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ABSTRACT

This report contains five action research papers in science education. Papers include: (1) "Does Classroom Size in an Industrial Technology Laboratory Affect Grades and Success in Class?" (Chad Bruns); (2) "The Effects of Project Based Learning on Students' Engagement, Independence, and Interest in Physical Geology Class" (Jill Dahl); (3) "Will an Interactive Lab Safety Program Create a Safer Laboratory Environment for Students in Biology Class?" (Laura Espeset); (4) "Will Random Sampling of Science Terms Increase Students' Long-Term Recall?" (Ann Miller); (5) "Using Rubrics to Improve Student Independence in Active Scientific Inquiry" (Tony McGee). (KHR)

WINONA STATE UNIVERSITY

COMPILATION OF K-12 ACTION RESEARCH PAPERS IN SCIENCE EDUCATION

2000-2002 LEARNING COMMUNITY MASTERS IN EDUCATION.

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COMPILATION OF K-12 ACTION RESEARCH PAPERS IN SCIENCE EDUCATION

These papers are partial fulfillment of the requirements for the Master of Science Degree in Education at Winona State University.

Action Research was encouraged to stimulate a practitioner approach to curricular and instructional renewal and improvement. The traditional format for the papers helped to coach fundamental research strategies. The students were encouraged to keep their questions and hypothesis directed at very specific issues in their teaching environment.

Each student was required to assemble an advisory team that included:

1) One facilitator or lead advisor, to provide support in the research design and process,
2) Four-to-six fellow graduate students to interpret and synthesize the organizational and writing process, and an
3) Outside content specialist to assure the knowledge base. Outside refers to a person outside the learning community who is a recognized specialist in the content area of the action research. Thus, if the action research related to music, a music specialist was required as a member of the advisory team.

The advisory team provided critical support to the successful paper.

The action research concluded with an oral examination or presentation to encourage and develop leadership skills through informing their associates, their departments or their schools.

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EFFECTS OF CLASSROOM SIZE IN LEARNING IN A SECONDARY INDUSTRIAL AGRICULTURE TECHNOLOGY LABORATORY

By

Chad Earl Bruns

B.S., North Dakota State University, 1996

A thesis submitted to the

Faculty of the Graduate School of

Winona State University in partial fulfillment

Of the requirement for the degree of

Master of Science

Department of Education

2002

This thesis entitled:
Effects of classroom size in a Secondary Industrial Agriculture Setting
Written by Chad Earl Bruns
Has been approved for the Department of Education

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Bruns, Chad Earl (M.S., Education)

Effects of Classroom Size In Learning in a Secondary Industrial Agriculture Technology Class

Thesis directed by Dr. Thomas Sherman

The question has been asked over and over about classroom size. Schools have been debating this more recently. As classroom numbers increase due to budget cuts in the past year the increase in the debate of the quality of the education because of the teacher to student ratio increases. The debate of this will be researched in my classroom this year by comparing the successes of student's projects and grades between two classes that I teach at Triton High School.

This study will benefit student's academic successes in high school classrooms. I think by evaluating these classes and comparing them we as teachers will better understand the nature of students and how they will react to the difference in the teacher to student ratio. This could help in the aid in the saving of programs being cut or teachers eliminated or show that we need to operate more efficiently in our school systems.

Finally, I hope to see a better understanding of how class size will affect student's grades, attitudes, and successes in class.

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CHAPTER 1

INTRODUCTION

This capstone project was developed for use in my industrial agriculture class at Triton High School in Dodge Center, Minnesota. Triton is a public school, which has an enrollment of approximately 420 students in grades 7-12. The quarter long industrial agriculture class was taken by eighth grade students to fulfill their technical reading standard for the Minnesota Graduation Standards. I have taught this course for five years at two different schools during my teaching career.

In an effort to show what affects class size has on learning, I decided to compare two classes that varied in size dramatically. I used the exact same teaching techniques, lectures, assignment, and group lab activities to compare the learning process of the two classes. I developed rubrics for each project and illustrated all assignment in the same manners for both classes. The rubrics were handed out before the students were allowed to work on their projects, so they better understood my expectations and goals of these projects. I then compared the scores and grades of these two classes. I also kept track of the number of discipline actions and absentees needed to keep an atmosphere that would be most favorable to learning.

Need for the Study

I feel this study could benefit student's academic success in high school classrooms. I think by evaluating these classes and comparing them we as teachers will better understand the nature of students and how they will react to the difference in the teacher to student ratio. This could help save programs from being cut or teachers eliminated. Also show that we need to operate more effectively in our school systems.

Statement of the Capstone Problem

Does classroom size in an industrial technology laboratory affect grades and success in class?

Statement of the Question/Hypothesis

I will do this study with a class that I teach twice daily, but with a very contrasting number of students. The second hour has a class size of eighteen students and the second hour has a class of nine. These classes cover the same material at the same time during the semester. By comparing these classes I hope to discover which class achieves more progress through this term.

Definitions of Terms

The terms that I use could relate to an industrial agricultural technology class. The terms may not be familiar to some people.

Limitations of the Study

There will be some limitations and variables that could enter into the determination of the outcome in this research.

Independent Variables

a. Sex of Students-97% male enrollment in class

b. Age of students-All students were in eighth grade

c. Time of class during the day-both classes that were analyzed were during the last two periods of the day.

d. Intelligence level of students-My classes are usually derived from less than 15 percent of students who maintain a B grade point average and above.

e. Socio-economic class of students-80 percent of students parents are from blue collar working families. Where as most parents have only achieved a high school education.

Control Variables

a. Number of students in each class-Each class was limited to the number stated in the result. One class had an enrollment of 9 students and the other a class of 18 students.

b. Subject matter covered in class-Each class was instructed with the same resource material and at the same pace.

c. Lab activities are the same format-Each students was allowed the same time and instruction.

d. Grading procedures are the same-Each class followed the same grading procedures and were evaluated equally.

Moderator Variables

a. Teacher is the same-limited amount of substitutes

b. Teacher has same motivation and enthusiasm

c. Classroom instruction and methods of teaching did not vary.

d. Classroom temperature was maintained at 74 degrees through both classes taught.

CHAPTER II.

LITERATURE REVIEW

As described earlier my Capstone Project was to compare classroom size and see if there was a difference in grades and success by the students. I was educated in a very small school when I was in high school. In fact, it is the smallest public school in Minnesota. I was always under the impression that a bigger school would be better. I thought this for a number of reasons. One was the stable environment of knowing your school would not close because of a lack of enrollment. The other is the different classes and organizations that a larger school would offer. I did understand however, that the personalization would be lost by being a student at a larger school. I have seen the school districts consolidate to make them more efficient and offer more opportunities to students. I have read a number of articles on the comparison with class size and realized that bigger is not always better. I have also learned this by teaching in a larger school as well. Ironically, one argument for consolidation was the array of extracurricular activities big schools could offer: more clubs, more sports, and more choices. Unfortunately, experience proves that as school size grows, the rate of participation drops. Just try to become a cheerleader or a basketball player in a school of 2,000 or 3,000 (a common size for today's high schools). The result will usually be rejection. "The bigger the schools get, the more people are marginalized," says education researcher Kathleen Cotton. Not only do a higher proportion of students in small schools join in extracurricular activities. ""They have and ability says Cotton, to fill more important roles. In a small school you can be somebody"" Langdon (2000). Students lose the closeness and interaction with one another. Bonds with students and teachers within schools with large class sizes are lost in that atmosphere. Even as our population grows in the United States, the number of elementary and secondary public schools fell from about 200,000 in 1940 to 62,037 in 1990. This was done despite a 70 percent increase in population Langdon (2000). I can see by my literature research that this was done to increase efficiency but so has increased classroom size dramatically.

As research to classroom size is being evaluated there are many more factors to consider with this concept. The larger the class size, the less time the teachers are allowed to understand each student in there class. Students become numbers instead of names and faces. Teachers lose insight of student's lives. "In a class of 30 to 35 students, teachers can't pay particular attention to these individuals, and they sometimes fall through the cracks. And a great number of them are from dysfunctional homes" Gentry (1998).

Along with this, there are more minorities enrolled in schools in the United States today. Class size will also become a factor to their success as well. Reducing class sizes in early grades improves overall performance and narrows the achievement gap between black and white students, according to a recently released study by Princeton University Jet (2001). Krueger said his report shows that smaller class size have greater impact on Black students than White students. Black students in smaller classes were more likely to take ACT and SAT tests. Even White students saw a dramatic increase in the number of these tests taken in smaller classes. This report also noted that the teen birth rate for those students in smaller assigned classes was one-third less. A more dramatic change for Black males entering teen fatherhood was 40 percent Jet (2001).

One positive reaction to the Columbine shootings should be to cap school populations and build new schools when population grows, rather than creating larger structures. The objection, of course, is dollars. It's cheaper to operate one larger school than two small ones. After all, every school, no matter its size has to have it's own administration, clerical staff, custodians, heating system, gym, library, etc.-and those cost money. But if spending money will help teachers and administrators get to know their students better, and if that can help to avert the situation where students feel neglected or put upon to act out their aggression, money would not be a factor Abramson (1999).

We know, too, that when classes are too large, even highly talented, exceptionally trained teachers spend more time on discipline and less time on teaching. When smaller classes are led by highly skilled teachers, student learning can truly accelerate and discipline problems improve. The specific approach toward that goal of smaller classes taught by the best teachers will vary from school to school. In some places, the teachers are already well prepared, but the classrooms are overflowing; in others greater priority must be placed on programs that strengthen skills of the teachers themselves Riley (1999).

Far to many teachers are ignorant of the subjects they teach and are an educational liability, no matter how small their classes Lartigue (1999). As the head of one private school recently said, "We believe that a poor teacher can't even teach five students, and a good teacher can teach a hundred" Lartigue (1999). About one-third of public school teachers lack majors or minors in the subjects they teach. The more advanced the subject, the greater the percentage of unqualified teachers Lartigue (1999).

Indeed class size reform in California has had profound unanticipated consequences: in its first two years the teacher workforce increased by 39 percent, causing a drop in teacher qualifications that disproportionately affected school districts already struggling with overcrowding, poverty, and language barriers. The overall costs to implement this type of structure were considerably higher for these school districts Phi Delta Kappan (2001).

In an article ready by Jehlen (2000), low salaries make it hard to attract and keep qualified teachers. Texas has 500,000 certified teachers who have left the profession. It only needs 270,000 to staff every classroom, but districts can't fill vacancies. Last year, there were 12,000 teachers on emergency permits and 10,000 permanent subs. So in order to reduce class size we need to hire more teachers. The problem is that there are not enough teachers to fill the required need.

As stated in an article by Bell (1998), state legislatures are debating whether to reduce the size of classes in elementary schools to provide higher quality of education. Supporters of the proposal are using the results from a study of fourth graders in Michigan, which resulted in a 43 percent increase in the passing rate for the state reading examination, and an 18 percent increase for the state-administered math test. However, such an initiative requires a stable amount of funding and more qualified teachers. This article demonstrated some of the best characteristics for reducing and implementing class reduction. Class size reduction should be concentrated in the primary years, particularly kindergarten through third grade. Tennessee students returning to regular classes as early as fourth grade maintained significantly higher achievement levels.

Classes should be reduced to fewer than 20 students. Programs that reduce groups to below 20 have found to be more effective than programs that retain more than 20 students, but use teacher aides and other techniques to lower student-teacher ratios Bell (1998).

Urban students, particularly minority pupils, benefit more than their peers from smaller classes. In Tennessee, inner city minority students also had significantly higher self-concept and third grade motivation scores than other inner city students Bell (1998).

Class size reduction works best when coupled with professional development opportunities for teachers. Educators should be trained in new teaching techniques that take advantage of smaller class sizes.

Even if the research did demonstrate a clear link between class size and student performance, the question remains whether limiting class size is the smartest investment compared to other education reforms.

CHAPTER III

DATA COLLECTION PROCESSES

Participants and procedures

Participants in this study were students in my eighth grade industrial agriculture technology class during the third and fourth quarters of the 2001-2002 school year. There were eighteen students in one class and nine in the other.

During each quarter , traditional teaching methods were used in the industrial agriculture technology class. This included lectures, reading from handouts, lab activities, videos, and one project. Students completed coursework on measuring, drafting, shop safety, and welding metal work. The students were allowed to work together on their metal project, allowing a teamwork effort to be shown in this area of the course. They were only allowed to work individually in the other coursework.

Data Collection Tools

One of my challenges was to measure each class accurately and keep the same pace of subject matter throughout the quarter. I did have to adapt to changes in class scheduling because of school functions that were done during these periods. These functions were such things as assemblies of the student body, and pep fests.

The one way that I analyzed the metal project was the development of a rubric. I also graded students in a number of other areas ranking them on a four-point scale. These areas were discussion, group activities, leadership, listening, and on-task time.

I feel that this data is valid because all students were evaluated on the same scale and the same methods. There were no abnormalities in any grading procedures or activities. Each student had there course objectives and were clearly explained the grading procedures of the class.

Data Collection

Data was collected during each of the topic areas covered during the quarter and recorded in the grade book. I also collected data on student absentees and discipline. I collected data in discipline in three categories of severity. The categories were number of warnings, detentions, and interaction between the Dean of Students with individual class members, due to disciplinary actions. These actions were rated from a one to three scale, with three being the severest disciplinary action taken. I hoped to reach a conclusion if classroom size may have an effect on these areas as well. A rubric was collected for each student in the grading evaluation of his or her project during the quarter as well.

Examples of rubrics and other data collection can be found in the Appendix. No names our individual data was used to assure anonymity. Only entire class data was used in this Capstone process.

CHAPTER IV

ANALYSIS OF DATA

Process

To analyze the data I set up four Excel spreadsheets to record the data for each comparison. The Excel spreadsheets were on the grade levels between each class for quarter three, quarter four, absentees during the semester, and number disciplinary actions. In the grading portion I calculated an overall average for each class during the third and fourth quarters to see if there were any dramatic changes due to the students comfort levels and understanding of my teaching styles.

I set up another Excel spreadsheet to analyze the average number of absentees per student in each of the two classes. This also analyses the number excused absence and unexcused absences This data was kept in our school attendance records and averaged for each of the quarters.

The last Excel spread sheet I set up was using the level and number of disciplinary actions during each of the quarters between the two classes. These were ranked from a scale of one to three. The rankings here showed the severity of the discipline actions needed.

RESULTS

Table 1 and table 2 summarize the results of my third quarter comparison of grades between the two class sizes. I evaluated them in areas of discussion, group activity, leadership, listening, and on-task time. All areas of comparison showed an increase in the smaller classes effectiveness. The overall average difference in overall grade comparison for both quarters together showed an increase of .351 for the smaller class. There was a difference of .458 for the third quarter and a .244 difference for the fourth quarter. I credit the average difference decreasing in the fourth quarter due to students being more familiar with both me as an instructor and the subject matter covered.

GRADE COLLECTION DATA QUARTER 3

Table 1

	Large Class	Small Class
Discussion	2.7	3.14
Group Activities	2.89	3.65
Leadership	2.67	2.98
Listening	2.54	2.76
On Task	2.78	3.34
Average Overall Grade	2.716	3.174

GRADE COLLECTION DATA QUARTER 4

Table 2

	Large Class	Small Class
Discussion	2.8	2.98
Group Activities	2.78	3.12
Leadership	2.67	2.78
Listening	2.54	2.83
On Task	2.77	3.07
Average Overall Grade	2.712	2.956

Table 3 summarizes the difference between classes for each quarter and the severity of the discipline actions taken. These were actions taken by the instructor and was moderated by my record keeping of each of the classes. After reviewing the table I found that the smaller class in both quarters had lower numbers of total discipline per student. I also found that when analyzing the number of instances, the fourth quarter did become very close in the total number of instances, but there were more severe cases of discipline needed. I do credit each class however for decreasing the total number of instances in the fourth quarter.

DISCIPLINE COMPARISON

Table 3

	Quarter 3 Small Class	Quarter 3 Large Class	Quarter 4 Small Class	Quarter 4 Large Clas
Level 1 Offence	0.4	0.67	0.33	[illegible]
Level 2 Offence	0.14	0.23	0.21	[illegible]
Level 3 Offence	0.06	0.11	0	[illegible]

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Table 4 illustrates the difference in the class attendance between the two classes for each quarter. Each class was also analyzed by the number of unexcused absences for each quarter also. After comparing the two classes the smaller class had less overall average absentees per student.

ABSENTEE COMPARISONS BETWEEN CLASS SIZES

	Quarter 3 Small Class	Quarter 3 Large Class	Quarter 4 Small Class	Quarter 4 Large Class
Average Number of Excused Absences	2.34	3.44	2.27	2.93
Average Number of Unexcused Absences	0.14	0.23	0.21	0.12

CHAPTER V

CONCLUSION

The overall picture provided by the data showed that the smaller classes performed better in all the data that I researched. I think students could benefit dramatically by the smaller teacher to student ratio. I do think however that the larger class of eighteen that I taught did develop a better structure to the class. Students there did not ask as many questions but were more formal during class time.

The problem with the student to teacher ratio is the cost and organization classes would encounter. Overall spending would increase dramatically by school districts that already are having financial shortfalls. Also, building space would not be able to handle the additional class space needed. Educators need to realize that not all people understand what outcomes and achievement these opportunities could have on our students.

My conclusion to this topic is that we need to analyze where this concept would be most beneficial to our student. In other words, where we would get the most bang for the buck. Places such as early elementary and places where safety of the student is needed would be optimal places to use his concept of education.

In closing the teacher demand is already to great in the United States to fill every position with qualified teachers the way it is. After teaching five years this has become more of a concern. Teachers that are not educated in topics they are familiar with have to teach these classes. This is a liability to our schools and is an injustice to our students. We as teachers need to grow and learn to adjust our teaching styles to meet the needs of today's students in an ever-changing world.

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Name_____________
Grade_____________
Date_____________

"C" Clamp Grading Procedure

I. PROBLEM STATEMENT

The problem is to construct a "C" Clamp using a flat 1-inch X ½ inch piece of metal. The dimensions are on the backside of this worksheet.

II. PROCEDUES & ABILITIES

Students will learn and demonstrate these skills in completion of the "C" Clamp project

1. Cut metal to desired length
2. Debur metal edges with file
3. Weld metal joints of "C" Clamp
4. Grind and prepare metal surfaces
5. Brazing metals
6. Tap and Die Work
7. Painting
8. Cost and project Planning

III. GRADING PROCEDURES

Students will be graded on the following basis for project grade determination.
Excellent =10-9 points Good=8-7 points Average=6-5 point Poor=5 & below

1.	Measurements	10 points possible	Total Points________
2.	Welding and metal fill	10 points possible	Total Points________
3.	Straightness and correctness	10 points possible	Total Points________
4.	Grinding and metal preparation	10 points possible	Total Points________
5.	Painting and presentation	10 points possible	Total Points________
			Total Points________

DISCIPLINE COMPARISON

	Quarter 3 Small Class	Quarter 3 Large Class	Quarter 4 Small Class	Quarter 4 Large Class
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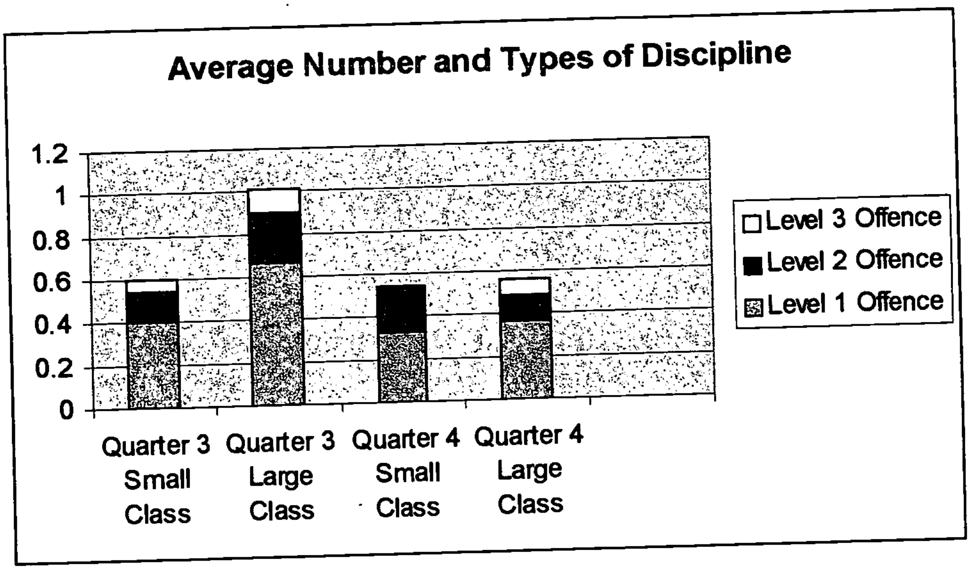

ABSENTEE COMPARISONS BETWEEN CLASS SIZES

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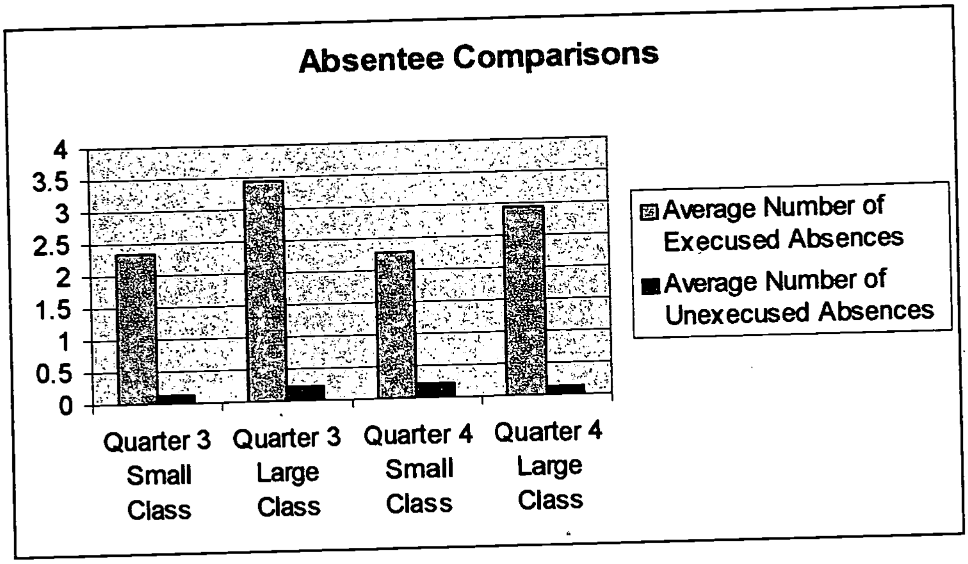

