for that opinion is in itself scientific. Regarding the degree of science-based reasoning in the "Little Mito" case, 18 of the 23 letters containing supportive reasoning contained *scientific* supportive reasoning. This is 78% of the sample, a vast improvement over the 58% of letters containing scientific reasoning displayed in the first set of letters. Due to the nature of the case, there was less emotional opinion involved in these letters, which may be one explanation for the disparity between the two interventions.

Additional evidence that case method teaching has the potential to be successful in the science classroom is the recorded statements made by students during our whole class discussions (see Figures 10, 11, 14 and 15). These were lively discussions in a class period in which 90% of the students participated. Many of the supportive reasons that students gave in the first case were not scientific in nature, but I feel that is mainly due to the nature of the subject. Again, just being able to look at the evidence on both sides of the issue is a scientific skill. In the second case, most evidence that students gave to support the two theories were scientifically correct concepts. I found that 14 of the 17 reasons given were scientifically correct, with only 3 being opinion based or incorrect.

The case-based method was able to foster learning of science concepts and to facilitate student development of the argument-forming skills. In addition, based on student attitudes surveys and questioning, students generally enjoyed the lessons that were case-based. Student attitudes in regards to believing science is important rose 25% and beliefs that science would be useful outside of the classroom rose 30%. I am fully aware that students may "like" things that do not necessarily help them learn, but I do feel that the students often know themselves best when it comes to learning style. Additionally, if students are more engaged by any lesson, they are more likely to learn more. Therefore the academic preparation that the case method may bring to the high school science classroom is supplemented by students finding it enjoyable and engaging.

Reflections on My Research Experience

I initially began this process wary of the extra work that completing this project would entail in addition to all of the everyday stresses associated with being a first-year teacher. Even though previous students and professors stated that this work would not be additional work, but an integral part of my teaching, I did not believe them. I actually did not realize that they were correct until I began to analyze data and examine in depth the effect that my teaching has had on my students. It is true that this research became a completely integrated part of what I was doing in my classroom. I am thankful to have had the opportunity to explore questions that I had about my students and my teaching in a structured way. I fear that without having gone through this process, I would have missed a valuable and reflective first year of teaching, as it is easy to get caught up in the daily distractions of our work and home lives. I also feel that going through this process has cemented my lifelong desire to ask questions and investigate them as they pertain to my students and my teaching. In "Researchers in Our Own Classrooms: What Makes a Teacher Researcher?" Jane Hansen says: "A teacher researcher, among other things, is a questioner. Her questions propel her forward." I have always been an inquisitive individual, which is how I became a scientist. Now I feel that I cannot only ask the questions, but I also have the tools to find out the answers. I am especially grateful for having such wonderful professors to guide me through the process of becoming an educator and a teacher researcher. I would like to especially thank Rick Pomeroy, Larry Horvath, Cindy Passmore, and of course my guide this year, Pam Castori. I plan to continue both formally and informally investigating questions about my teaching practice. I can only hope that my next project will bring as much insight, and raise as many new questions as this project did.

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