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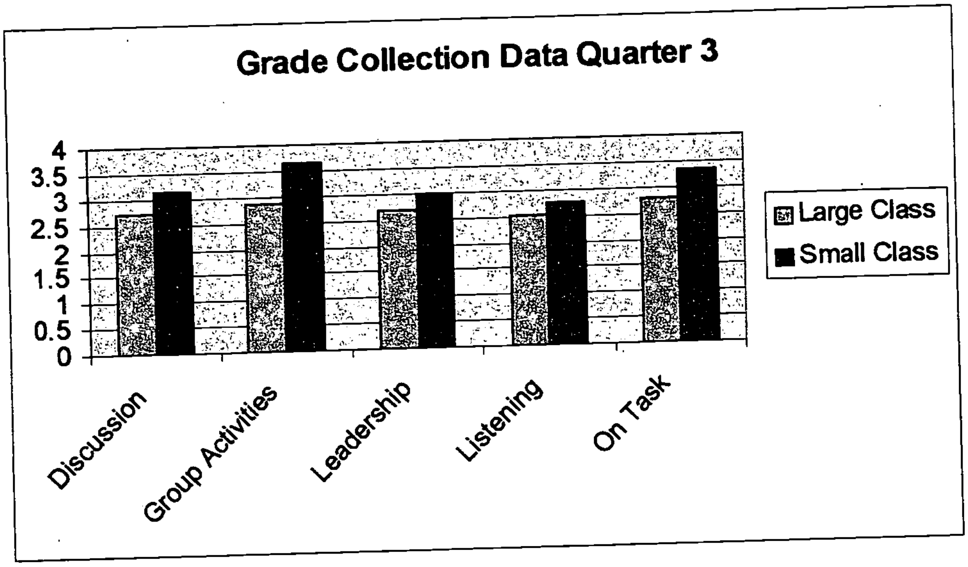

GRADE COLLECTION DATA QUARTER 4

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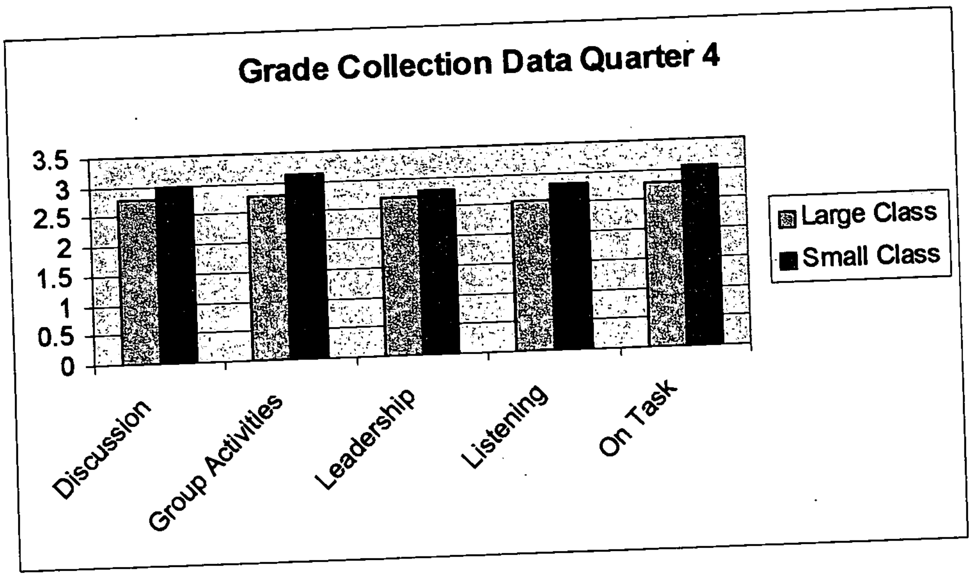

EFFECTS OF PROJECT BASED LEARNING

IN A SECONDARY GEOLOGY CLASS

By

JILL MELISSA DAHL

B.A., Concordia College, 1997

A thesis submitted to the

Faculty of the Graduate School of

Winona State University in partial fulfillment

of the requirement for the degree of

Master of Science

Department of Education

2002

This thesis entitled:
Effects of Project Based Learning in a Secondary Geology Class
written by Jill Melissa Dahl
has been approved for the Department of Education

Julie Onken

Karen Martin

Micki Breitsprecher

Sandi Blank

Margaret Lundquist, M.S.
Faculty Advisor

Date 11/03/02

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Dahl, Jill Melissa (M.S., Education)

Effects of Project Based Learning in a Secondary Geology Class

Thesis directed by Margaret Lundquist, M.S.

In an attempt to increase student engagement, independence, and interest, Project Based Learning (PBL) was incorporated into a physical geology class for one quarter. Rubrics were completed weekly by students and the teacher to measure engagement and independence, and surveys were completed monthly by students to measure interest. Results from the quarter where PBL was used were compared with results from the non-PBL quarter to determine if the use of PBL did in fact increase engagement, independence, and interest. Analysis of the data showed an increase in all three areas during the PBL quarter, and statistical analysis shows that the increases could be considered statistically significant with varying levels of confidence.

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CHAPTER I

INTRODUCTION

This capstone project was developed for use in my physical geology class at Cotter High School in Winona, Minnesota. Cotter is a Catholic high school with an enrollment of approximately 380 students. The semester-long physical geology class is taken primarily by juniors and seniors to fulfill part of their science requirement; other juniors and seniors who have fulfilled their science requirement take the class as an elective. I have taught the physical geology course every semester (with the exception of Fall 2001) since I began teaching at Cotter in 1997. I have often been frustrated with the physical geology textbook, which is designed for college students, and the lack of resources for hands-on activities. I have also felt there is a lack of student interest in studying geology and a deficiency of skills in conducting geology-related research.

In an effort to develop a more student-centered approach in my geology class, I decided to incorporate Project Based Learning as an essential part of the geology curriculum during part of the semester-long class. After using more traditional methods to introduce the study of physical geology during the first half of the semester long class, I implemented PBL during the second half of the semester as students explored topics in local geology. I used surveys to record student interest in geology at the beginning of each month to see if the use of PBL resulted in an increased interest in general science, general geology, and the specific study of southeastern Minnesota geology. I also developed a rubric to measure student engagement and independence; these rubrics were completed weekly by both students and me. I then compared rubric data from the first and second halves of the class to see if there was an increase in student engagement and independence.

Need for the Study

I have often been frustrated with the college-level physical geology textbook, which is difficult for some students to read. In addition, no teacher resources for hands-on activities were provided with the text. I have also felt that there was a lack of student interest in studying geology and a deficiency of skills in conducting geology-related research. I wanted to know if using a PBL approach to this geology class would increase interest and engagement in geology as well as allow students to develop independent research skills in geology.

Statement of the Problem

Students who have taken physical geology in the past have shown little interest in geology. There has also been a lack of independence in learning and a lack of skill in conducting geology-related research.

Statement of the Question

Does Project Based Learning increase student engagement, independence, and interest in learning in a physical geology class?

Definition of Terms

Thomas, Mergendoller, and Michaelson (1999, p. 1) define Project Based Learning (PBL) as "a teaching and learning model that focuses on the central concepts and principles of a discipline, involves students in problem-solving and other meaningful tasks, allows students to work autonomously to construct their own learning, and culminates in realistic, student-generated products".

Students who show independence in learning are able to produce a "plan of action" for their research, and then follow through on this plan by locating resources and using the resources in their project. This process takes place with minimal guidance from the instructor.

Students who show engagement in learning are on task during class sessions as demonstrated by participation in class discussions and group activities, listening, and sometimes assuming a leadership role in the class.

Limitations of Study

Limitations for this study included a small sample size and a lack of random sampling. My geology class for the spring semester of the 2001-2002 school year consisted of only ten students; in addition, these students did not seem to me to be the "typical" geology class that I have experienced in the past. These students were already, for the most part, interested in geology and motivated academically, qualities that typically did not usually describe previous geology classes.

Another limitation was the difficulty in measuring qualities like "interest" and "engagement". I attempted to do so by using an interest survey and rubrics that were completed by both students and me during the study. The rubrics, in particular, seemed to create another limitation during the course of the survey, because students did not like to complete the rubrics and often hurried to complete them, causing me to question the accuracy of the students' data.

A limitation that I was concerned about prior to the study was the difficulty of getting accurate results during fourth quarter, when many students, especially seniors, seem to have a very hard time staying interested in academics and focused on class work. After completing the study, I would say that I felt that the timing of the study did not affect the results; students' attitudes and academic behaviors did not seem to drop off during fourth quarter as they typically have in the past.

CHAPTER II

LITERATURE REVIEW

As described earlier, Project Based Learning (PBL) is "a teaching and learning model that focuses on the central concepts and principles of a discipline, involves students in problem-solving and other meaningful tasks, allows students to work autonomously to construct their own learning, and culminates in realistic, student-generated products" (Thomas et al., 1999, p. 1). However, the acronym PBL is sometimes also used to refer to Problem Based Learning, which can lead to some confusion because the two teaching methods are similar. Both are student-centered approaches where students are cooperatively engaged for extended periods of time in open-ended projects (Esch, 1998). The differences, as described by Esch, between the two teaching strategies are subtle: as the names imply, Project Based Learning is driven by a project, or end-product, while Problem Based Learning is driven by a problem for students to work through. However, distinctions between the two approaches are often blurred, as teachers incorporate bits and pieces of both methods simultaneously. As much as possible, I have tried to limit my literature review to information specifically about Project Based Learning, which I will refer to using the acronym PBL. I have included data about Problem Based Learning only when it specifically referred to science education or to secondary school situations.

As the research pertaining to PBL is evaluated, it is important to keep several factors in mind. Stites (1998) pointed out that PBL is often implemented as part of comprehensive educational reforms, and thus it is difficult to pinpoint the educational results due solely to PBL; also PBL is not always implemented the same way, and so comparing results from classroom to classroom may not give an accurate picture of what is really happening. Standardized tests, so commonly used in America to gauge educational success, may not accurately reflect the benefits of PBL, because the tests do not do a good job of measuring the higher-level thinking skills that researchers and teachers claim are a positive outcome of PBL (Stites, 1998). Finally, I have noticed through my own search for research on PBL that much research focuses on elementary and middle school classrooms, as well as college and graduate level settings; I have found little research related to the use of PBL in high schools, the setting that I am most interested in.

Though PBL is often thought of as a recent innovation in education, historical research has found that PBL actually had its origins in late sixteenth century European architectural schools; two centuries later the project method was being implemented in engineering schools in both Europe and America. But it wasn't until the early twentieth century that PBL gained more widespread use throughout the American educational system (Knoll, 1997). One particularly noteworthy advocate of PBL was William H. Kilpatrick, a student of John Dewey and a professor at Teachers College of Columbia University. Kilpatrick believed that PBL was most effective when students were entirely in charge of "purposing, planning, executing, and judging" projects that interested them, not topics selected by the teacher (Knoll, 1997, Psychologizing the Project Method by Kilpatrick, ¶3). Dewey, however, was not completely in agreement with Kilpatrick, as he argued that children needed the guidance of a teacher as projects are planned and evaluated (Knoll, 1997). Dewey's criticism perhaps decreased the momentum of the PBL movement, but today PBL has gained wide acceptance in American education because of the numerous benefits provided by this teaching strategy.

One benefit is students' "in-depth understanding of subject matter content" (Thomas et al., 1999, p. 9). After using PBL in a seventh grade science classroom to cover units on water and acid rain, Scott (1994) reported that her students displayed:

> a basic understanding of concepts such as watersheds, local water source and treatment, water pollutants, nitrogen cycle, positive and negative effects of nitrates, observable characteristics of acids and bases, causes of acid rain, consequences of acid rain, control measures for acid rain, as well as the political nature of environmental pollution. (p. 86)

This is indeed a broad, yet deep understanding of the project topics. Thompson (1996) identified the same level of understanding on final exam essay questions when he incorporated Problem Based Learning in an introductory college geology course.

In addition to a deeper understanding of content, PBL also allows students to learn skills and strategies used by professionals in a particular discipline (Thomas, 1998; Thomas, et. al., 1999). Scott (1994) compared science skills, such as data collection and analysis, developed by students in her PBL classroom with students in traditional classrooms, and found that PBL students did in fact demonstrate higher levels of proficiency in those areas.

The drawback to the deep level of understanding and skill development afforded by PBL is that this level of in-depth learning requires time. The time spent on project learning limits the breadth of content that can be covered (Lewis, 1996; Scott, 1993). This can be a source of concern for parents, who want to be assured that basic skills are being taught, as well as for administrators, who want to be assured that nothing is left out of the curriculum (Thomas, 1998). Krynock and Robb (1996) argued, however, that the same amount of curricula can be covered in a Problem Based Learning eighth grade science classroom as in a traditional classroom. It is also interesting to note that the National Research Council (1996) is encouraging teachers to cover a smaller number of fundamental concepts in a more integrated fashion, which would fit well in a PBL setting.

In addition to limiting the breadth of content, there are other disadvantages or perceived challenges to PBL implementation that prevent or discourage more teachers from using this approach. One PBL concern stated by teachers in Thomas's research (1998, p. 25) was that students may not participate or "might not learn the 'right' stuff." One study related to the use of PBL in post-secondary classrooms found that indeed some students did not stay on track and course objectives were omitted from their projects (Lewis, 1996).

Because of this concern that important content might not be covered, some teachers feel as though they are giving up control in their classrooms when a PBL approach is used (Thomas, 1998). It's also difficult for teachers and students to break out of their traditional classroom mindsets where the teacher is seen as the "disseminator of knowledge"(Lewis, 1996, ¶ 4). Other teacher concerns recorded by Thomas are difficulties in developing assessments, uneasiness because of lack of teacher knowledge about project content, lack of technology training when guiding students in multimedia projects, and worry about criticism from parents and the community.

Despite these challenges, I feel that research shows that the benefits of PBL far outweigh the disadvantages. In addition to developing an in-depth understanding of content and developing skills specific to the content area, PBL also gives students an excellent opportunity to use higher level thinking skills (Thomas, 1998; Katz, 1994; Stites, 1998; Krynock & Robb, 1996). After observing middle and elementary school classrooms where PBL was occurring, Thomas (1998, p. 2) noted that "students appear to engage eagerly in what's usually described as 'higher cognitive thinking activities' such as relating concepts and using existing criteria to evaluate new ideas." Thomas also described the improved "richness" (p. 7) of students' learning due to the project approach; students generate their own ideas, process ideas by thinking about their significance and by connecting information, and evaluate information critically.

PBL has also been touted as a method that accommodates a variety of the intelligences described by Howard Gardner (Wolk, 1994; Thomas, 1998). According to Walters (1994), traditional instructional methods not only favor linguistic learners, they also limit development of other intelligence areas. Conversely, projects "offer multiple ways for students to participate and to demonstrate their knowledge", while also challenging students to develop weaker areas of intelligence by moving students away from "doing only what they typically do" (Thomas, 1998, p. 7).

In addition to intellectual development, Thomas (1998) observed that students in PBL classrooms gained confidence in their skills, respect for the viewpoints of others, and increased feelings of self-worth. Teachers in those same PBL classrooms reported that increased student self-confidence carried over to other activities and that students felt more connected to the community; students reported that they felt that they could make a difference (Thomas, 1998). Thomas also observed that students in PBL classrooms displayed a love of learning and a desire for further education.

Advocates of PBL cite increased life skills, such as working cooperatively with others, making thoughtful and informed decisions, and developing independence and responsibility, as another major benefits of the project method (Thomas, et. al., 1999; "Why do", 1997; Thomas, 1998; Thompson, 1996). Thomas (1998, p. 22) reported that even elementary and middle school students were aware that they were developing life skills: "We were using skills we knew we would need in our jobs, like using time wisely, exercising responsibility, and not letting the group down." Krynock and Robb (1996) and Thomas (1998) directly observed increased cooperative learning skills through PBL as compared with traditional instructional methods; working well with others is also cited by several other sources as a benefit of PBL ("Why do", 1997; Souders & Prescott, 1999; Katz & Chard, 2000).

Students in a PBL classroom develop skills in making thoughtful and informed decisions (Knoll, 1997; "Why do", 1997; Thomas, 1998). Thompson (1996) described this as one of the most important benefits of using Problem Based Learning in his college level introductory geology class:

> These students were not and will not be scientists, and have little need of traditional, content-driven, information-heavy science instruction. However, they will need to be logical and scientific throughout their lives, to evaluate evidence, and take positions on complex issues in every facet of their lives. (¶ 1)

Scott (1994, p. 86) found that her middle school science students were much better prepared to defend their positions on the need for controls on acid rain pollutants after "students became aware of the consequences and understood some of the causes" of acid rain.

Developing student independence and responsibility is one of the benefits of PBL described by Knoll (1997), and one of the benefits that I particularly wanted to monitor in my classroom for this capstone project. After observing middle and elementary school classrooms where PBL was being used, Thomas (1998) reported that students were learning self-management skills, working with little supervision for extended time periods, and using various tools and resources "autonomously, spontaneously, and creatively" (p. 2), thus moving responsibility for learning from the teacher to the student. Teachers who implemented PBL also reported to Thomas that they witnessed increased student autonomy in their classrooms.

Another highly documented benefit of PBL that I wanted to attempt to measure for my capstone project was increased student engagement and interest. In Thomas's classroom observations (1998), increased engagement was noticed by students, teachers, and by Thomas himself. Students described being excited because "Everybody felt needed and had a part. Nobody got left out" (p. 22). Teachers observed that even withdrawn students slowly began to participate when PBL was used. Thomas noticed that the "off-task behavior" of middle school students dropped off significantly. Why does PBL increase engagement? Relevance seems to be a key theme. Students in PBL classrooms create meaningful products (Thomas et al., 1999) and consider "real world questions students care about" (Thomas, 1998, p. 4) in a setting that is often interdisciplinary ("Why do", 1997). Students are able to pursue projects that interest them, thus increasing intrinsic motivation for learning (Katz, 1994; "Why do", 1997; Stites, 1998; Thomas, 1998). According to Civian et. al, the relevance provided by PBL seems to be especially important in encouraging female and minority students to participate (as cited in O'Hara, Sanborn, & Howard, 1999).

Research documents numerous benefits of PBL as described in this literature review. My own research, as discussed below, was to evaluate if PBL could potentially increase interest, engagement, and independence of students in my physical geology class.

CHAPTER III

DATA COLLECTION PROCESSES

Participants and Procedures

Participants in this study were students in my physical geology class during the second semester of the 2001-2002 school year. There were originally eleven students in the class, but one student withdrew after two weeks. Because this student was not involved in the PBL portion of this study, the limited data obtained from the student was not included in this study.

During the third quarter (the first half of second semester), traditional teaching methods were used in the physical geology class. This included lectures, reading from handouts, lab activities, videos, and one mini-project. PBL was implemented during the second half of second semester (during fourth quarter). Students completed projects on sedimentary processes, geologic time, and a final project on a topic related to southeastern Minnesota geology. For the first project, students worked with partners; for the second project, the entire class worked together, with each student responsible for a particular period in geologic time; and for the final project, students worked individually.

Data Collection Tools

One of my challenges was to measure student engagement, independence, and interest, characteristics that are seemingly intangible and definitely can't be measured with standardized tests. I chose to develop two data collection tools. First, I created a rubric based on a four point scale to be used weekly by both teacher and students that would quantify engagement and independence (see Appendix A). This rubric measured student engagement by looking at participation in discussions and group activities, leadership, listening, and on-task time, while independence was measured through an item called self-directed learning. Second, I created an interest survey that would be completed monthly by students (see Appendix B); students rated their interest on a scale of one to ten in general science, general geology, and southeastern Minnesota geology.

I feel that my data is valid because, although the attempt to measure independence and engagement may be somewhat subjective, the rubric I used listed specific behaviors that could be used to indicate levels of independence and engagement. I also feel that it was important that levels of independence and engagement were measured by both students and me. If only I had completed rubrics for each student weekly, there would be a potential source of bias because I was working with the knowledge that PBL should increase both independence and engagement. On the other hand, I began to doubt the accuracy of student responses after I saw them rush through the rubrics each week; I encouraged them to take their time and fill them out thoughtfully, but I don't think that all students did that every week. Having a combination of data from students and the teacher help to make my results more reliable.

Data Collection

Data was collected weekly using the engagement/independence rubric. On the last school day of the week, each student completed the rubric based on his or her classroom behaviors during the previous week; I also completed a rubric for each student.

The interest surveys were completed by students once a month, which roughly corresponds with the beginning of third quarter, the middle of third quarter, the end of third quarter/beginning of fourth quarter, the middle of fourth quarter, and the end of the fourth quarter.

I collected rubrics and surveys and kept them in my desk until the end of the semester when I began to analyze the data. One problem that came up during data collection was student absences. Sometimes I forgot to give students surveys to complete if they had been gone the previous Friday. Other times students did not return to class until Wednesday of the next week or later, so it was difficult for them to accurately reflect on their classroom behaviors during the previous week. Another problem was the use of a two-sided rubric. I did not realize until collating my data that one student only completed one side of the rubric for several weeks.

Examples of completed rubrics and surveys can be found in Appendix A and B. Names have been replaced by initials to assure anonymity. Initials were also used in the data analysis process.

CHAPTER IV

ANALYSIS OF DATA

Process

To analyze engagement data, I set up five Excel spreadsheets to record student and teacher responses for the following rubric items for each week: discussion, group activity, leadership, listening, and on-task. I then calculated an overall average for third quarter for each student and compared that to the overall average for that student during fourth quarter to see if there had been an increase in that particular area after PBL was implemented. Student and teacher data were kept separate so that I could compare my impressions and student impressions. I then used a paired t-test to determine if the change from third quarter to fourth quarter in each area was statistically significant. The same process was used to analyze independence data. (See Appendix C for spreadsheets containing raw data and Appendix D for statistical analysis.)

I set up another spreadsheet using Excel to analyze interest data collected from students. I recorded interest numbers for each student for each data collection date and then calculated an average for each student for third quarter and for fourth quarter in three areas: interest in general science, general geology, and southeastern Minnesota geology. Again, I used a paired t-test as statistical analysis to determine if a significant change took place during fourth quarter when PBL was implemented. (See Appendix C for spreadsheets containing raw data and Appendix D for statistical analysis.)

Results

Table 1 summarizes my results on engagement as measured in five areas: discussion, group activity, leadership, listening, and on-task time. All areas measuring engagement showed an increase from third quarter to fourth quarter in the data obtained from both the students and me; however, the gains in the teacher data were greater than those reported by students. Looking at the data from the teacher perspective, statistical analysis using a paired t-test for each area showed all of the increases can be considered statistically significant with a confidence level of more than 99.5%. Though the data obtained from the students also showed increases in all areas, the level of confidence that these gains are statistically significant dropped to between 75% and 90% in all areas except listening. The level of confidence that listening levels increased from third quarter to fourth quarter is between 97.5 and 99%.

Table 1

Engagement Data						
	Teacher Perceptions			Student Perceptions		
	Average Gain	T-score	Confidence level	Average Gain	T-score	Confidence level
Discussion	0.705	8.757	>99.5%	0.091	1.026	75-90%
Group activity	0.493	5.595	>99.5%	0.073	0.740	75-90%
Leadership	0.671	5.326	>99.5%	0.197	1.186	75-90%
Listening	0.462	5.005	>99.5%	0.218	2.685	97.5-99%
On-task	0.712	10.310	>99.5%	0.102	1.006	75-90%

Table 2 summarizes my results on independence as measured on the rubric with an item called "Self-Directed Learning". Gains were observed in both student and teacher perspectives in this area. The increase in self-directed learning can be considered statistically significant with a confidence level of 97.5% to 99% when looking at the student data and with a confidence level of more than 99.5% when looking at the teacher data.

Table 2

Independence Data						
	Teacher Perceptions			Student Perceptions		
	Average Gain	T-score	Confidence level	Average Gain	T-score	Confidence level
Self-Directed Learning	0.698	6.089	>99.5%	0.211	2.740	97.5-99%

Table 3 summarizes my results on interest as measured five times during the course of the semester using interest surveys. The surveys completed by students showed gains in all interest areas measured by the survey. Statistical analysis showed that the increases in the areas of interest in science and interest in geology were significant with a confidence level of 97.5% to 99%. The increase in interest in Southeastern Minnesota geology could only be considered statistically significant to a level of 75% to 90%.

Table 3

Interest Data			
	Average Gain	T-score	Confidence level
Interest in science	0.992	2.339	97.5-99%
Interest in geology	0.942	2.680	97.5-99%
Interest in Southeastern Minnesota geology	0.692	1.286	75-90%

Graphs summarizing the information can be found in Appendix E.

CHAPTER V

CONCLUSION

The overall picture provided by the data showed that the use of PBL during fourth quarter did increase engagement, independence, and interest in my geology class, but to varying levels. While data obtained from students showed an increase in all areas, the increases observed by me as the teacher were greater than the gains perceived by the students. I believe that there may be several possible reasons for this discrepancy. First, students gave themselves higher scores than I gave them during third quarter, meaning that during fourth quarter, there was less room for improvement. Second, students often rushed through the rubrics, especially during fourth quarter, and did not take the time to thoughtfully complete each item.

Taking into account the data I collected, as well as my personal impressions of the use of PBL and conversations I had with students about PBL, I will likely continue to use projects in my geology curriculum. However, I will not use an entirely project based curriculum. As students worked through three different projects during fourth quarter, I could see that some of the topics worked well in a PBL setting, while other topics did not. I could also see that some students excelled in a PBL setting where they could work independently, while other students needed more continual guidance and were not ready to work in a total project based environment. Therefore, I will continue to use projects occasionally in my geology class, particularly when studying geologic time and in place of a final exam, but I will also implement more traditional teaching methods such as lab activities, lectures, and computer activities when appropriate.

CHAPTER VI

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Student Name ________________________________
Date _______
Teacher Evaluation ______ Student Evaluation ______

Rubric for Participation in Group and Individual Work

(Engagement, Leadership, Group Participation Skills, Self-Directed Learning)

"On Task" During Class Work Time:

1 Student does not participate; wastes time; works on unrelated material
2 Student participates but wastes time regularly and/ or is rarely on task
3 Student participates most of the time and is on task most of the time
4 Student participates fully and is always on task in class

Participation in Class Discussions:

1 Student never contributes to class by offering ideas and asking questions
2 Student rarely contributes to class by offering ideas and asking questions
3 Student proactively contributes to class by offering ideas and asking questions once per class
4 Student proactively contributes to class by offering ideas and asking questions more than once per class

Leadership:

1 Student shows no evidence of leadership
2 Student may lead on occasion or may attempt to dominate group
3 Student shows leadership on many occasions
4 Student assumes leadership role regularly and handles it well. Helps keep group on topic

Listening:

1 Student never listens to others and/ or interrupts often
2 Student listens some of the time and seldom interrupts
3 Student listens most of the time
4 Student listens to others obviously pays attention to what they have to say

Group Activity Participation:

1 Student shows no participation; impedes goal setting process and impedes group from meeting goals
2 Student shows little participation; shows no concern for goals
3 Student shows regular participation; helps direct the group in setting and meeting goals
4 Student shows regular, enthusiastic participation; helps direct the group in setting and meeting goals

Self-directed Learning:

1 Student requires help setting goals, completing tasks, and making choices; does not yet take responsibility for own actions

2 Student seldom sets achievable goals, has difficulty making choices about what to do and in what order to do them, needs help to review progress, and seldom takes responsibility for own actions

3 Student often sets achievable goals, considers risks and makes some choices about what to do and what order to do them, usually review progress, and often takes responsibility for own actions

4 Student regularly sets achievable goals, considers risks and makes choices about what to do and what order to do them, reviews progress, and takes responsibility for own actions

Rubric information collected from:
http://www.tiac.net/users/sharrard/timerubric.html
http://www.teach-nology.com/web_tools/rubrics/
http://www-ed.fnal.gov/trc/rubrics/group.html
http://www.bham.wednet.edu/online/volcano/daily.htm
http://www.theriver.com/Public/tucson_parents_edu_forum/performance.html

Geology Interest Survey

Name ____________________
Date ________

On a scale of 1-10 (1 is low, 10 is high), please indicate your interest in the overall study of science.

____

On a scale of 1-10, please indicate your interest in the overall study of geology.

____

On a scale of 1-10, please indicate your interest in the study of geology in southeastern Minnesota.

____

Raw Data - Engagement

Discussion - Teacher

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q 3 Ave.
AP	3	3	2	2	3	3	3	*	2.714
BH	3	3	3	2	3	3	3	*	2.857
DM	2	2	2	2	3	2	3	*	2.286
EB	3	2	2	2	2	2	2	*	2.143
HH	3	3	3	3	3	4	3	*	3.143
HM	1	1	1	2	1	2	1	*	1.286
JO	3	3	3	3	3	3	3	*	3.000
KV	2		2	2	2	3	2	*	2.167
SM	1	1	1	1	1	1	1	*	1.000
TC	1	1	1	1	1	1	1	*	1.000

**Note that no data was collected by the teacher on 22-Mar*

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	3	3	4	4	4	4	4	3.714
BH	3	3	4	4	3	3	4	3.429
DM	3	2.5	4	3	3	4	4	3.357
EB	3	2	3	3	2	2	3	2.571
HH	4	4	4	4	4	4	4	4.000
HM	2	2	3	2	2	1	1	1.857
JO	3	3	4	4	3	3	4	3.429
KV	3	3	4	3	3	3	3	3.143
SM	1	1	3	2	1	1	1	1.429
TC	2	1	2	2	2	2	1	1.714

Discussion - Student

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q 3 Ave
AP	1	4	3	4	4	3	3	4	3.250
BH			3	2	3	3	3	3	2.833
DM		4	3	3	3	4	3	3	3.286
EB	3	3	3	3	3		3	3	3.000
HH	4	3		3	4	3	3	4	3.429
HM	2	3	2	3	2	2	2	3	2.375
JO	4	3.5	4	4	4	4	4	4	3.938
KV	3	3	3	2	3	4	3	3	3.000
SM	2		3	4	3	3	2		2.833
TC	2	2	2	3	2	2	2	2	2.125

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q 4 Ave
AP	3	3	4	4	4	4	3	3.571
BH	3	3	4		3	3	3	3.167
DM	4	3	2	3	3	3	3	3.000
EB	3	3	3		3	3	3	3.000
HH	4	3	4	4	4	3	3	3.571
HM	2	3	3	3	3	3	3	2.857
JO	4	4	3		4	4	3	3.667
KV	3	3	4	3	2.5	4	4	3.357
SM	3	2	4	2.5	1.5	3	2.5	2.643
TC	2	2	2	2	2	2	3	2.143

Raw Data - Engagement

Group Activity Participation - Teacher

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	3	3	3	3	3	3	3	*	3.000
BH	3	3	2	3	3	3	3	*	2.857
DM	3	2	3	3	3	3	3	*	2.857
EB	2	2	2	3	3	2	2	*	2.286
HH	3	4	4	3	3	3	3	*	3.286
HM	2	3	2	3	3	3	2	*	2.571
JO	3	3	3	3	3	3	3	*	3.000
KV	2		2	3	3	3	2	*	2.500
SM	2	2	1	3	2	2	2	*	2.000
TC	2	3	1	3	3	3	3	*	2.571

**Note that no data was collected by the teacher on 22-Mar*

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	4	4	4	4	4.000
BH	3	3	3	3	3	3	3	3.000
DM	3	3	3	3	4	4	4	3.429
EB	3	2	2	2	2	3	3	2.429
HH	4	4	4	4	3	3	4	3.714
HM	3	3	3	3	3	3	3	3.000
JO	3	3	4	4	3	3	3	3.286
KV	3	3	3	3	3	3	3	3.000
SM	3	2	3	3	3	3	3	2.857
TC	3	3	3	3	3	3	4	3.143

Group Activity Participation - Student

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	3	4	3	4	4	4	3	3	3.500
BH			4	3	3	3	2.5	3	3.083
DM		3	2.5	2	3	3	3	3	2.786
EB	4	3	3	3	3		3	3	3.143
HH	4	3		3	3	4	3	3	3.286
HM	3	3	3	3	3	4	4	4	3.375
JO	3.5	3.5	4	4	4	4	3	3	3.625
KV	3	3	4	3	4	4	3	3	3.375
SM	3		2	2	3	3	3		2.667
TC	3	3	3	3	3	3	3	3	3.000

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	3	4	4	4	3.857
BH	3	3	4		3	3	3	3.167
DM	3	4	3	4	4	3	4	3.571
EB	3		3		3	3	3	3.000
HH	3	4	4	3	3	3	3	3.286
HM	3	4	4		3	3	3	3.333
JO	4	4	2	3	4	4	3	3.429
KV	4	4	4	4	3	3	3	3.571
SM	3	2.5	3	2.5	2.5	2	3	2.643
TC	3	3	3	2	3	3	2	2.714

Raw Data - Engagement

Leadership - Teacher

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	2	2	2	2	3	3	3	*	2.429
BH	3	3	2	2	2	2	2	*	2.286
DM	4	1	2	2	2	2	3	*	2.286
EB	1	1	1	2	2	2	1	*	1.429
HH	3	4	4	3	4	4	3	*	3.571
HM	2	2	1	2	1	2	2	*	1.714
JO	2	1	2	3	3	3	3	*	2.429
KV	2		1	2	2	3	2	*	2.000
SM	1	1	1	1	1	1	1	*	1.000
TC	1	1	1	2	2	2	2	*	1.571

**Note that no data was collected by the teacher on 22-Mar*

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	4	4	4	3	3.857
BH	3	3	3	3	3	3	3	3.000
DM	2	2	3	3	3	3	3	2.714
EB	2	2	2	2	2	2	3	2.143
HH	4	4	4	4	3	3	4	3.714
HM	3	2	1	1	2	2	2	1.857
JO	3	3	4	4	2	2	3	3.000
KV	3	2	2	2	3	3	3	2.571
SM	2	1	3	3	2	1	2	2.000
TC	3	3	2	2	3	2	3	2.571

Leadership - Student

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	3	3	3	4	4	4	4	4	3.625
BH			2	2	2	2	3	2	2.167
DM		3	3	2.5	3	3	3	4	3.071
EB	3	3	3	3	3		3	3	3.000
HH	3	4		2	3	3	3	2	2.857
HM	2	2	3	2	3	2	3	3	2.500
JO	3	2.5	4	3	4	4	4	4	3.563
KV	2	3	3	3	2	4	3	3	2.875
SM	3		3	2	2	2	3		2.500
TC	2	2	3	3	3	3	3	2	2.625

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	3	3	4	4	3.714
BH	3	3	3		3	3	3	3.000
DM	3	4	3	3	4	3	3	3.286
EB	2	3	3		3	3	3	2.833
HH	3	3	4	3	2	3	3	3.000
HM	3	4	2	4	4	4	4	3.571
JO	4	4	2		3	4	3.5	3.417
KV	4	4	4	3	4	3	3	3.571
SM	2	3	1.5	3	3	2	2	2.357
TC	2	2	2	2	2	2	2	2.000

Raw Data - Engagement

Listening - Teacher

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	3	4	3	3	3	3	3	*	3.143
BH	1	2	3	3	3	3	3	*	2.571
DM	4	3	3	3	3	3	3	*	3.143
EB	1	2	2	2	2	2	2	*	1.857
HH	3	3	4	3	3	3	3	*	3.143
HM	2	3	3	3	2	3	2	*	2.571
JO	1	3	3	3	3	3	3	*	2.714
KV	2		2	3	3	3	3	*	2.667
SM	2	2	2	2	2	2	2	*	2.000
TC	3	3	3	3	3	3	3	*	3.000

**Note that no data was collected by the teacher on 22-Mar*

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	4	4	3	4	3.857
BH	3	3	3	3	3	3	3	3.000
DM	3	3	3	3	3	3	4	3.143
EB	3	2	3	3	3	3	3	2.857
HH	4	4	4	4	2	3	4	3.571
HM	3	3	3	3	2	3	3	2.857
JO	3	3	3	3	3	3	4	3.143
KV	3	3	3	4	3	3	3	3.143
SM	3	2	3	3	2	3	3	2.714
TC	3	3	3	4	3	3	3	3.143

Listening - Student

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	4	4	4	4	4	4	4	4	4.000
BH			3	3	3	3	3	3	3.000
DM		2	2	2.5	2	4	3	3	2.643
EB	3	3	3	3	3		3	3	3.000
HH	3	3		3	2	2	2	3	2.571
HM	4	4	2	3	4	3	4	4	3.500
JO	3	4	3.5	4	3	4	4	4	3.688
KV	3	2	3	4	3	3	3	4	3.125
SM	3		2	3	2	3	2		2.143
TC	3	4	3	3	4	4	4	4	3.625

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	4	4	4	4	4.000
BH	3	3	4	4	3	3	3	3.286
DM	3	3	2	2	3	2	3	2.571
EB	2	3	3		3	3	3	2.833
HH	3	3	3	1.5	2	4	2	2.643
HM	4	4	4	4	4	4	4	4.000
JO	4	4	4	4	4	3	4	3.857
KV	4	4	4	4	3	3	4	3.714
SM	3	2	2.5	2	3	2.5	3	2.571
TC	4	4	4	4	4	4	4	4.000

Raw Data - Engagement

On Task - Teacher

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	2	3	3	3	3	3	3	*	2.857
BH	3	3	2	3	3	3	3	*	2.857
DM	3	3	3	3	3	3	3	*	3.000
EB	1	1	2	3	2	1	2	*	1.714
HH	3	3	3	3	3	3	3	*	3.000
HM	2	3	2	3	2	3	3	*	2.571
JO	2	2	3	3	3	2	3	*	2.571
KV	2		1	3	3	2	2	*	2.167
SM	1	3	1	3	2	1	1	*	1.714
TC	2	3	3	3	3	3	3	*	2.857

**Note that no data was collected by the teacher on 22-Mar*

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	3	4	4	4	3.857
BH	4	3	3	4	3	3	4	3.429
DM	4	3	3	4	4	3	4	3.571
EB	3	2	3	3	2	2	3	2.571
HH	4	4	3	4	3	3	4	3.571
HM	3	2	3	3	3	3	4	3.000
JO	4	3	3	3	3	3	4	3.286
KV	3	2	3	4	3	4	4	3.286
SM	3	2	3	2	2	2	3	2.429
TC	4	3	3	4	3	3	4	3.429

On Task - Student

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	2	4	3	4	4	3	3	4	3.375
BH			3	3	3	3	3	3	3.000
DM		3	3	3	3	3	3	3	3.000
EB	3	3	3	3	3		4	3	3.143
HH	3	3		3	3	3	2	3	2.857
HM	3	3	3	3	3	3	3	3	3.000
JO	3.5	3	3	3.5	4	3	4	4	3.500
KV	3	3	3	3	3	4	4	3	3.250
SM	1		1	2	3	2	3		1.714
TC	3	3	3	3	3	3	3	3	3.000

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	3	3	4	3	3.571
BH	3	3	4	3	3	3	3	3.143
DM	3	3	3	3	3	3	3	3.000
EB	3	3	3		3	3	3	3.000
HH	3	3	4	3	3	2	3	3.000
HM	2	4	4	3	3	3	4	3.286
JO	4	4	3	3	3	3	3	3.286
KV	3	3	3	3	3	3	3	3.000
SM	2	3	2	3	2	3	3	2.571
TC	3	3	3	3	3	3	3	3.000

Raw Data - Independence

Self-Directed Learning - Teacher

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	2	2	3	3	3	3	3	*	2.714
BH	3	2	1	3	2	3	2	*	2.286
DM	3	3	3	4	3	3	3	*	3.143
EB	2	1	1	3	2	2	2	*	1.857
HH	3	4	4	3	3	4	3	*	3.429
HM	2	2	2	3	2	3	2	*	2.286
JO	2	2	2	3	2	3	3	*	2.429
KV	2		1	3	2	3	2	*	2.167
SM	1	2	1	3	1	2	2	*	1.714
TC	2	2	2	3	2	3	2	*	2.286

**Note that no data was collected by the teacher on 22-Mar*

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	4	4	4	3	3.857
BH	4	3	3	4	3	3	4	3.429
DM	3	3	3	4	4	4	4	3.571
EB	3	2	2	3	2	3	3	2.571
HH	4	4	4	4	4	4	4	4.000
HM	3	3	3	3	3	3	2	2.857
JO	3	3	2	3	2	2	2	2.429
KV	3	2	3	4	3	4	4	3.286
SM	3	2	3	2	2	2	2	2.286
TC	3	3	3	3	3	3	3	3.000

Self-Directed Learning - Student

Quarter 3

Student	30-Jan	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	Q3 Ave
AP	4	4	4	4	4	4	4	4	4.000
BH				3	2	3	2	3	2.600
DM		2	3	3	2	3	3	3	2.714
EB	3		3	3	3				3.000
HH	3	3		3	3	3	3	3	3.000
HM	3	3	3	3	3	3	3	3	3.000
JO	2.5	2.5	4	4	4	4	4	4	3.625
KV	4	3	3	2	3	3	3	3	3.000
SM	2		3	2	4	2	3		2.286
TC	3	3	3	3	3	3	3	3	3.000

Quarter 4

Student	5-Apr	18-Apr	26-Apr	3-May	10-May	17-May	24-May	Q4 Ave
AP	4	4	4	4	4	4	4	4.000
BH	3	3	3	3	3	3	3	3.000
DM	3	3	3	3	3	4	3	3.143
EB			3		3	3	2	2.750
HH	4	4	4	3	4	3	3	3.571
HM	3	4	3	3	3	3	3	3.143
JO	4	4	4	4	4	4	3	3.857
KV	3	3	3	4	4	3	3	3.286
SM	2	3	3	2	2.5	3		2.583
TC	3	3	3	3	3	3	3	3.000

Raw Data - Interest

Interest in General Science

Quarter 3

Student	28-Jan	5-Mar	1-Apr	Q3 Ave
AP	5	7	8	6.667
BH	8	8	9	8.333
DM	5	7	6	6.000
EB	7	8	9	8.000
HH	9	9	8	8.667
HM	6	8	2	5.333
JO	9	10	9	9.333
KV	9	9	9	9.000
SM	2	1	4	2.333
TC	5	7	5	5.667

Quarter 4

Student	2-May	28-May	Q4 Ave
AP	9	9	9.000
BH	9	10	9.500
DM	7	6	6.500
EB	9	9	9.000
HH	10	10	10.000
HM	5	3	4.000
JO	10	10	10.000
KV	8	8.5	8.250
SM	6	5	5.500
TC	7	8	7.500

Interest in General Geology

Quarter 3

Student	28-Jan	5-Mar	1-Apr	Q3 Ave
AP	8	8	8	8.000
BH	8	7	8	7.667
DM	2	5	5	4.000
EB	7	8	9	8.000
HH	10	9	9	9.333
HM	5	3	2	3.333
JO	9	10	9	9.333
KV	8	7	7	7.333
SM	2	1	3	2.000
TC	5	6	5	5.333

Quarter 4

Student	2-May	28-May	Q4 Ave
AP	8	9	8.500
BH	8	9	8.500
DM	6	5	5.500
EB	9	9	9.000
HH	9	8	8.500
HM	5	4	4.500
JO	10	9	9.500
KV	7.5	7	7.250
SM	5	5	5.000
TC	7	8	7.500

Interest in Southeastern Minnesota Geology

Quarter 3

Student	28-Jan	5-Mar	1-Apr	Q3 Ave
AP	10	9.5	9	9.500
BH	7	5	6	6.000
DM	1	4	3	2.667
EB	8	6	5	6.333
HH	8	7	6	7.000
HM	4	5	2	3.667
JO	9	8	9	8.667
KV	7	7	7	7.000
SM	3	1	4	2.667
TC	5	6	5	5.333

Quarter 4

Student	2-May	28-May	Q4 Ave
AP	8.5	10	9.250
BH	6	7	6.500
DM	5	4	4.500
EB	9	9	9.000
HH	8	7	7.500
HM	6	5	5.500
JO	4	7	5.500
KV	7	6	6.500
SM	5	4	4.500
TC	7	7	7.000

Statistical Analysis - Engagment

Discussion - Teacher

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	2.714	3.714	1.000
BH	2.857	3.429	0.571
DM	2.286	3.357	1.071
EB	2.143	2.571	0.429
HH	3.143	4.000	0.857
HM	1.286	1.857	0.571
JO	3.000	3.429	0.429
KV	2.167	3.143	0.976
SM	1.000	1.429	0.429
TC	1.000	1.714	0.714

Average Difference Q4-Q3
0.705

Standard Deviation
0.255

T-Score
8.757

Confidence Level
Greater than 99.5%

Discussion - Student

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	3.250	3.571	0.321
BH	2.833	3.167	0.333
DM	3.286	3.000	-0.286
EB	3.000	3.000	0.000
HH	3.429	3.571	0.143
HM	2.375	2.857	0.482
JO	3.938	3.667	-0.271
KV	3.000	3.357	0.357
SM	2.833	2.643	-0.190
TC	2.125	2.143	0.018

Average Difference Q4-Q3
0.091

Standard Deviation
0.280

T-Score
1.026

Confidence Level
Between 75-90%

Statistical Analysis - Engagment

Group Activity Participation - Teacher

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	3.000	4.000	1.000
BH	2.857	3.000	0.143
DM	2.857	3.429	0.571
EB	2.286	2.429	0.143
HH	3.286	3.714	0.429
HM	2.571	3.000	0.429
JO	3.000	3.286	0.286
KV	2.500	3.000	0.500
SM	2.000	2.857	0.857
TC	2.571	3.143	0.571

Average Difference Q4-Q3
0.493

Standard Deviation
0.279

T-Score
5.595

Confidence Level
Greater than 99.5%

Group Activity Participation - Student

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	3.500	3.857	0.357
BH	3.083	3.167	0.083
DM	2.786	3.571	0.786
EB	3.143	3.000	-0.143
HH	3.286	3.286	0.000
HM	3.375	3.333	-0.042
JO	3.625	3.429	-0.196
KV	3.375	3.571	0.196
SM	2.667	2.643	-0.024
TC	3.000	2.714	-0.286

Average Difference Q4-Q3
0.073

Standard Deviation
0.313

T-Score
0.740

Confidence Level
Between 75-90%

Statistical Analysis - Engagment

Leadership - Teacher

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	2.429	3.857	1.429
BH	2.286	3.000	0.714
DM	2.286	2.714	0.429
EB	1.429	2.143	0.714
HH	3.571	3.714	0.143
HM	1.714	1.857	0.143
JO	2.429	3.000	0.571
KV	2.000	2.571	0.571
SM	1.000	2.000	1.000
TC	1.571	2.571	1.000

Average Difference Q4-Q3
0.671

Standard Deviation
0.399

T-Score
5.325

Confidence Level
Greater than 99.5%

Leadership - Student

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	3.625	3.714	0.089
BH	2.167	3.000	0.833
DM	3.071	3.286	0.214
EB	3.000	2.833	-0.167
HH	2.857	3.000	0.143
HM	2.500	3.571	1.071
JO	3.563	3.417	-0.146
KV	2.875	3.571	0.696
SM	2.500	2.357	-0.143
TC	2.625	2.000	-0.625

Average Difference Q4-Q3
0.197

Standard Deviation
0.524

T-Score
1.186

Confidence Level
Between 75-90%

Statistical Analysis - Engagment

Listening - Teacher

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	3.143	3.857	0.714
BH	2.571	3.000	0.429
DM	3.143	3.143	0.000
EB	1.857	2.857	1.000
HH	3.143	3.571	0.429
HM	2.571	2.857	0.286
JO	2.714	3.143	0.429
KV	2.667	3.143	0.476
SM	2.000	2.714	0.714
TC	3.000	3.143	0.143

Average Difference Q4-Q3
0.462

Standard Deviation
0.292

T-Score
5.005

Confidence Level
Greater than 99.5%

Listening - Student

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	4.000	4.000	0.000
BH	3.000	3.286	0.286
DM	2.643	2.571	-0.071
EB	3.000	2.833	-0.167
HH	2.571	2.643	0.071
HM	3.500	4.000	0.500
JO	3.688	3.857	0.170
KV	3.125	3.714	0.589
SM	2.143	2.571	0.429
TC	3.625	4.000	0.375

Average Difference Q4-Q3
0.218

Standard Deviation
0.257

T-Score
2.685

Confidence Level
Between 97.5-99%

Statistical Analysis - Engagement

On Task - Teacher

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	2.857	3.857	1.000
BH	2.857	3.429	0.571
DM	3.000	3.571	0.571
EB	1.714	2.571	0.857
HH	3.000	3.571	0.571
HM	2.571	3.000	0.429
JO	2.571	3.286	0.714
KV	2.167	3.286	1.119
SM	1.714	2.429	0.714
TC	2.857	3.429	0.571

Average Difference Q4-Q3
0.712

Standard Deviation
0.218

T-Score
10.310

Confidence Level
Greater than 99.5%

On Task - Student

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	3.375	3.571	0.196
BH	3.000	3.143	0.143
DM	3.000	3.000	0.000
EB	3.143	3.000	-0.143
HH	2.857	3.000	0.143
HM	3.000	3.286	0.286
JO	3.500	3.286	-0.214
KV	3.250	3.000	-0.250
SM	1.714	2.571	0.857
TC	3.000	3.000	0.000

Average Difference Q4-Q3
0.102

Standard Deviation
0.320

T-Score
1.006

Confidence Level
Between 75-90%

Statistical Analysis - Independence

Self-Directed Learning - Teacher

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	2.714	3.857	1.143
BH	2.286	3.429	1.143
DM	3.143	3.571	0.429
EB	1.857	2.571	0.714
HH	3.429	4.000	0.571
HM	2.286	2.857	0.571
JO	2.429	2.429	0.000
KV	2.167	3.286	1.119
SM	1.714	2.286	0.571
TC	2.286	3.000	0.714

Average Difference Q4-Q3
0.698

Standard Deviation
0.362

T-Score
6.089

Confidence Level
Greater than 99.5%

Self-Directed Learning - Student

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	4.000	4.000	0.000
BH	2.600	3.000	0.400
DM	2.714	3.143	0.429
EB	3.000	2.750	-0.250
HH	3.000	3.571	0.571
HM	3.000	3.143	0.143
JO	3.625	3.857	0.232
KV	3.000	3.286	0.286
SM	2.286	2.583	0.298
TC	3.000	3.000	0.000

Average Difference Q4-Q3
0.211

Standard Deviation
0.243

T-Score
2.740

Confidence Level
Between 97.5-99%

Statistical Analysis - Interest

Interest in General Science

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	6.667	9.000	2.333
BH	8.333	9.500	1.167
DM	6.000	6.500	0.500
EB	8.000	9.000	1.000
HH	8.667	10.000	1.333
HM	5.333	4.000	-1.333
JO	9.333	10.000	0.667
KV	9.000	8.250	-0.750
SM	2.333	5.500	3.167
TC	5.667	7.500	1.833

Average Difference Q4-Q3
0.992

Standard Deviation
1.341

T-Score
2.339

Confidence Level
Between 97.5-99%

Interest in General Geology

Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	8.000	8.500	0.500
BH	7.667	8.500	0.833
DM	4.000	5.500	1.500
EB	8.000	9.000	1.000
HH	9.333	8.500	-0.833
HM	3.333	4.500	1.167
JO	9.333	9.500	0.167
KV	7.333	7.250	-0.083
SM	2.000	5.000	3.000
TC	5.333	7.500	2.167

Average Difference Q4-Q3
0.942

Standard Deviation
1.111

T-Score
2.680

Confidence Level
Between 97.5-99%

Interest in Southeastern Minnesota Geology

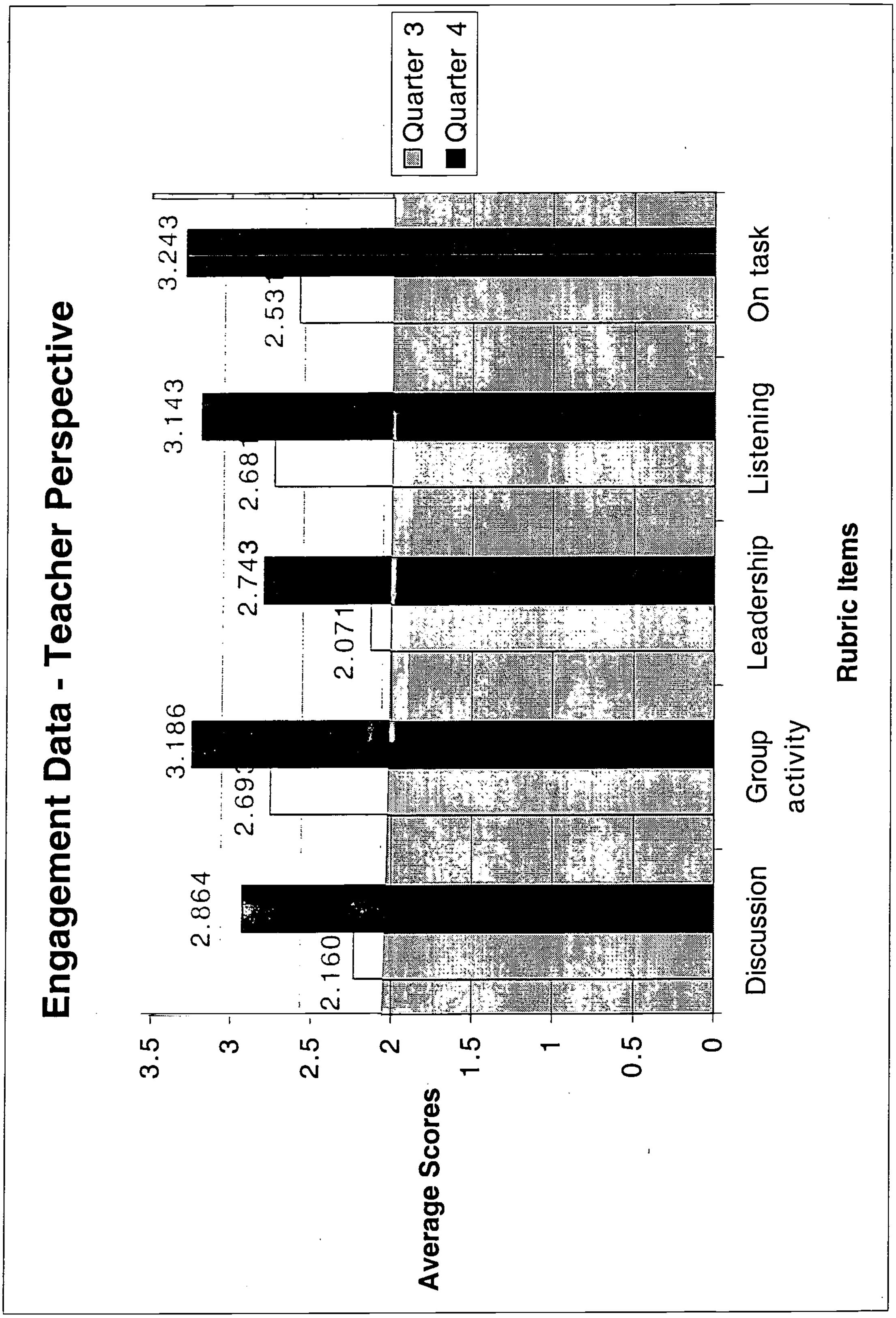
Student	Q3 Ave	Q4 Ave	Q4 - Q3
AP	9.500	9.250	-0.250
BH	6.000	6.500	0.500
DM	2.667	4.500	1.833
EB	6.333	9.000	2.667
HH	7.000	7.500	0.500
HM	3.667	5.500	1.833
JO	8.667	5.500	-3.167
KV	7.000	6.500	-0.500
SM	2.667	4.500	1.833
TC	5.333	7.000	1.667

Average Difference Q4-Q3
0.692

Standard Deviation
1.701

T-Score
1.286

Confidence Level
Between 75-90%


Engagement Data - Teacher Perspective
Quarter 3
Quarter 4
Average Scores
3.5
3
2.5
2
1.5
1
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0
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2.864
2.69
3.186
2.071
2.743
2.68
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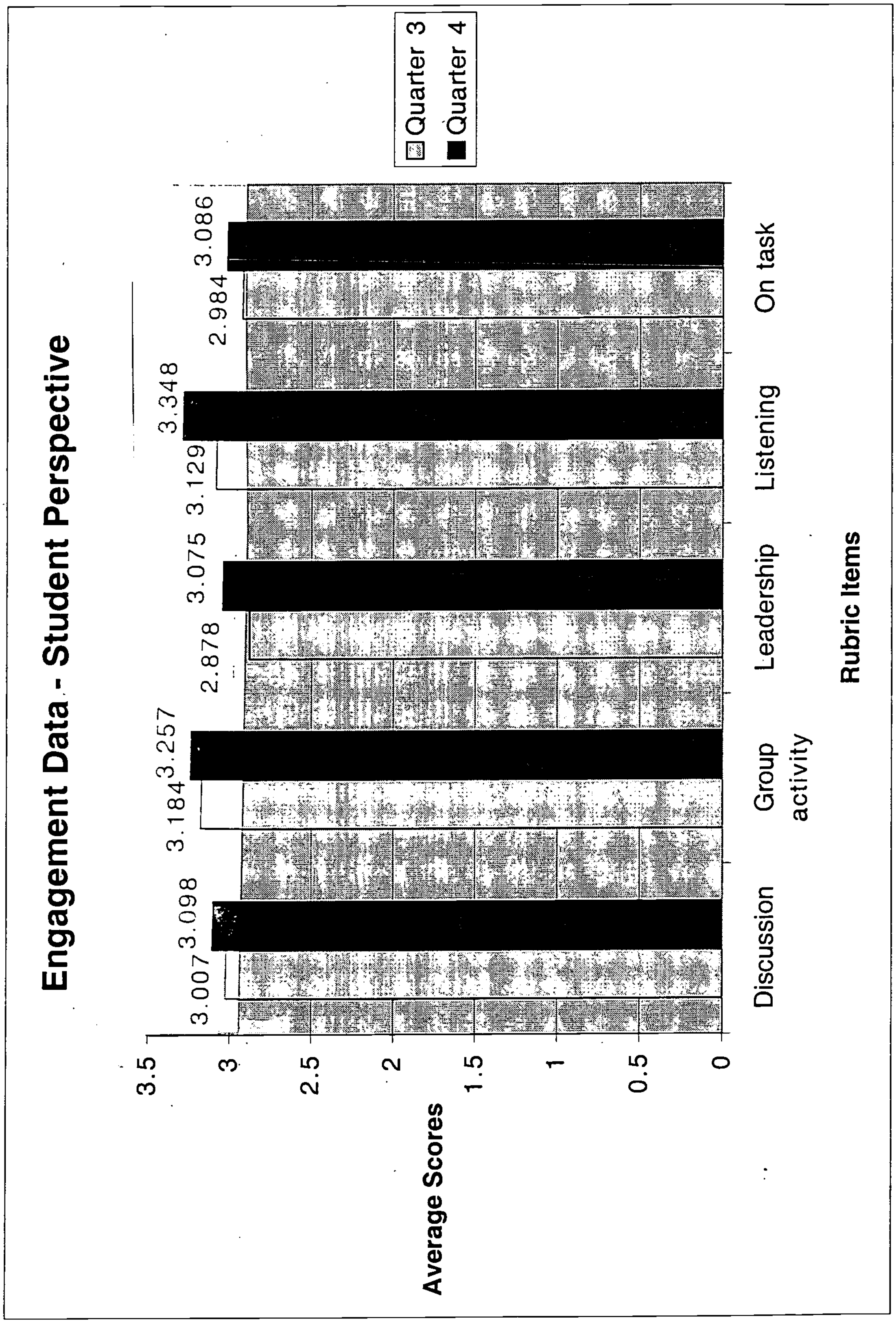
2.53
3.243
Discussion
Group activity
Leadership
Listening
On task
Rubric Items



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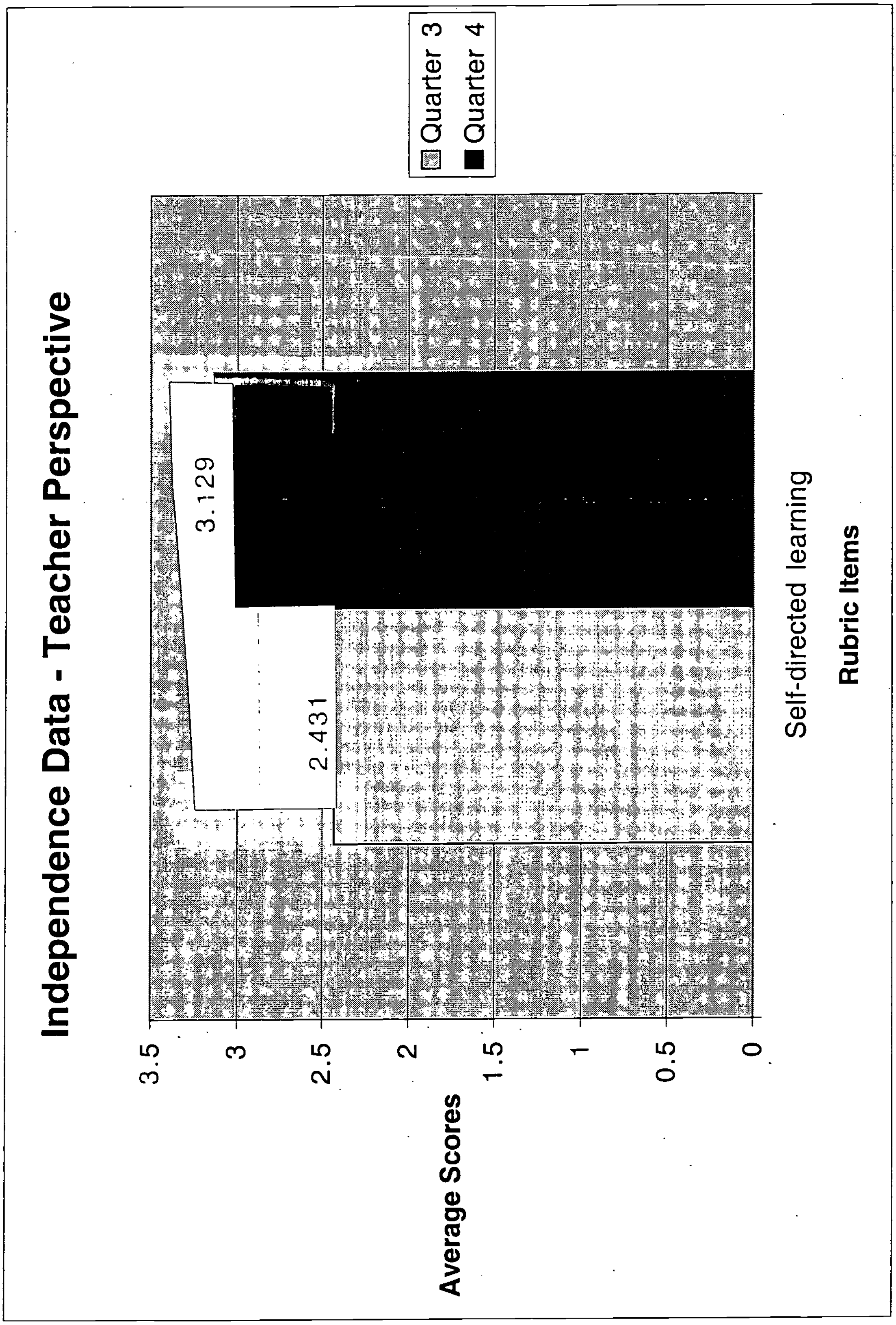
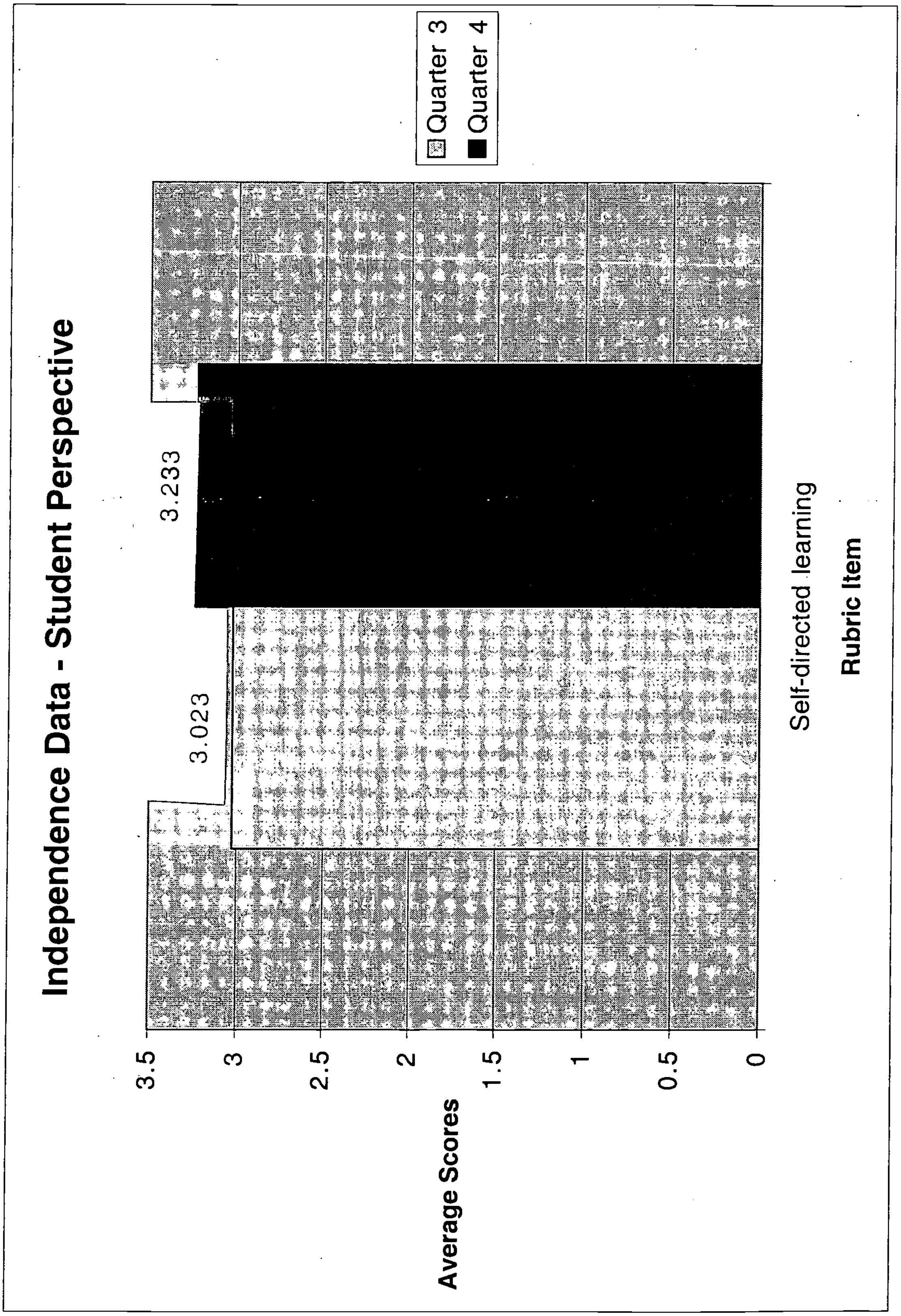

Independence Data - Teacher Perspective
Quarter 3
Quarter 4
3.129
2.431
3.5
3
2.5
2
1.5
1
0.5
0
Average Scores
Self-directed learning
Rubric Items


Independence Data - Student Perspective
Quarter 3
Quarter 4
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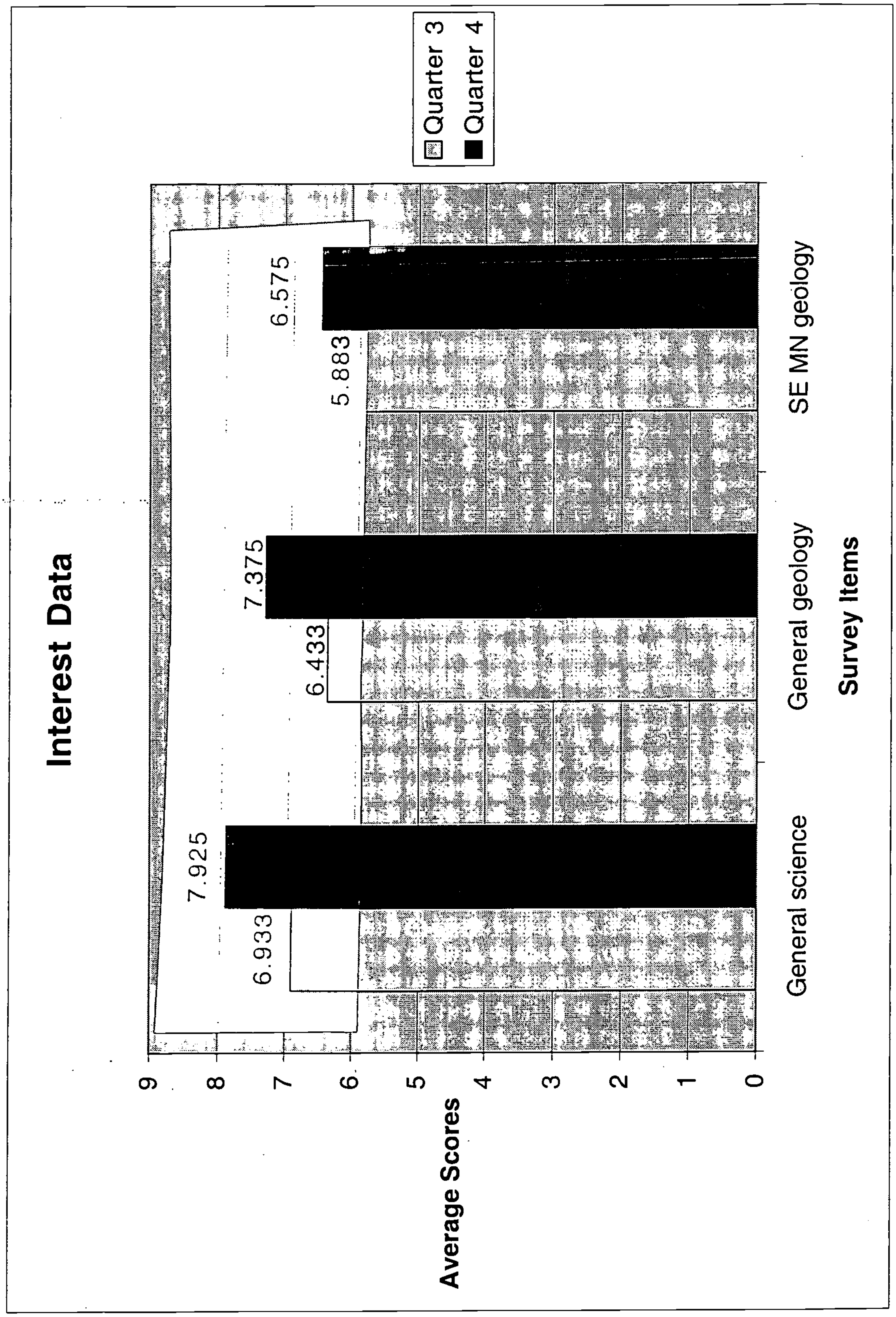
3.023
3.5
3
2.5
2
1.5
1
0.5
0
Average Scores
Self-directed learning
Rubric Item


Interest Data
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9
8
7
6
5
4
3
2
1
0
6.933
7.925
6.433
7.375
5.883
6.575
General science
General geology
SE MN geology
Survey Items

WILL THE USE OF A LAB SAFETY PROGRAM CREATE A SAFER LEARNING ENVIRONMENT FOR STUDENTS IN BIOLOGY CLASS?

by

Laura Espeset

B.S., University of Wisconsin - Madison 1997

A thesis submitted to the

Graduate School of Winona State University

In partial fulfillment of the requirement for the degree of

Master of Science

Department of Education

2002

This thesis entitled:
Will the use of a lab safety program
create a safer learning environment in a Biology Class?

written by Laura Espeset

Has been approved for the Department of Education

Dr. Thomas Sherman

Date 12/12/02

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline

HRC protocol # ____________________

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Will the use of a lab safety program create a safer learning environment in a Biology class?

Thesis directed by Dr. Thomas Sherman

Research shows that the incidence of science classroom lab accidents and related lawsuits is on the rise. This increase could be due to the new science standards which demand more hands-on labs or could be resulting from several other factors: poor teacher preparation, overcrowded classrooms, lack of proper equipment, and/or poorly trained students.

Currently, the method of covering lab safety used by my colleagues in the school district and myself is to give the students a list of safety rules and procedures, read over it with the students, demonstrate the procedures, have the students sign it, and file away the lists with the signatures. There is no standard that teachers use from class to class other than what they have in their list of rules, their mind, and their lesson plan. Additionally, there is no consistent standard shared by teachers, so students hear several different lab safety protocols throughout their science class experiences.

In order to provide my students with a consistent and thorough lab safety program, I developed a biology lab safety tutorial for my biology students. The biology class computer tutorial included an in depth presentation of lab safety guidelines and procedures. Students were taught lab safety in two ways: either the students were given the traditional list of rules, the speech and the demonstrations, or

the students were given a power point presentation on the computer. The students were given identical safety contracts and worksheets which were kept on file in the event of a laboratory incident. Worksheet scores were compared and questionnaire data was analyzed.

In general, there was little difference between safety test scores and survey results between the classes. Possible reasons for this could be the moderator variables as to how I presented the information to the classes without the tutorial, or the lack of difference could be due to the fact that students already have a considerable amount of background in lab safety. Although scores were very similar and little relation is shown between how safe the laboratory environment has become with the additional tutorial, the tutorial provides an extra safeguard for teachers and students. It ensures that all the students receive the same instruction in lab safety and that all safety rules and procedures are covered by the students.

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CHAPTER I

INTRODUCTION

Need for study

Research shows that the incidence of science classroom lab accidents and related lawsuits is on the rise. Several factors including new national and state science standards (which require science classes to include more hands-on, inquiry-based labs) could be causing this increase. Other possible causes of classroom accidents include: poor teacher preparation, overcrowded classrooms, lack of proper equipment and poorly trained students. To better ensure student safety and teacher accountability, a system of school safety regulation at classroom, district, state and national levels should be considered.

According to research done in Iowa, there were 674 accidents in the three school years from 1990 to 1993. In the following three school years, 1993 to 1996 there were more than 1000 accidents. The number of lawsuits also increased during that time period (Gerlovich et. al 1998). A possible cause of the increase in accidents could be the implementation of new science standards. According to the new federal and state science standards, hands-on, inquiry-based labs are highly recommended and required. Although these new labs have been found to be educationally beneficial, they increase student exposure to potentially dangerous situations.

In addition to new standards, another possible cause for the increase in laboratory accidents could be poor teacher preparation. According to Gerlovich's studies in eighteen states, an average of 55 to 65 percent of teachers have never been trained in safety. Other research conducted by Gerlovich et al. shows that in 1995 and

1997, science educators in Wisconsin did not have command of essential safety information. Teachers needed more instruction in laws, codes and standards. At the annual Wisconsin Society of Science Teachers (WSST) convention 1999, results also showed that teachers were lacking in knowledge concerning the responsibilities listed in federal and state laws, codes, and standards. Since these findings, Wisconsin has developed a three-phase program of training for new teachers which includes assessment, in-service training, and a chemical cleanup sweep. Since the implementation of the new safety initiative in Wisconsin, the Wisconsin DPI now feels that teachers are safety conscious enough to begin the statewide sweep of unwanted chemicals. Although it is a different state, Minnesota also seems to be lacking in safety preparation. Speaking from personal experience, I have never taken a class on laboratory safety and I received no formal training before I started teaching.

Over the past several years, budgets have been cut in districts. These cuts could indirectly affect the safety of classrooms. The laboratory class size recommended by the State of Minnesota, the National Science Teachers Association (NSTA), and the Council of State Science Supervisors (CSSS) is twenty-four students per class. Contractually, science teachers in the Rochester public school district are permitted to have up to 160 students in no more than five classes. This results in class sizes which may contain an average of thirty-two students per class. According to state and national recommendations, a laboratory class containing more than the recommended number of twenty-four students is overcrowded and could present a safety hazard to the students and teachers inside the room. When dealing with overcrowded class sizes, science teachers face several options: a) risk being negligent of state safety recommendations, b) to remove extra students from lab situations, c) adapt curriculum to leave out the more risky, hands-on, inquiry-based lab activities highly recommended by science standards.

Budgets cuts could also affect the amount of money available to spend on laboratory equipment and supplies. The CSSS recommends that science classrooms are equipped with the following items: safety posters, broken glass containers, goose necked faucets, eyewash stations, fume hoods, safety goggles, UV cabinets or alcohol swabs for goggles, wool fire blankets, nonabsorbent, chemical-resistant aprons, lockable storage containers, special lab surfaces, ground fault circuit interrupters, etc. These items are expensive and may break or wear out. Laboratory standards change. Teachers and administrators must stay current on safety recommendations. The 1999 research in Wisconsin done by Gerlovich et al. shows that at least 71% of all school science labs did not meet all NSTA equipment recommendations. It also shows that only 17% of Wisconsin lab-lecture rooms were large enough to accommodate twenty-four students.

Finally, the last possible reason for the occurrence of laboratory accidents is the lack of adequate student safety training. Perhaps students have not been adequately instructed in lab safety and procedures. If teachers are lacking in knowledge, then it is possible that students may not be knowledgeable in important lab safety protocol.

Problem

National and state standards require more hands-on, inquiry-based labs. As students experiment more with potentially dangerous chemicals and laboratory equipment, the risk of injury increases. The problem addressed by the research done in this paper is, "What can be done to make a Biology science laboratory more safe?"

Question

In order to create a safer laboratory environment for students, I decided to create and implement the use of a lab safety program. The question researched was, "Will the use of a lab safety program create a safer learning environment in a Biology Class?"

Definition of Terms

The lab safety program refers to the power point presentation given to students in class. The presentation is viewed with a worksheet which follows the order of the presentation. Students are allowed to work on the sheet while observing the presentation.

Variables

There were several variables that may have influenced the results obtained in my research. One variable is that the effectiveness of a computer tutorial was measured against my own presentation and demonstration. My enthusiasm and behavior could have affected the recall of students working on the worksheet. Some students vary in English language abilities, which could also affect comprehension and resulting scores. The majority of my students have been in science classes before and have already received science lab safety instruction. The different experiences in science labs also affects their knowledge base and comfort with lab safety protocol. Because of these variables, my research focused primarily on the results from the surveys given to both classes.

Limitations of Study

The study took place during the fall semester of 2002. Students from two different biology classes were given the different forms of instruction and were surveyed after each lesson.

CHAPTER II

LITERATURE REVIEW

The National Science Education Standards state that teachers of science should "plan an inquiry-based science program for their students" and that "Emphasizing active science learning means shifting emphasis away from teachers presenting information and covering science topics." Additionally the National Standards state that "Learning science is something that students do, not something that is done to them." This belief is supported by most science teachers, and now science teachers are developing lessons that incorporate more important inquiry-based activities. The National Science Education Standards envision a changing emphasis from "Presenting scientific knowledge through lecture, text, and demonstration" to "Guiding students in active and extended scientific inquiry" (National Science Education Standards, 1995). According to studies, there has been an increase in science classroom laboratory accidents since the development of the new National Science Education Standards. An Iowa study shows that the number of incidents increased from 674 accidents in the three school years from 1990 to 1993, to more than 1000 accidents the following three school years, 1993 to 1996. The number of lawsuits also increased during that time period (Gerlovich et al, 1998). Experts like Janet Gerking agree that "While safety guidelines are established from the beginning in any science class, the responsibility given to students in an inquiry-based lesson is more complex" (Gerking, 2002).

In addition to new standards, another possible cause for the increase in laboratory accidents could be poor teacher preparation. According to Gerlovich's studies in eighteen states, an average of 55 to 65 percent of teachers have never been trained in safety. Research conducted shows that in 1995 and 1997 science educators in Wisconsin did not have command of essential safety information. Teachers needed more instruction in laws, codes and standards. At the annual Wisconsin Society of Science Teachers (WSST) convention 1999, results also showed that teachers were lacking in knowledge concerning the responsibilities listed in federal and state laws, codes, and standards. Since these findings, Wisconsin has developed a three-phase program for training new teachers which includes assessment, in-service training, and a chemical cleanup sweep. Since the implementation of the new safety initiative in Wisconsin, the Wisconsin DPI now feels that teachers are safety conscious enough to begin the statewide sweep of unwanted chemicals (Gerlovich et al, 2001).

Another possible cause for the increase in laboratory accidents may be ill-equipped laboratories. Basic laboratory equipment includes: safety posters, broken glass containers, goose necked faucets, eyewash stations, fume hoods, safety goggles, UV cabinets or alcohol swabs for goggles, wool fire blankets, nonabsorbent, chemical-resistant aprons, lockable storage containers, special lab surfaces, ground fault circuit interrupters, etc. (CSSS, 2002). In addition to expensive equipment, the National Science Teachers Association (NSTA) states that "science classes should be limited to twenty-four students in elementary, middle level, and high school science labs unless a team of teachers is available"(NSTA, 1996).

In order to create a thorough lab presentation and contract, I incorporated several resources. The Lab Safety Rules and Procedures/Safety Contract (appendix A) is based on Biology Rules used by Cheryl Moertel at Century High School.

Adaptations to the contract such as the inclusion of the statement "I understand that a science lab setting can potentially be dangerous and I understand that if I do not follow the safety rules, I could injure myself or someone else" were taken from the Flinn book, Science Classroom Safety and the Law - a Handbook for Teachers (2001). The Flinn book recommends sending home a note or contract to parents that requires a signature. The parent signature acknowledges that they are aware of dangers and consent to their child's participation in a science lab. Although not legally binding, it could be used to protect a teacher in cases of student injury or when a student is facing disciplinary action for breaking laboratory rules.

The power point tutorial (appendix B) covers the rules and procedures with in-depth information such as using the PASS technique when handling a fire extinguisher and safety equipment instruction. Sources for this information included Science and Safety, Making the Connection (CSSS 2002) and my school district's Chemical Hygiene Plan (2002). The idea to incorporate a worksheet/quiz sheet (appendix C) originated from two articles in The Science Teacher. ("Idea Bank," 2002 and Hensley, 2002) This combination of resources helped me to create the researched lab safety program.

CHAPTER III

DATA COLLECTION PROCESS

Participants and Procedures

Participants in the study were tenth grade Biology students at Century High School. The classes are comprised mainly of Euro-American students who have upper/middle class backgrounds, there are few minority students in my classes. The classes are each 51 minutes long the tutorial class contained 28 students and the traditional method class contained 27 students.

Students in each of the two different Biology classes were given a different form of lab safety instruction, the traditional method or the new tutorial.

The first class surveyed, or the control group, was given the traditional lab safety orientation. Each student was given the Biology Lab Safety Rules and Procedures/Safety Contract (appendix A). I read the through the contract with the class, demonstrated procedures, pointed out the locations of the safety equipment, and answered questions. Students were given the Biology Lab Safety Protocol Worksheet (appendix C) to complete in class. When all the worksheets were turned in, the students were asked to fill out the Lab Safety Questionnaire (appendix D).

The second class surveyed was given the Biology Lab Safety Computer Tutorial (appendix B). The tutorial is a 24 slide power point presentation with graphics and detailed information about safety procedures and rules. I projected this in the front of the room, read through the presentation aloud, and pointed out the locations of the safety equipment. The equipment is located in different locations in different science rooms, therefore equipment location was left out. This enables the presentation to be used in different rooms. Students completed the Biology Lab Safety Protocol Worksheet and then filled out the Lab Safety Questionnaire.

Data Collection Tools

Data from each class was collected from identical forms. The first form of data collection used was the Biology Lab Safety Tutorial Worksheet which was comprised of fifteen true/false questions. The second form of data collection was a nine question survey addressing issues such as background knowledge, confidence in lab safety, and thoughts about the lab safety instruction they received. This data was then compiled and analyzed.

CHAPTER IV

ANALYSIS OF DATA

Process

Data was collected in two forms, the Biology Lab Safety worksheet and the Lab Safety questionnaire. Biology Lab Safety worksheet scores were collected once they were completed by the students. The results from the lab safety questionnaire were collected at the end of the hour. The majority of the data used in this research was taken from the lab safety questionnaire. (Table 1)

The data was analyzed to determine if students who took the tutorial received higher scores on the worksheet, to gauge student comfort with science lab safety, and to collect student feedback on the lab safety tutorial program.

During the analysis of the worksheet scores, several variables needed to be considered. The first variable was my delivery of both types of lab safety instruction. Did I stress key facts more than I normally would, did I act differently when presenting data, and did I steer the discussion in the different classes? Another variable is that students asked different questions in each of the different classes.

The analysis of the questionnaires was more straightforward. Students completed surveys by selecting a number that best represented their feelings about laboratory safety. Questions ranged from how safe students felt in Biology class to how whether or not they had learned about lab safety in the past.

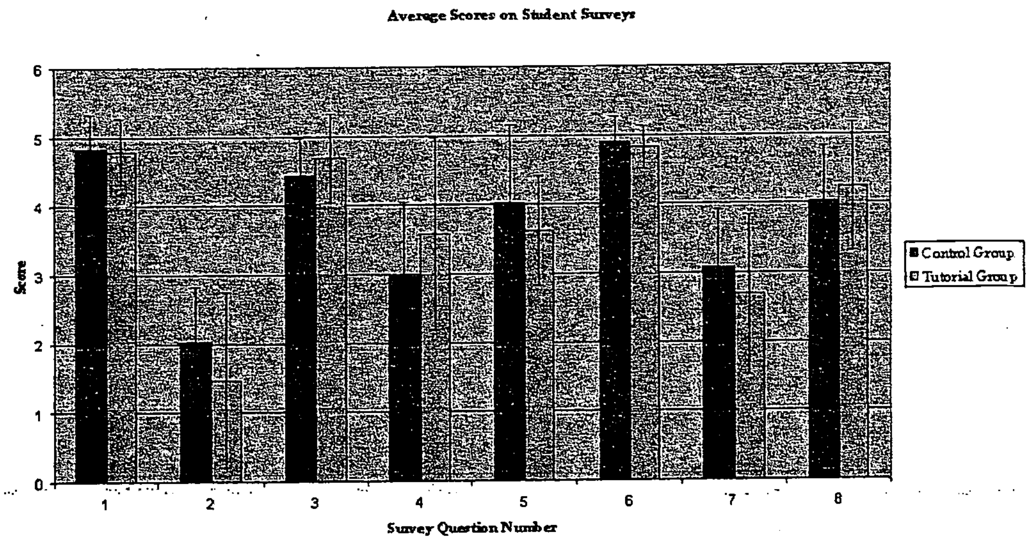
Results

Worksheet scores were close. Out of fifteen questions, the average score in the control group was 13.897 with a standard deviation of 1.144. The average score received by the tutorial group was 13.679 with a standard deviation of 1.156. More students would need to be tested to ensure accuracy. However, data shows that students who were given the traditional lesson scored slightly higher. This difference could have been due to the fact that I knew which policies and protocols they would be tested on, or it could be due to students' preexisting knowledge about laboratory safety. Another reason they could have done better on the worksheet completed with the traditional instruction is because they might have found my traditional lesson more engaging than the computer tutorial. Whatever the case may be, the data is too close to significantly determine which system is best for information recall.

The purpose of including comfort level questions was to establish whether or not the students felt a need for a more thorough and structured lab safety program. Questions numbered one, three, six, seven, and eight were included to measure how comfortable students felt in the classroom (Table 1). In response to statement one, "I understand biology laboratory safety," the averages between both classes were at 4.79 for the traditional group and 4.82 for the tutorial group. This fell in between a score of four which is "agree" and five, which is "strongly agree".

TABLE 1

AVERAGE SCORES ON STUDENT SURVEYS (GRAPH)



By tenth grade, students should have had several lab safety lessons. Questions two and seven were used to gauge their backgrounds in science lab safety. Question number two stated, "I have been in a science class in which I did not learn laboratory safety." Results were not surprising. Class averages ranged from 1.49 in the control group and 2.04 in the tutorial group. Ideally the score would have been a one (strongly disagree) in both cases. Question number seven stated, "Lab safety needs to be addressed more in science class." The control group of students averaged a score of 2.69, which is a slight disagree. The tutorial group averaged a 3.07, neutral. I expected scores in this range. Although they might already know most of the data and feel that the instruction is redundant, I would also hope that they saw the importance of lab safety instruction.

TABLE 2

AVERAGE SCORES ON STUDENT SURVEYS (CHART)

Tutorial Instruction

Question	Average	Standard Dev.
1	4.821429	0.475595
2	2.035714	1.261455
3	4.428571	0.634126
4	2.964286	1.400586
5	4.035714	0.792658
6	4.892857	0.31497
7	3.071429	1.152407
8	4.035714	0.922241
Worksheet	13.67857	1.156418

Traditional Instruction (control)

Question	Average	Standard Dev.
1	4.785714	0.498675
2	1.482759	0.784706
3	4.689655	0.54139
4	3.586207	1.086187
5	3.62069	1.115277
6	4.827586	0.384426
7	2.689655	0.849514
8	4.241379	0.786274
Worksheet	13.89655	1.144703

Student responses to statement number three “I would know what to do if there was a laboratory accident,” fell between the “agree and “strongly agree” range. The traditional group received an average score of 4.69 and the tutorial group averaged a score of 4.42. Students would be expected to find an adult if an emergency occurred, perhaps students were uncertain if this question was regarding specific first-aid procedures or if they should contact the person in charge.

Number six, "I understand that if I do not follow lab protocol, I could injure myself or someone else," was inspired by recent court cases. Students and parents need to be aware that violations of safety rules could lead to injury or removal from class. This question received the highest averages. The control group averaged a 4.83 and the tutorial group averaged a 4.89. Most students strongly agreed that they were aware of the consequences of not following the safety rules.

Question eight was slightly open to interpretation. The statement provided was "I feel safe that there will be no accidents in biology class." If I were to survey students again, I would change the question to "I feel certain that I will not be injured in biology lab." To some students, an accident could be someone tripping over a desk. Sometimes accidents happen, hopefully they would feel that injuries are more controllable. Students in the control group averaged a score of 4.24 (agree). Students in the tutorial group averaged at 4.04 (agree).

Questions four and five were the questions that I depended on to determine the instructional values of the traditional method versus the tutorial method. Number four stated "I learned a lot in the lab safety orientation." The class averages were 3.59 in the control group and 2.96 in the lab tutorial group. This indicates that students with the traditional form of instruction felt they learned more. However, I wanted to account for prior knowledge, so number five "I already knew everything in the safety orientation" addressed that issue. Students in the control tutorial responded with an average of 3.62. Students in the tutorial group felt more confident of their prior knowledge with an average in the agree range. The tutorial group averaged a 4.04. These scores were based strictly upon opinion. To be more accurate, next time I would administer a lab knowledge pretest before the tutorial and a posttest after the tutorial.

Overall, data for both groups was very similar. Scores indicated that students instructed with the traditional method may have been more comfortable in a lab safety situation, but were they safer?

CHAPTER V

CONCLUSION

The goal of this study was to determine whether or not a laboratory safety tutorial created a safer environment for biology students. The number of classroom accidents could not be compared because there were no accidents in either class, therefore data was collected from student worksheets and student surveys. Data showed that students were slightly more comfortable with the lab safety instruction they received via the traditional method versus the lab safety tutorial.

The lab safety tutorial, although thorough and consistent, did not seem to be as well-received as the traditional method. The traditional method is more open to gaps in instruction due to forgetfulness and ignorance, but perhaps it is more engaging to students.

As a moderator, I had fun discussing lab safety with the class, role-playing emergency situations, and answering questions. I felt more connected with the students in the traditional instruction group than I did with the students in the power point group. Perhaps this has to do with the context of the class than with the type of presentation. Maybe this means that I am a competent teacher and that I am well-informed of safety protocol.

Whatever the case may be, laboratory safety is crucial. Administrators, legislature, and teachers should work together to ensure that all students receive adequate safety instruction. Teachers should find a way to engage students in the safety instruction process with techniques such as role-playing, group discussion, etc. Additionally, I believe that a combination of a tutorial, contract, and quiz should be implemented in all districts. Although it might seem excessive at first, each of these pieces would serve an important purpose. The tutorial would ensure that students have received instruction in all areas of laboratory safety. The contract requiring parent and student signatures ensures the understanding of possible hazards and consent to participate in lab activities. Finally, the quiz would demonstrate student comprehension of laboratory safety. Together, the teacher's instruction, the tutorial, the contract and the quiz, reduce the possibility of teacher negligence and increase student safety.

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APPENDIX

APPENDIX A

BIOLOGY LAB SAFETY RULES AND PROCEDURES/SAFETY CONTRACT

Biology Lab Safety Rules and Procedures /Safety Contract

The following rules are for the safety of the student as well as for the protection of others. The student should become familiar with these rules, understand their meaning, and put them into practice. A copy of the rules will be posted in the laboratory and signed copies will be kept on file.

1. Report any accident to the person in charge immediately, no matter how minor
2. Know where to find and how to use first aid, safety and fire fighting equipment.
3. Observe all signs, labels, and directions, especially those that recommend caution. Never begin an investigation until you have read and have a complete understanding of the procedure.
4. Take special care in handling or using any equipment to prevent damage or breakage.
5. Do not handle any laboratory equipment, materials, plants, or animals without permission.
6. Safety glasses, goggles or shields must be worn during any activity involving heat, chemicals, or other materials potentially injurious to the eye.
7. Be careful of loose clothing and tie back long hair when working around any flame or burner. Turn off when not in use.
8. When inserting glass rods or tubing in rubber stoppers, lubricate with glycerol and use a gentle twisting motion. Follow the same technique when removing the tubing. (Remove all glass tubing from stoppers immediately after use.)
9. Throw all solids and paper to be discarded into a waste jar, basket or proper container.
10. Lab work areas and equipment should be cleaned and wiped dry at the end of each lab activity.
11. No foods or beverages are permitted in any science laboratory.
12. Students are not permitted in lab storage rooms or work rooms unless permission is given.
13. On field trips, students will always work with one or more partners, never alone.
14. Always follow live animal policies and regulations when handling or attending to an animal habitat.
15. Failure to abide by the rules and procedures above could result in the removal from the lab and could affect grades earned in biology labs.

I have read, understand and agree to abide by the safety regulations and procedures above. I understand that a science lab setting can potentially be dangerous and understand that if I do not follow the safety rules, I could injure myself or someone else.

____________________ ____________________

Student Signature Parent Signature

APPENDIX B

LAB SAFETY TUTORIAL ADMINISTERED TO STUDENTS

Biology Lab Safety Tutorial

Ms. Espeset

Directions: Read through each safety rule and procedure. Use the tutorial to answer the questions on your worksheet.

1. Report any accident to the person in charge immediately, no matter how minor.

- This includes small cuts or injury, any broken lab equipment, and/or any spills.
- Do NOT attempt clean-up without telling the teacher first!

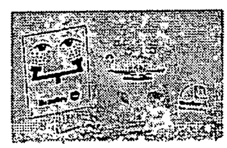
2. Know where to find and how to use first aid, safety and fire fighting equipment.

- First aid: Inform the teacher of any injury immediately. Follow emergency information by the phone.

2. Know where to find and how to use first aid, safety and fire fighting equipment.

Chemical in Eye:

- Proceed to <u>Eye Wash</u>
- Hold eyelids apart as wide as possible and flush eye for at least 15 minutes or until emergency personnel arrive.
- Do not try to remove chemically adhered contact lenses.



2. Know where to find and how to use first aid, safety and fire fighting equipment.

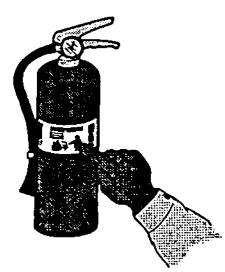
If you catch on fire:

- Douse area with water from <u>Sink</u> or <u>Safety Shower</u> depending on area ignited.
- If you are too far from the shower: Stop, drop and roll, smother flames with a <u>Fire Blanket.</u>

2. Know where to find and how to use first aid, safety and fire fighting equipment.

Fire Extinguisher (PASS)

- P: Pull the pin
- A: Aim low
- S: Squeeze the handle
- S: Sweep from side to side.



2. Know where to find and how to use first aid, safety and fire fighting equipment.

- In all cases of emergency:

Notify the teacher immediately!!!!!!

3. Observe all signs, labels, and directions, especially those that recommend caution. Never begin an investigation until you have read and have a complete understanding of the proedure.

- Follow directions carefully. This means all written lab instructions or those given verbally by the teacher.
- Unauthorized experiments are prohibited.

4. Take special care in handling or using any equipment to prevent damage or breakage.

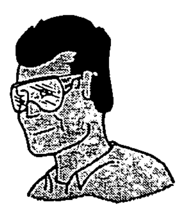
- Most damage in the classroom occurs because of misuse and carelessness.
- Notify the teacher immediately if any damage or breakage occurs.
- Do not use equipment if it is broken or cracked.
- Dispose of broken glassware in the appropriate container, NOT the garbage!

5. Do not handle any laboratory equipment, materials, plants, or animals without permission.

- Mishandling of the above could result in injury or damage to it or to yourself.

6. Safety glasses, goggles or shields must be worn during any activity involving heat, chemicals, or other materials potentially injurious to the eye.

- Failure to wear safety glasses may result may result in your removal in lab without the opportunity to make it up.



6. Be careful of loose clothing and tie back long hair when working around any flame or burner. Turn off when not inuse.

- Avoid wearing loose-fitting clothing on lab days.
- Hair that is longer than shoulder length should be tied-back when working with flame

8. When inserting glass rods or tubing in rubber stoppers, lubricate with glycerol and use a gentle twisting motion. Follow the same technique when removing the tubing. (Remove all glass tubing from stoppers immediately after use)

- Failure to use proper technique could result in broken equipment or serious injury.

9. Throw all solids and paper to be discarded into a waste jar, basket or proper container.

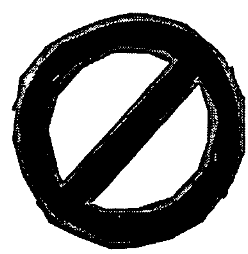
- Solids do NOT go down the sink!!

10. Lab work areas and equipment should be cleaned and wiped dry at the end of each lab activity.

- Keeping the laboratory clean and safe is the responsibility of the students entering the lab, students leaving the lab and the teacher.

10. No foods or beverages are permitted in any science laboratory.

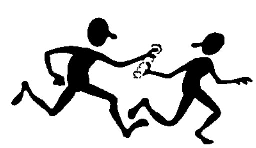
- That includes:
- Water bottles
- Candy
- Snacks
- We will be working with bacteria and other hazardous materials, which could cause illness when ingested.



12. Students are not permitted in lab storage rooms or work rooms unless permission is given.

- That also includes teacher areas such as drawers and cupboards.

13. On field trips, students will always work with one or more partners, never alone.



- This includes lab investigation conducted on the school campus.
- Always choose a "buddy" and keep an eye on each other.

14. Always follow live animal policies and regulations when handling or attending to an animal habitat.

- Always get permission before handling any animal.

14. Always follow live animal policies and regulations when handling or attending to an animal habitat.

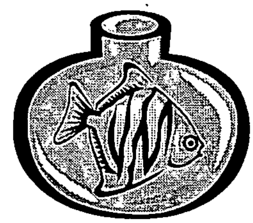
- Wash your hands with antibiotic soap after touching any animal.

14. Always follow live animal policies and regulations when handling or attending to an animal habitat.

- Do not feed the animals unless specifically instructed to do so.

14. Always follow live animal policies and regulations when handling or attending to an animal habitat.

- Never tease, harass or in any way harm any animal or animal habitat (cage).



14. Always follow live animal policies and regulations when handling or attending to an animal habitat.

- If you are bitten or scratched, report the incident to the teacher immediately.

15. Failure to abide by the rules and procedures above could result in the removal from the lab and could affect grades earned in biology labs.

- If you ever have any questions about lab protocol, see the teacher.
- Have fun in biology!!

APPENDIX C

BIOLOGY LAB SAFETY PROTOCOL WORKSHEET

Biology Lab Safety Tutorial
Worksheet

Name____________________
Period_____

Directions: Read through each safety rule and procedure on the tutorial. Use the Tutorial to answer the questions on your worksheet.
Circle the correct answer. Change the words to correct false statements.

1. T or F - It is necessary to inform the teacher of all lab injuries even if there is no blood.

2. T or F - The teacher would be happy if you helped to clean up a broken test tube.

3. T or F - It is necessary to keep your eye in the eye wash for at least 10 minutes or until emergency personnel arrive.

4. T or F - Do not touch eyelids if there are chemicals in your eye and you are rinsing it in the eyewash.

5. T or F - The safety shower can be used to put out people when they are on fire.

6. T or F - the first S in PASS stands for Sweep.

7. T or F - It is okay to modify an experiment without asking the teacher, only if you know what you are doing.

8. T or F - When a test tube is broken it should be wrapped in a paper towel and gently placed in the garbage.

9. T or F - Safety goggles are NOT need when working with non-injurious materials like water, even if it is being heated.

10. T or F - It is okay to put small pieces of plants down the sink, because the garbage disposal will be able to chop them up.

11. T or F - If a mess is left from the hour before, and you didn't make it, it isn't your responsibility to make sure it is cleaned up.

12. T or F - It is okay to bring a water bottle to class if you are sick.

13. T or F - It is okay to feed the chinchillas raisins or carrots without asking because those are safe foods for the chinchillas to eat.

14. T or F - If another student gets to pet the animals without asking, it is okay for you to pet the animals without asking.

15. T or F - It is possible to become injured in a science lab if you don't follow safety rules.

SCORE __________/15

APPENDIX D

QUESTIONNAIRES USED IN STUDY

Espeset Lab Safety Questionnaire A

Please circle the number that best addresses your answer.
1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

1. I understand biology lab safety.	1	2	3	4	5
2. I have been in a science class in which I did not learn laboratory safety.	1	2	3	4	5
3. I would know what to do if there was a laboratory accident.	1	2	3	4	5
4. I learned a lot in the lab safety orientation.	1	2	3	4	5
5. I already knew everything in the lab safety orientation	1	2	3	4	5
6. I understand that if I do not follow lab protocol,. I could injure myself or someone else	1	2	3	4	5
7. Lab safety needs to be addressed more in science class.	1	2	3	4	5
8. I feel safe that there will be no accidents in biology class.	1	2	3	4	5

Espeset Lab Safety Questionnaire B

Please circle the number that best addresses your answer.
1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

1. I understand biology lab safety.	1	2	3	4	5
2. I have been in a science class in which I did not learn laboratory safety.	1	2	3	4	5
3. I would know what to do if there was a laboratory accident.	1	2	3	4	5
4. I learned a lot in the lab safety orientation.	1	2	3	4	5
5. I already knew everything in the lab safety orientation	1	2	3	4	5
6. I understand that if I do not follow lab protocol,. I could injure myself or someone else	1	2	3	4	5
7. Lab safety needs to be addressed more in science class.	1	2	3	4	5
8. I feel safe that there will be no accidents in biology class.	1	2	3	4	5

Winona State University
Rochester Graduate Learning Community IV

Capstone Project

Will random sampling of science terms increase students' long-term recall?

by
Ann Miller
B.S., Winona State University, 1989
September 2002

This action research entitled:
Will random sampling of science terms improve students' long-term recall?
written by Ann Miller
has been approved by this evaluation team.

Karmen Beyer

Kelly Hansen

Dwight Miller

Sarah Ohm

Jon Wright

Margaret Lundquist, M.S.

Paul Tennis, M.S.
(Outside resource advisor)

The final copy of this capstone has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

BEST COPY AVAILABLE

Miller, Ann (M.S., Elementary Education)
Will random sampling of science terms increase students' long-term recall?
Capstone directed by Margaret Lundquist, M.S.

Topic:

Will random sampling of science terms increase students' long-term recall?

Objective:

To determine whether or not using random sampling of science terms will have a positive affect on students' long-term recall of those terms.

Procedures and Assessment:

1) Enlisted cooperation from another grade 5 teacher to use his class as a control group.
2) Research group's vocabulary pretest scores (collected before any teaching began) were recorded.
3) Taught the Landform science module while incorporating random sampling. Every second or third day multi-sided dice were rolled to determine the seven randomly sampled terms to be given. Sometimes the students were read the definition and needed to write the term, other times the students were read the term and needed to write the definition. The terms and definitions were then displayed on the overhead projector and a *very brief* discussion followed.
4) Students filled in their personal run chart and noted progress.
5) Students plotted scores on scatter diagram kept in room. This was followed by a discussion of whole class progress.
6) After completion of unit, students vocabulary post test scores were recorded. At this time we compared the scores from the pretest to the scores from the post test.
7) Taught Landform science module to control group class. Followed teacher guide and taught unit as usual. Gave the same vocabulary pretest and post test.
8) Fifteen days after unit completion, administered vocabulary test to each class.

Results:

The results of the study suggest that the use of random sampling did improve student performance. The research group had higher average scores on all three tests, including the pretest. The greatest positive discrepancy was exhibited on the post test that was taken immediately following instruction. Overall, it seems that the random sampling did not increase scores significantly, but the students enjoyed it and it was an opportunity to practice record keeping.

Recommendations:

I would recommend using this technique. My students enjoyed it and looked forward to the days that we did the random sampling. Constant review and preview is a positive practice that I would like to continue to some degree.

TABLE OF CONTENTS

APPENDIX

CHAPTER I

Introduction

In September of 2001 I was fortunate to be involved in a workshop entitled "School Improvement DataNotGuesswork" presented by Dr. Lee Jenkins. Much of the training and discussion focused on Deming's Quality principles and how to apply them in the classroom. One concept that we practiced was random sampling of end of workshop information. This provided a constant review of what had already been taught as well as a preview of what was yet to come. I was amazed and intrigued by its apparent effectiveness and was excited to see its results in my own classroom.

I teach fifth grade at Hoover Elementary School in Rochester, Minnesota. I have been in this position for 12 years. Our school has very little diversity. Most students come from upper-middle class two parent homes. We have a Newcomer Center that does not mainstream students into the classrooms at our school and an EBD room that mainstreams when possible. We provide LD resource services, MMMI resource services, adaptive PE, counseling, and EBD resource services. My current class has one EBD student, three LD students (one non-reader), two students diagnosed with ADD/ADHD, four students "of color" and two students who live in poverty.

My goal is to teach students what they need to know and to help them become responsible learners. This project helped me to do both of those things. The students are used to keeping data on their performance and viewing performance data of the entire class, but my research involved the use of different tools. The students recorded their scores on a personal run chart as well as a class scatter diagram. The constant preview kept students looking forward and anticipating future lessons and the constant review kept the previously learned information in the lessons.

Need for the study

My purpose for researching this topic was my desire to know if this method would positively affect my students' long-term recall. According to Lee Jenkins, the way our school systems are set up gives our learners "permission to forget." I hoped to find a way to assist students in committing relevant information to long-term memory.

Statement of the problem/question

Will random sampling of science terms increase students' long-term recall?

Definition of terms

Long-term recall: 15 school days after completion of final unit test

Random sampling: square root of total items, sample every other class period, multi-sided dice

Run chart: Data plotted on a line graph over time.

Scatter diagram: A statistical tool that plots the values of two variables on a graph in order to study the extent of the relationship between the two variables.

Limitations of the study

I used two different classes for this study. I gave the same pre-test and post-test to each class. I taught the unit exactly the same way to each group except for the addition of the random sampling to the research group. I taught the research group (my class) first, and taught the control group later in the year. I feel that the time of year may have had an impact on the results and the learning style of the class may have also. The control group came to my room from another teacher, so my expectations and style may have had an impact on the results.

CHAPTER II

Literature review

"Increase the positives and decrease the negatives so that all students keep their yearning for learning" (Deming, 1992). W. Edward Deming offered this as the overall aim for education. Dr. Deming originally advised those in the manufacturing field on how to better manage their people to create an improved product. He offered the same advise to educators on how to create improved learning.

Improvement occurs because somebody's theory is proven accurate (Jenkins, 1997). The theory that students can be responsible for their learning and can track their own progress, as long as they know what is expected, is accurate. Knowledge and learning can be tracked on run charts and scatter diagrams.

Quality measurement of knowledge involves (1) stating course expectations; (2) developing rubrics for single events and continuums to measure quality over time; (3) assessing students regularly; (4) organizing the assessment data into a classroom run chart and a classroom scatter diagram; and (5) regularly using the feedback to make course corrections so all can be successful (Jenkins, 1997).

Squires, Huitt and Segars (1983) suggest that teachers can have an impact on student achievement, by planning, managing and instructing in ways that keep students actively involved. In order to improve student learning, teachers may employ the Plan, Do, Study, Act (PDSA) cycle (Jenkins,1997; Shipley and Assoc.,2000). This cycle allows teachers to plan the content of a lesson/unit, give instruction and opportunity for learning, study the results and performance and then act on those results or performances in order to improve the outcome.

Random sampling of end of unit terms allows for a constant review of what has been taught and a constant preview of future learning. This practice removes the "permission to forget" that is embedded in our traditional teaching practice (Jenkins, 2001).

CHAPTER III

Data collection process

Participants:

I worked with two classes of fifth grade students for this project. One of the classes was my 22 homeroom students that I teach all subjects to. The other class consisted of 24 students from Mr. Kirk Colwell's homeroom. I chose to use my class as the research group because we had flexibility in scheduling and I could use the extra time for random sampling. We also had the scatter diagram posted in our classroom to view on a regular basis. Mr. Colwell and I switch science classes often, so our schedule was already designed to accommodate this activity.

Procedure:

To conduct my research I followed the teacher guide that is provided in the FOSS Landforms module for both classes. The guide is very specific as to what to say and how to set up the work stations. I was conscious of saying and doing the same things with both groups of students.

On the first day of class for both groups I gave them a matching vocabulary test (Appendix A). After correcting them I handed them back and posted a frequency distribution on the board. We did not discuss the items. At this time every student was given a copy of all 42 terms with their definitions (Appendix B). I told them that they would be taking the same test at the end of the unit and should study the terms regularly.

After the instruction was completed, I gave the students the matching vocabulary test to complete. I again handed back the scored tests and posted a frequency distribution. At this time we discussed the answers and any questions that the students had.

After fifteen school days had passed I surprised the students by giving the vocabulary test to them again. They did not have the chance to review the terms before taking the test. I scored and returned the tests and posted a frequency distribution. The students were told at that time that this score was not part of their grade, but part of my research.

During instruction with the research group, I included random sampling of terms. Every other class period the students would take turns rolling a twelve sided die and a four sided die. What ever numbers came up were multiplied together and that was the number of the term. Sometimes I would read the term and the students would need to write the definition and other times I would read the definition and the students would write the term. We did seven terms each day.

After the students had recorded their seven answers I would put the terms and definitions on the overhead projector. We quickly, with no discussion, corrected their answers. At that time, each student recorded their personal score on their run chart (Appendix C) and then put a sticker on the class scatter diagram (Appendix D). We would then have a class discussion about the scatter diagram, making observations and inferrences regarding the data.

Tools:

For the purpose of this study I used two fifth grade classes from Hoover Elementary School. The FOSS Landforms module served as our curriculum during the study. Each student was provided with a list of terms and definitions that would be assessed throughout the unit. The test group was briefed and given practice with displaying data using a personal run chart as well as a class run chart and a class scatter diagram. Each student had the opportunity to complete a vocabulary matching test three times. The terms were randomly sampled using one four sided die and one twelve sided die.

The data I collected for the purpose of this study were the scores on the three vocabulary matching tests. However, as part of the study the students kept track of their own progress on a run chart and we kept track of class progress on a scatter diagram.

This data fits the problem because it gave me "snapshots" of progress at different points in the instruction.

I believe that this data is a valid indicator of what I was researching because it is constant with the two classes and each answer is either right or wrong.

The potential bias discovered while random sampling was that some terms would never be rolled. Unless a number was a quantity of 1-4 multiplied by 1-12, it would be impossible to be sampled.

I believe the data is adequate to convince a skeptic because the scores were recorded and the graphs show the results.

Data Collection:

I collected my data over the course of study of two different classes. I collected data at the beginning of the unit, at the conclusion of the unit and again fifteen days after the final test. The data was collected by administering the same matching vocabulary test on these three occasions. The only source of data I used for my conclusions were these tests.

CHAPTER IV

Analysis of Data

Process:

After both classes had completed all three tests, I determined the total number of students from each class that completed each test, the total points scored on each of the three tests and then figured the mean score for each test. I was then able to compare the results.

Results:

These results tell me that the random sampling was an effective technique to use in my classroom. The most significant positive discrepancy between scores was on the post-test given immediately after the unit instruction was complete. This resulted in the research group earning an average score of 39.05, and the control group earning an average score of 34.7. This showed a positive result of +4.35. Although I was encouraged by this, the results on the post-test given fifteen days later only showed a discrepancy of +2.4. I was hoping to see more of a positive result, but this discrepancy shows a difference of six percentage points, which could easily result in a higher letter grade for many students.

The control group's average score from post-test to post-test fell 1.75 points while the average score for the research group fell 3.7 points from post-test to post-test (Appendix E).

I was pleased with my data collection tools. I think giving the same test all three times to both classes ensured consistency. I also feel that giving the students a matching test ensured that any bias or "superstitious knowledge" on my part could not occur.

CHAPTER V

Conclusion

I was encouraged by the results of my study. The scores in the research group were higher on both post-tests than the scores for the control group. Research I had read suggested that long-term recall would increase when this practice was used and I found that to be true. I fully intend to use this practice again, not only while teaching this unit, but during other courses of study as well.

I also feel that the data collection that the students practiced was a valuable skill. They were each able to track personal growth as well as class progress. The students also enjoyed the random sampling and saw it as an effective way to learn (Appendix F). There is definitely something to be said about an anticipatory set that excites a group of students day after day!

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Appendix A

Vocabulary matching test-answer sheet and terms.

Name______________________________

Landform Vocabulary Test

1. ______ boundary
2. ______ cartographer
3. ______ grid
4. ______ key
5. ______ landform
6. ______ map
7. ______ model
8. ______ structure
9. ______ symbol
10. ______ canyon
11. ______ channel
12. ______ delta
13. ______ deposition
14. ______ erosion
15. ______ floodplain
16. ______ meander
17. ______ mouth
18. ______ river
19. ______ slump
20. ______ stream
21. ______ valley
22. ______ flood
23. ______ levee
24. ______ slope
25. ______ base
26. ______ bench mark
27. ______ elevation
28. ______ intermittent stream
29. ______ peak
30. ______ perennial stream
31. ______ profile
32. ______ sea level
33. ______ topographic map
34. ______ aerial photograph
35. ______ alluvial fan
36. ______ contour interval
37. ______ contour line
38. ______ intermittent lake
39. ______ rapids
40. ______ ridge
41. ______ diatomaceous earth
42. ______ earth material

A. a low area between hills and mountains, where a river often flows

B. high land between two valleys

C. drawings on a flat surface of an area, usually looking down on it

D. a stream that always has water flowing in it

E. a fan-shaped (triangular) deposit of earth materials at a mouth of a stream

F. a line on a topographic map that connects points that have the same elevation or height

G. the limit of an area: a border

H. photograph of the land taken form an airplane

I. the part of a stream where it enters another body of water

J. an embankment along a stream that protects land from flooding, it can be natural or constructed

K. object or picture used to represent something else, such as a building

L. a line separating the land and the oceans; zero elevation

M. the wearing away of earth materials by water, wind, or ice

N. surveyor's marker placed permanently in the ground at a known position and elevation

O. the downward movement (collapse) of a mass of earth material

P. a lake that contains water only during certain times of the year

Q. the angle or slant of a stream channel

R. a map that uses contour lines to show the shape and elevation of the land

S. a network of vertical and horizontal lines that form squares

T. the process by which eroded earth materials settle out in another place

U. a flow of water in a channel

V. distance in elevation between contour lines

W. a mixture of ½ sand and ½ diatomaceous earth

X. vertical distance, or height, above sea level

Y. a fan shaped deposit of earth material on dry land

Z. land that is covered with water during a flood

AA. a (large) natural stream of water that flows into another body of water

BB. a part of a river channel where the water moves rapidly over obstacles, such as large boulders

CC. the highest point or top of a mountain

DD. the bottom of a mountain or other landform

EE. a person who constructs maps

FF. a curve or loop in a river

GG. a very heavy flow of water, greater than normal

HH. made from the shells of tiny organisms called diatoms

II. an explanation of symbols used on a map

JJ. the course a stream follows

KK. a shape of the land

LL. side view or cross section of a landform

MM. a stream that has water flowing in it only during certain times of the year

NN. something built by people

OO. a V-shaped valley eroded by a river or stream

PP. a representation of an object or process

Appendix B

List of terms given to each student at the beginning of the unit of study.

Landforms Vocabulary

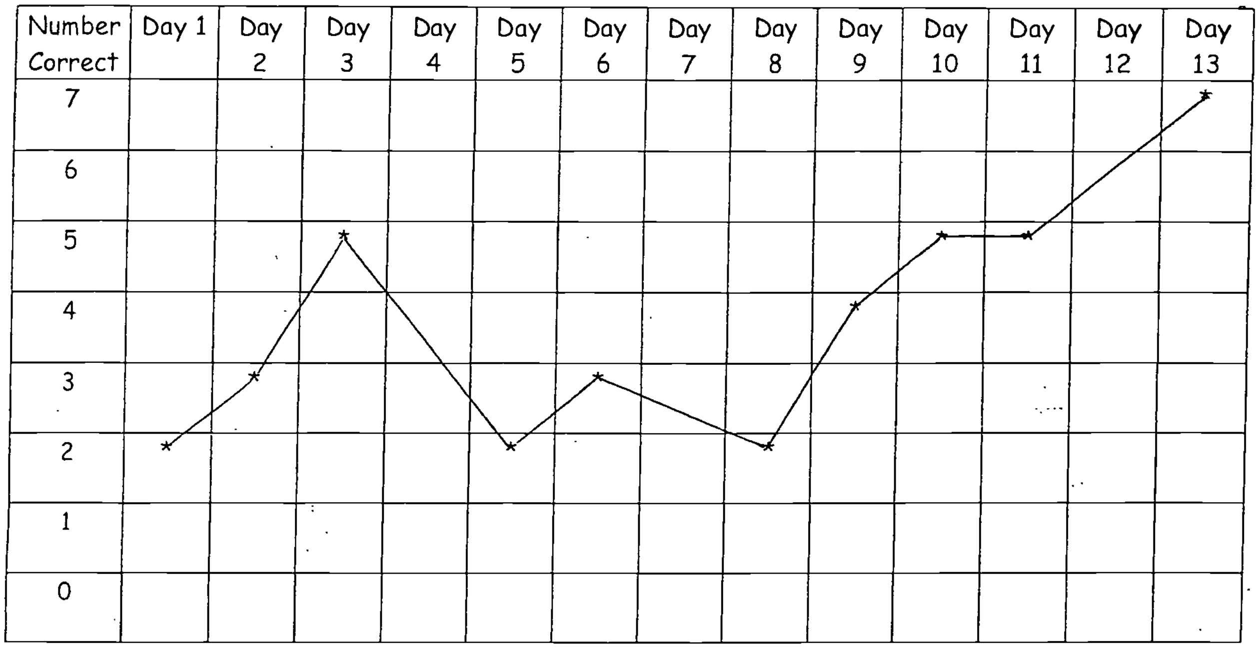
1. **Boundary**: the limit of an area: a border
2. **Cartographer**: a person who constructs maps
3. **Grid**: a network of vertical and horizontal lines that form squares
4. **Key**: an explanation of symbols used on a map
5. **Landform**: a shape of the land
6. **Map**: drawings on a flat surface of an area, usually looking down on it
7. **Model**: a representation of an object or process
8. **Structure**: something built by people
9. **Symbol**: object or picture used to represent something else, such as a building
10. **Canyon**: a V-shaped valley eroded by a river or stream
11. **Channel**: the course a stream follows
12. **Delta**: a fan-shaped (triangular) deposit of earth materials at a mouth of a stream
13. **Deposition**: the process by which eroded earth materials settle out in another place
14. **Erosion**: the wearing away of earth materials by water, wind, or ice
15. **Floodplain**:land that is covered with water during a flood
16. **Meander**: a curve or loop in a river
17. **Mouth**: the part of a stream where it enters another body of water
18. **River**: a (large) natural stream of water that flows into another body of water
19. **Slump**: the downward movement (collapse) of a mass of earth material
20. **Stream**: a flow of water in a channel
21. **Valley**: a low area between hills and mountains, where a river often flows
22. **Flood**: a very heavy flow of water, greater than normal

23. **Levee**: an embankment along a stream that protects land from flooding. Levees can be natural or constructed
24. **Slope**: the angle or slant of a stream channel
25. **Base**: the bottom of a mountain or other landform
26. **Bench mark**: surveyor's marker placed permanently in the ground at a known position and elevation
27. **Elevation**: vertical distance, or height, above sea level
28. **Intermittent stream**: a stream that has water flowing in it only during certain times of the year
29. **Peak**: the highest point or top of a mountain
30. **Perennial stream**: a stream that always has water flowing in it
31. **Profile**: side view or cross section of a landform
32. **Sea level**: a line separating the land and the oceans; zero elevation
33. **Topographic map**: a map that uses contour lines to show the shape and elevation of the land
34. **Aerial photograph**: photograph of the land taken from an airplane
35. **Alluvial fan**: a fan shaped deposit of earth material on dry land
36. **Contour interval**: distance in elevation between contour lines
37. **Contour line**: a line on a topographic map that connects points that have the same elevation or height
38. **Intermittent lake**: a lake that contains water only during certain times of the year
39. **Rapids**: a part of a river channel where the water moves rapidly over obstacles, such as large boulders
40. **Ridge**: high land between two valleys
41. **Diatomaceous earth**: made from the shells of tiny organisms called diatoms
42. **Earth material**: a mixture of ½ sand and ½ diatomaceous earth

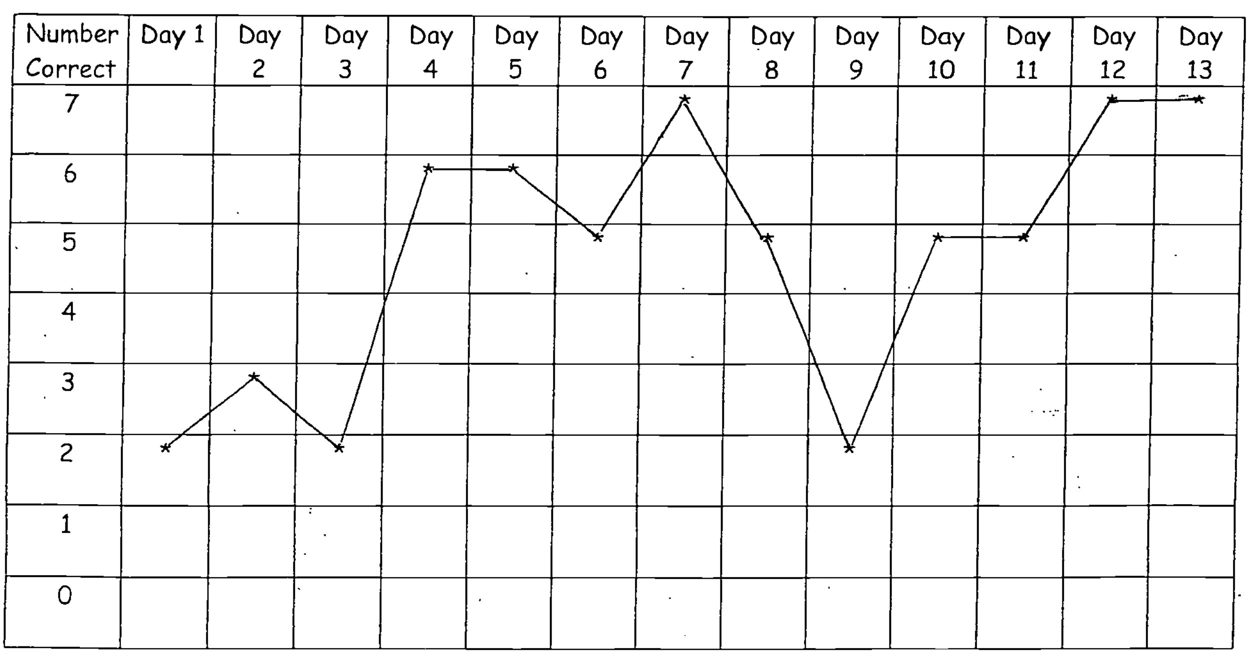
Appendix C

Examples of student run charts.

Alissa's Run Chart



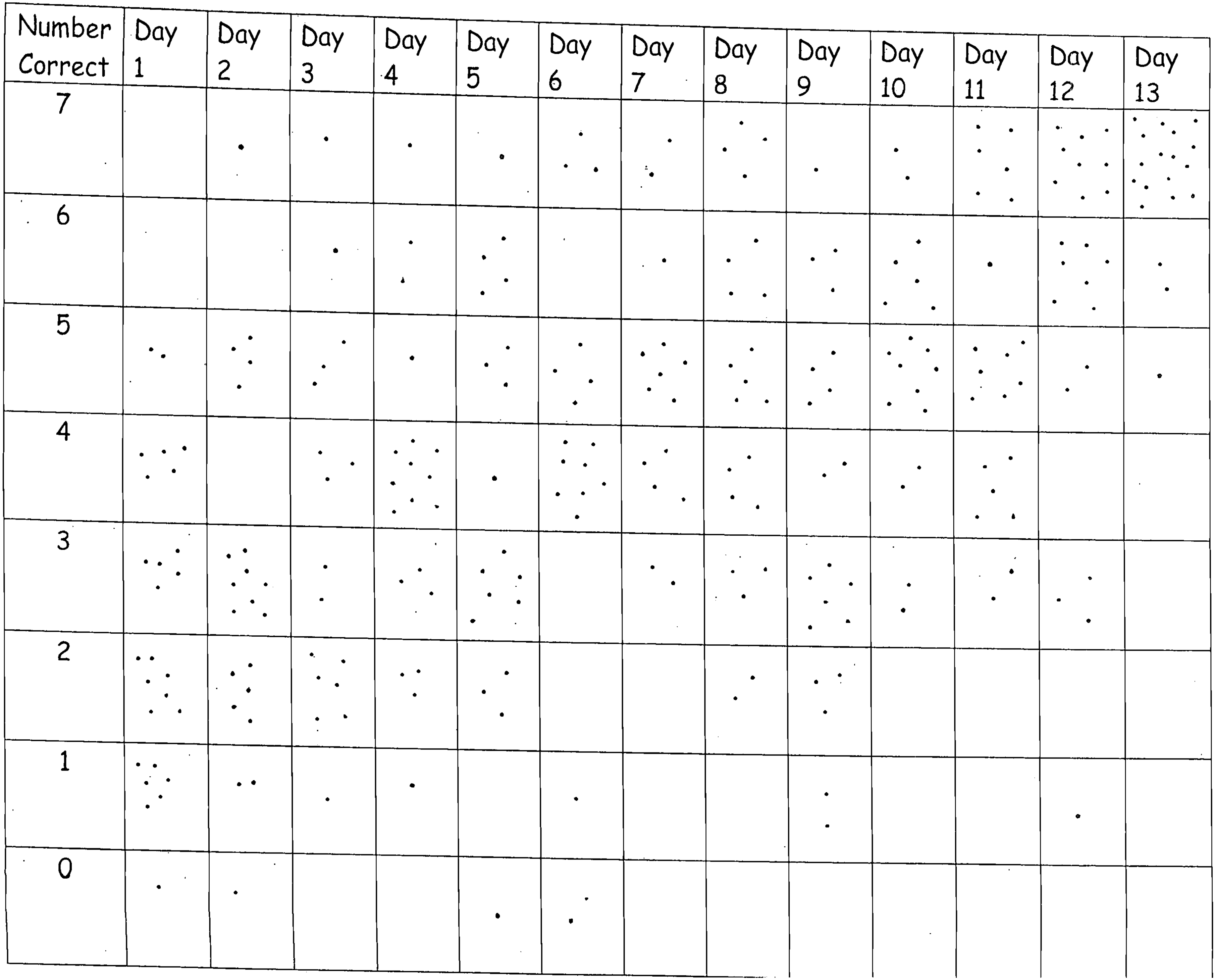
Joe's Run Chart



Appendix D

Research group's scatter diagram.

Scatter Diagram



Appendix E

Mean test scores for research group and control group for all tests given.

Control group (Mr. Colwell's students):

Pre-test: 9.46

Post-test: 34.7

Post-test (15days after completion of unit): 32.95

Research group my homeroom students):

Pre-test: 11.1

Post-test: 39.05

Post-test (15 days after completion of unit): 35.35

Appendix F

Student comments regarding random sampling.

I think that the random sampling is working. I think that after doing the random sampling it is going to help me do better on the test.

Megan

I think it's working because sometimes we get the same ones. You could also get different ones, too. It's fun too because you don't know what's going to come up. We also get chances to roll.

Tony

I think it is fun because instead of just trying to cram it all in your head this way it is easier to remember.

Sofia

I think that the random sampling with dice is kind of working because I can't remember the terms but I think that it is working for some people. I like it better when you give us the words and we study. I can remember more words that way, so I still have to study at home, not just at school to remember the meanings of the words.

Chelsea

I think random sampling is a fun thing to do, and it will help us at the end when we have the test. I think it's a good and fun idea.

Lauren

I think random sampling is fun because you get to roll dice and it can be any number.

Alissa

I think doing random sampling is a good idea and it is fun. But most likely we won't get to all of them, so we won't practice them. (But we will study all or them for the test.)

Jamie

I think random sampling is working well because if we don't have enough time at home we can study at school. Random sampling is really cool because it is fun to roll the dice and multiply.

Joe

I think that you could learn more if you use random sampling. But a disadvantage is that sometimes the same numbers come up. I think if you don't know what's coming up next, you learn faster and better. So I think random sampling is a good idea.

Johanna

I think random sampling is fun and it's helping us learn. It's fun because everyone gets a chance to roll. It's also helping us because we don't know what number it will turn out to be.

Steven

The Graduate School

Of

Winona State University

Will Teaching Science Through Inquiry Allow my Students to Better Grasp the Concepts That are Taught?

Capstone Action Research Write Up By

Shane Hewitt

Master of Science Degree in Education

Fall of 2002

Rochester Learning Community IV

This thesis entitled:
Will Teaching Science Through Inquiry Allow my Students to Better Grasp the Concepts That are Taught?
Written by Shane Hewitt
has been approved for the Department of Education

Faculty Advisor-Margaret Lundquist

Kim Hewitt

Angela Meister

Eric Kartheiser

Tony Mcgee

Outside Resource-Jinger Gustafson

Date 12/7/02

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above-mentioned discipline

Hewitt, Shane (Master of Science Degree in Education)

Will Teaching Science Through Inquiry Allow my Students to Better Grasp the Concepts That are Taught?

Thesis directed by Faculty Advisor Margaret Lundquist

My study focused on how teaching science using an inquiry-based approach helped students learn weather concepts that are taught. I created a baseline for my study by analyzing student District Earth Science test scores, focusing only on students' weather results, for my first two years of teaching at John Adams Middle School. During my first two years at John Adams I used more of a traditional approach to teaching Earth Science; in which case I used a textbook, worksheets, and gave notes to drive the lessons. The year of my study I created a weather unit that allowed students to work at stations to discover the concepts on their own. What I discovered was that students truly do learn better when an inquiry approach is taken.

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CHAPTER I

Introduction

I have been teaching science since the fall of 1998. During this time I have taught in both high school and middle school environments. My students have come from both urban and rural communities and represented a wide spectrum of ethnic and socioeconomic groups. At each school where I have taught at it has become obvious to me that students seem to be more interested in science when they are involved in labs, where they have the opportunity to discover scientific concepts on their own. As an educator, I wanted to provide my students with the best chance to succeed. Therefore, I developed a unit that allows students to discover weather concepts through a series of inquiry-based lab stations. Before designing these stations I researched the best practices in implementing inquiry-based labs into the classroom. The stations that were developed force students to observe, experiment, and research the individual weather concepts that were required within the Rochester Public Schools Science Curriculum. I will now evaluate my Inquiry-Based Weather Unit that was implemented during the 2001-2002 school year, in a research model and will conduct a review of the relevant literature in order to be better informed in this area.

Need for Study

Should science teachers use inquiry-based methods in order to successfully teach science? The traditional "telling" approach has allowed science teachers to cover many topics within a school year. However, student achievement has been nothing short of pathetic. Standardized test scores in 1992 when compared to 1969-

70 has shown no gain and in some cases a decline in achievement (Willis, 1995). Students have also become bored and alienated with the telling or lecture approach. Many students drop out of science classes as soon as they are able to. Each year science enrollment drops roughly in half; students who do continue on and succeed in science classes do not necessarily make the best scientists. Due to all of these problems, the science community is working swiftly to reform itself. Major organizations—such as the National Science Foundation (NSF), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the National Academy of Sciences—are vigorously promoting the inquiry-based approach (Willis, 1995).

According to a poll taken by the Bayer Corporation of Pittsburgh students who were exposed to hands-on experiments and team problem solving in their science classrooms had a better attitude toward science than those that were exposed to lectures only (Jarrett, 1997). Each year that I have taught science I have seen increased motivation in learning when activities have been more inquiry-based. Students like inquiry-based labs because they are allowed to discover concepts and ideas on their own without a teacher telling them what to think. This gives the students ownership in what they are learning. Alfie Kohn states, "What matters is not how motivated someone is, but how someone is motivated" (Kohn, 1993). Learning takes place within students when there is a need or want to learn whatever is being taught.

There is evidence that inquiry-based instruction enhances student performance fostering scientific literacy, understanding of scientific process, vocabulary knowledge, critical thinking, and creative thinking (Jarrett, 1997) The Third International Math and Science Study (TIMSS) results reveal, the value of inquiry-based learning in which students apply their knowledge using the scientific method achieved better than students who had science with a more traditional curriculum (Ricki Lewis, 1997).

The science community and other educational leaders are stressing the fact that changes in need to be made in science education. Inquiry-based learning seems to be the leading way to teach science to students. The need to determine whether or not this is an effective method of teaching seems to me to be an appropriate direction to go. My study will attempt to see if using inquiry-based learning in the classroom increases student achievement.

Statement of the Problem

In my short tenure as an educator, I have noticed that students become very bored whenever I am up in front of them talking too long about a concept. I truly believe that I am an exciting and interesting speaker. However, even the best speaker will become boring eventually. Students need to be actively involved in their education. Whenever students are actively engaged in a lab that I have set up, I can feel their interest and excitement level rise. They are very much on task, and do not need a whole lot of monitoring. Seventh and eighth graders have a lot of energy and if they are not constructively using that energy a teacher will usually see a lot of off task behaviors. I believe that developing inquiry-based science units will positively affect the way my students grasp the concepts that I am teaching.

Statement of the Question

Will teaching science through inquiry allow my students to better grasp concepts that are taught?

Definition of Terms

- AAAS: American Association for the Advancement of Science. This is a professional association that is striving for all students to be scientifically literate by the year 2061.
- Inquiry Teaching: The process of helping pupils learn by asking questions that prompt discovery, the acquisition of information, and understanding; also known as the "Socratic method of teaching."
- NSF: National Science Foundation. This is a federal program that promotes the progress of science and engineering in education. They also help scholars attain grants.
- NSTA: National Science Teachers Association. This is a national group of educators that strive to strengthen the profession of science teaching.
- TIMSS: Third International Math and Science Study. This study looked at how the United States compared with forty-one other countries in test scores and curriculum.

Limitations of the Study

Limitations of the study include the following: a small experimental group of fifty-four students, a change in students from year to year, students learning styles are not the same, and the time of day students have my class. All of these limitations affected the results of my study.

CHAPTER II

Literature Review

According to the National Research Council inquiry-based teaching methods are central strategy for teaching science (NRC, 2000). Many educators have a misconception as to what it is meant by inquiry, believing that the term applies to most things that they do in the classroom. What is inquiry one might ask? "Inquiry" refers to the work scientists do when they study and observe the natural world, then proposing explanations that include evidence gathered from their world around them. This term also applies to students—such as asking questions, planning experiments, and researching what is already known about the topic they are studying. Basically, the students mirror what the scientists do (Hanson, 2002). "Inquiry includes identifying assumptions, use of critical and logical thinking, and the understanding that other explanations might be possible (NRC, 2000).

There are four basic ways an educator can use an inquiry-based approach in the classroom. Full-inquiry can be used to allow students to answer questions that they have about a certain topic. They come up with their own question, then plan and conduct their own experiment. Once the experiment is complete students then show their results. Guided inquiry is only slightly different. In this case the instructor decides upon the question or problem to be answered. The students are then required to figure out a plan to conduct an experiment to test the question. Coupled inquiry involves both full inquiry and guided inquiry. First the teacher gives students a question to be answered. After this guided inquiry, students begin to research their own questions that relate to the question that the teacher originally gave to the students. Finally, structured inquiry is more like a cookbook type lab where the teacher gives all the directions in order to get one specific endpoint. Each method has its appropriate place in science education (Hanson, 2002). When using inquiry a teacher must consider their own skills, students' maturity level, and the goals they are trying to reach (Jarrett, 1997).

Inquiry became very popular in science education in the late 1950s and the early 1960's. The Biological Sciences Curriculum Study stressed the importance of inquiry in science (BSCS, 1970) during the post Sputnik era. More recently, the nation's science reform committees have released recommendations that highly encourage the use of inquiry in science classrooms (Chiappetta, 1997). Science for All Americans emphasizes that the teaching of science should be consistent with the nature of scientific inquiry (AAAS, 1990). The National Science Education Standards emphasize that inquiry is central to learning science (NRC, 1996). There have been many reports that call for many changes in the way science is being taught. Many of these reports call for a shift away from traditional teaching methods in favor of methods that get students more involved with their learning. These methods include hands-on and inquiry experiences (Rossman, 1993).

This literature review has talked about three main ideas. First of all, inquiry is a process by which scientists and students question, develop and conduct experiments, and show collected results in an organized fashion. Secondly, there are four different ways inquiry can be approached in the classroom. There is full inquiry, which is totally student-centered. Guided inquiry is still student-centered involving the instructor only to pose the question, the students do the rest of the process.

Coupled inquiry involves both full and guided inquiry. In this case, students create new questions from a guided inquiry investigation. The student then explores these questions through experimentation. The last type of inquiry is structured inquiry. This type of inquiry has the teacher helping students through the entire lab. Finally, many science educational organizations are leaning towards inquiry as the main method of teaching science in the classroom.

CHAPTER III

Data Collection

Participants

Will teaching science through inquiry allow my students to better grasp concepts that are taught?

John Adams Middle School, the location of my study, is a fairly large school with approximately eleven hundred students. My research was conducted with only Eighth grade students in my Earth Science class. The sizes of my classes were mainly between twenty-eight and thirty-two students. Each of my classes lasted about fifty-one minutes. I collected data for my study for two years. The baseline was set by my 1999-2001 Earth Science students, who were taught by traditional methods such as: lecturing, note taking, and answering questions out of a textbook. The experimental group was my 2000-2001 Earth Science students who were taught inquiry-based science.

Data Collection Tools

I used the Rochester Public Schools eighth grade Earth Science District Test and the Piaget Cognitive Ability Test to help me collect my data.

Procedure

I developed a weather unit that allowed my students in the experimental group to study basic weather concepts by seeing these concepts in action. This unit also forced students to use their creativity by making them create posters to show what they learned about the concepts covered. The unit used five basic stations to cover concepts such as: air pressure, wind, cloud formation, the water cycle, and weather forecasting. Each station had its own challenges for the students. The students worked in groups of three or four to complete each station. The students' reactions to their observations were recorded in their science notebook as a journal entry. The entries were put into their notebooks in a particular format (Appendix A).

Station one required student groups to observe a scenario where the students lit a candle in about a quarter of an inch of water. The students then placed a beaker over the candle. The candle then slowly was extinguished, and the observers watched as the water rose into the beaker. Students tried to determine what happened. The groups also observed a Cartesian diver in action. A Cartesian Diver is merely a bottle filled with water, with a water drop inside the bottle that floats and sinks depending on if the bottle is squeezed. Squeezing the bottle changes the water pressure inside the bottle. Again the students determined what they see happen when they squeeze the Cartesian diver. The diver dropped when the students squeezed the bottle because the density is increased as water entered the medicine dropper within the plastic bottle. Water entered the dropper because the volume of the bottle decreased as the water was squeezed which then increased the water pressure. Both observations within station one required students to problem solve from their observations (Appendix B).

Station two required students to create a poster that could be used to teach the following about clouds: how they form, what type of weather they forecast, and what the names of the clouds mean. Working in groups students first researched the information that was to be put on the poster, then students used this information to create a cloud tutorial (Appendix C).

Station three students observed a wind chamber to allow students to see how wind is created. The chamber is a box with two tubes extending from either side. There is a candle on the left side of the chamber and a piece of incense on the other. The incense created the smoke so the students could observe what happens when unbalanced heating occurs. The air above the candle was heated and began to rise due to a decrease in density. The air over the incense was cooler making it denser, causing it to move towards the candle to replace the rising air. This station also required students to observe how the wind is bent due to the Coriolis effect. Due to the spinning of the earth, the wind is bent in a certain direction depending on what hemisphere one is in. In the northern hemisphere the wind is bent to the right. However, in the southern hemisphere the wind is bent to the left. This is due to the fact that the earth spins from the west to the east. Each student was asked to take the world globe that is at the station and spin it in the west to east direction. The student then took a marker and drew a line from the North Pole to the equator. The students then observed how the line bent to the right. This process is repeated for the southern hemisphere where the marker line is bent to the left (Appendix D).

Station four again required students to create a poster that explains to others who view the poster how all of the elements of the water cycle work together. These elements would include evaporation, transpiration, run-off, condensation, and precipitation (Appendix E).

Station five had students viewing weather maps that show different weather fronts moving through the area. Students researched how each front can affect the weather. After viewing each map the students then were asked to answer questions about them (Appendix F).

Each of these stations required the students in the experimental to work together in teams to solve the problems that have been created at each station. Again, these stations are inquiry-based requiring students to take a more hands-on approach to their learning. I truly felt that this way of teaching this unit was very effective.

The collection of data for both the baseline group and the experimental group was done by having both groups take the District Earth Science final exam that was given to all eighth grade Earth Science students at the end of the year. After the test was given to the students each test was then sent to Dr. Paul Gustafson, the Rochester Public School's Research and Assessment Coordinator, to be corrected. The percentages on how each student did on the weather portion of the test were reported back to me after about two weeks. The results of the test were used to find the average for both the baseline and experimental group.

In order to fairly compare my baseline group with my experimental group I had to come up with a method to compare students with similar reasoning skills. Students who may have had lower cognitive abilities did not do as well on tests as students who had higher cognitive abilities no matter what method of teaching that was used. Luckily for me, it is an option for Eighth grade science teachers to give their students the Piaget Cognitive Ability Test. The Piaget Test has been used in the past to determine which students should be put into the advanced science classes when they get into the ninth grade. This test measures students' abilities to reason when solving abstract problems. They use a scale from 32 to 0 zero to measure a student's reasoning skills. Thanks to this test I was now able to compare students with approximately the same ability. Students in both the baseline and experimental groups were broken down into four different ranges depending on their Piaget score. The ranges on the Piaget test are as follows: high cognitive ability (32-25), medium high cognitive ability (24-16), medium low cognitive ability (15-9), and low cognitive ability. Averages on the weather portion of the district test could now be found for each range of the Piaget Test.

CHAPTER IV

Data Analysis

The main purpose of this study was to determine whether or not teaching science using an inquiry-based technique would improve the student's ability to grasp the concepts that are taught. In order to assess if the study was completed successfully I had to compare the data I collected from both the Earth Science District Test and the Piaget Cognitive Ability Test (Appendix H).

Using Microsoft Excel, I calculated the average, standard deviation, and the effect size for both the control and experimental group (Appendix G). I was able to use Excel successfully due to the tutorial from Dr. Paul Gustafson that was given to me while at the Winona State Learning Community IV September session. All of the statistics were compared depending on where they scored on the Piaget Test. The Piaget test has a thirty-two point rating system, which helped me group my students into four groups. The group's scores were divided up as follows: High Cognitive Ability (32-25), Medium High Cognitive Ability (24-16), Medium Low Cognitive Ability (15-9), and Low Cognitive Ability (8-0). Comparing students' averages and effect sizes by Piaget score allowed me to compare students with similar reasoning skills. The results of the comparisons are shown in tables 1-4.

Table 1

Piaget Student Group (32-25)	Effect Size	District Test Average (%)
Experimental Group	.4	83
Control Group	N/A	76

Table 2

Piaget Student Group (24-16)	Effect Size	District Test Average (%)
Experimental Group	.4	80
Control Group	N/A	74

Table 3

Piaget Student Group (15-9)	Effect Size	District Test Average (%)
Experimental Group	.3	71
Control Group	N/A	65

Table 4

Piaget Student Group (8-0)	Effect Size	District Test Average (%)
Experimental Group	.7	66
Control Group	N/A	53

The results showed that the experimental group seemed to have better results in each group. However, the lowest ability group seemed to have the highest increase in test percentage. The score improved 13 percentage points going from a 53 percent to a 66 percent. This result made me very happy because it always has been very difficult to get at-risk students to achieve to high levels of success.

Dr. Gustafson also showed us how to interpret our results. The effects size is a statistical measurement of the impact of the independent variable, in this case the experimental group, on the results (Gustafson, 2002). He gave our learning community a table to interpret how much of an effect there was. My experimental low ability group had a .7 effect. This effect size is considered to be large. This again proved that my inquiry unit had a strong effect on my at-risk students (Appendix I). The standard error and t-test were both calculated to determine the probability that these results were not random chance. This measurement takes into effect the sample used; probability ranges from (1) completely random, to zero (0), completely non-random (Gustafson, 2002). The probability that this was random was 1.97 X 10-7, which is a strong indication that this was very non-random indeed.

CHAPTER VI

Conclusion and Action Plan

Will teaching science through inquiry allow my students to better grasp concepts that are taught? This is the question that I attempted to answer in my study. What I found was that my students who were taught using inquiry were in-fact the ones who achieved higher scores on the District Earth Science Test. I also discovered that my lower ability students in my experimental group improved the most with an average of 66% compared to the control group's 53% average on the district test. In the end, I feel confident that using the inquiry method is the most effective way to teach science. I feel this way for the following reasons: all major educational science organizations are promoting inquiry as the main approach to teaching science, studies show that students achieve better when they are taught using the inquiry method, and my own study clearly showed that inquiry had at least a medium effect on my students' scores.

I plan to improve on my delivery of inquiry type units. I will do this by continuing to use this approach in my classroom. I believe that practice makes perfect. Research of this topic will also be big priority is my struggle to become a better facilitator of inquiry units. I truly enjoyed this study because I now feel that I am a better teacher because of it.

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Weather Journal
Day

Focus Question What causes our weather to change?

Daily Statistics
Temperature
Wind
Dew Point
Humidity
Barometer
Tomorrow's Forecast

Station (put # and type here)

Key Terms (Define Terms Here)
Diagrams (Include any drawings that help explain station)

Journal Questions
(Station Questions and answers go here)
Include these questions with every station!
1. What did you learn from this station?
2. What questions do you have about this station?
3. How does this station connect with the previous station?

Station #1
Air Pressure

To complete this station each of you will need to observe the following phenomenon:

1. Candle Lab
2. Cartesian Diver (Green Bottle)

Candle Lab Directions-

1. Fill Plastic Container with a half inch or less of water.
2. Place candle in clay then place in water.
3. Light Candle
4. Place beaker or flask over candle and observe.

Questions

1. What caused the water to rise? Try to give your best answer.
2. What does this lab have to do with air pressure? Explain.
3. What is the purpose of the candle in this experiment?
4. Now try 2 or 3 candles and observe.

Cartesian Diver

Squeeze green bottle and observe dropper.

Questions

5. Why does the dropper fall when you squeeze the bottle?
6. How does this observation relate to air pressure?

Define the following Terms:

Air Pressure, Barometer, Millibar, Sea Level Pressure, High and Low Pressure Pressure Gradient Force

STATION #2

CLOUD FORMATION AND IDENTIFICATION

To complete this Lab you will need to Create a Poster that teaches the following about clouds:

1.Cloud Formation (How do they form?)
2.Cloud Types (What are the four families of clouds?)
3. What are the meaning of cloud names?
4. What do clouds tell us about upcoming weather? (Use cloud chart in stairwell)

Terms (Define each in notebook)

Cumulus Clouds
Cirrus
Stratus
Alto
Nimbo

Station #3
Wind

To complete this lab you will create air currents by heating and cooling the air.

Wind Machine Directions

1.Place 1 or 2 cubes of ice next to smoke stick.
2.Light both candle and smoke stick. Carefully blow out smoke stick so it continues to smoke.
3.Place glass section to enclose smoke.
4.Observe the flow of the smoke.

Coriolis Effect Demo

While spinning globe take transparency marker and draw a line from the North Pole straight down. Observe line drawn. (pg. 528 and 529)

Terms

Sea and Land Breeze
Island Wind
Coriolis Effect

Questions

1. How does this lab explain how air pressure creates wind currents?
2. What direction is the smoke flowing? Why?
3. Explain how this demonstration relates to the terms sea breeze and island wind?(hint pg 527)
4. Draw a diagram in your journal that explains both island winds and sea and land breeze.
5. How does the Coriolis Effect affect the wind? (globe demo)
6. What is used to measure the wind?

Station #4
The Water Cycle

To complete the following lab you will need to make a poster that could be used to teach the class about the water cycle. Use a lot of colors. BE NEAT! You may use a textbook to give you some ideas on where to begin (page 150 and 499 in Black Text and 150 in the Weather Book). Make sure to put back all crayons and markers! Label the following parts of the water cycle:

Terms (Each term must also be defined in your notebook)
Evaporation
Condensation
Transpiration
Precipitation
Run-off
Hydrosphere

Questions
1. What is the hydrosphere?
2. Where does the water cycle get its energy from?
3. How does wind interact with the water cycle? Explain.
4. Describe in your own words how the water cycle works.
5. How much of the Earth's water supply is fresh water, ice, groundwater, and salt water?

Forecasting Station

Key Terms

Warm Front
Cold Front
Occluded Front
Stationary Front
Station Model
Air Mass
Continental Tropical cT
Continental Polar cP
Continental Arctic cA
Maritime Polar mP
Maritime Tropical mT

Question

1. Label location of all key stats. (Charts)
2. Complete assigned worksheet
3. Complete Standard Journal Questions

Experimental Group Data from 2001-2002 Earth Science Classes
Piaget vs. District Test Weather Scores

Students		Piaget Score		District Weather Score %
		28		55
		28		83
		28		81.5
		30		100
		28		100
		32		83
		32		43
		32		83
		32		81.5
		32		91
		30		90
Piaget (25-32)		28	District Score	73
Average	29.57895	28	83.84210526	71
Standard Deviation	2.168353	28	15.60987279	91
Effect Size		32	0.370146243	92
		30		100
		26		75
		32		100
		26		100
		24		100
		24		100
		24		91
		24		75
		24		53
		24		83
		24		83
		24		73
		24		63
		24		100
		22		91
		22		91
		20		73
		20		65
Piaget (17-24)		20	District Score	100
Average	22.625	18	80.75	51
Standard Deviation	2.028957	16	16.69131511	91
Effect Size		16	0.41180203	83
		16		70
		16		90
		16		55
		16		63.5

G

		16		83	
		14		73	
		14		70	
		10		55	
Piaget (9-16)		12	District Score	81.5	
Average	13.875	12	71.125	55	
Standard Deviation	2.247221	12	12.38614818	65	
Effect Size		10	0.308201058	55	
Piaget (0-8)		12	District Score	73	
Average	2	14	66.33333333	75	
Standard Deviation	2	2	6.110100927	65	
Effect Size		0	0.696791444	73	
		4		61	
Class Average Piaget (0-32)		21.3333333	District Score	78.18518519	
Standard Deviation		8.11947818		15.43993628	
Effect Size		0.71691176	Large	0.6	Large
Standard Error		1.10363121		2.099757041	
Confidence Interval+		23.486		82.29404	
Confidence Interval -		19.174		74.06596	
t-Statistic		5.33636364		5.994427029	
T-Test		1.9707E-06		1.76951E-07	

Baseline Data from the 1999-2001 Earth Science Classes
Piaget vs. District Test Weather Scores

Students		Piaget Scores		District Weather Scores %
		26		83
		26		38
		26		91
		28		75
		32		90
		28		81
		32		83
		28		75
		32		61
		28		0
		28		91
		26		90
		32		90
		28		81.5
		26		81.5
		30		71
		28		81.5
		26		56
		32		81
		28		100
		26		91
		26		91
		26		66
		26		100
Piaget (25-32)		28	District Score	63
Average	28.13333	28	76.5	81.5
Standard Deviation	2.096521	28	19.83248815	73
		28		73
		30		65
		28		91
		24		73
		20		73
		24		81.5
		24		46
		24		90
		18		81.5
		20		81.5
		24		71
		18		55
		22		56
		18		26
		20		81.5

H

		22		75
		22		73
		18		73
		22		90
		22		53
		20		63
		18		81.5
		24		100
		24		56
		22		56
		18		91
		18		65
		20		65
		24		63
		20		63
		24		81.5
		20		81.5
		24		73
		22		73
		18		63
		20		100
		20		65
		20		73
		18		73
		24		91
		20		100
		18		80
		24		81.5
		20		100
		20		73
Piaget (17-24)		18	District Score	73
Average	21.18367	24	74.26530612	91
	2.342305	24	15.76226442	73
		24		91
		22		100
		20		46
		24		73
		14		90
		16		81
		10		63
		14		73
		12		73
		14		8.5
		16		81.5
		14		65
		14		73
		14		73
		12		63.5

	H
16	91
16	81.5
16	91
14	53
12	73
16	81.5
16	63
16	45
14	56
12	73
16	38
12	65
10	26
10	91
14	73
12	81.5
12	73
12	65
16	55
12	73
14	71
16	81.5
16	73
10	56
16	91
10	73
16	63.5
10	73
10	65
12	65
14	73
12	73
12	41
10	73
14	73
14	81.5
14	81.5
12	65
10	8.5
16	48
10	38
14	91
14	43
12	45
10	40
10	73
10	46
16	45

		10		65
Piaget (9-16)		12	District Score	90
Average	13.26154	16	65.27692308	56
Standard Deviation	2.251922	16	18.88948756	90
		16		63.5
		14		35
		4		45
		8		81.5
		8		65
		4		63
		6		46
		2		46
		8		56
		8		46
		8		81.5
		4		65
		8		25
		8		65
		8		65
		0		90
		6		65
		6		46
		4		66
		4		30
		4		38
		8		41
		8		8.5
		6		75
		4		36
		4		63.5
		8		28.5
		0		56.5
		0		55
		2		75
		8		73
		4		65
		8		73
		2		55
		4		71
		6		51
		6		63.5
		8		43
		6		28
Piaget (0-8)		4	District Score	46
Average	5.333333	2	53.33333333	33
Standard Deviation	2.550817	2	18.69991087	71
Effect Size		6		10
		0		38

	4	70
	8	48
	6	71
	8	63.5
	4	55
	6	10
	8	55
	8	55
	6	48
Average	15.46666667	66.13846154
Std. Dev	8.167645153	20.06658934
Effect Size	0.7	0.6

Effect Size Ranges

Different authors specify different ranges

- Small 00.0- 0.20
- Medium 0.21- 0.50
- Large 0.51- 0.80
- Very Large 0.81+

Using Rubrics to Improve Student Independence in Active Scientific Inquiry

By

Tony McGee

Capstone Write Up of Action Research Submitted to the
Graduate School of Winona State University
in partial fulfillment of the degree Masters of Science

Rochester Learning Community IV
December 2002

This Capstone write up entitled:

Using Rubrics to Improve Student Independence at Active Scientific Inquiry

written by Tony McGee

has been approved for the Graduate School of Education

Margaret Lundquist M.S.

Kim Hewitt

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The final copy of this capstone has been examined by the signatories, and we find that the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Using Rubrics to Improve Student Independence at Active Scientific Inquiry

Capstone research advised by Margaret Lundquist M.S.

Will providing my students with a scoring rubric, to use in self-evaluation, increase their ability to independently engage in active scientific inquiry? The national and state goals for science education call for all students to engage in scientific inquiry as an important part of becoming scientifically literate. Rubrics have become a leading tool in the instruction and assessment of skills we want our students to learn.

Students in the study group were provided with a rubric for preparing a lab report I prepared based on published suggestions for their development. Instruction on how to understand and use the rubric took place using examples of quality work prepared by past students. When the students understood how to use the rubric, they were engaged in inquiry labs. When the inquiry process was complete, the students were required to prepare lab reports based on the criteria in the provided rubric.

Lab reports written by previous students, and saved as part of their portfolios, were re-scored using the same rubric provided to the test group. A numerical score was calculated for each paper in both the control and experimental groups in the same way. The scores earned by students in the experimental group were compared to those of the control group. Analysis of the resulting scores was performed using statistical functions in Microsoft Excel; it was found that the scores of the experimental group were significantly higher than those of the control group, that the use of the scoring rubric had a "large" effect on scores, and that it was very unlikely that this was due to random chance.

Although the scores on lab reports were clearly improved through the use of a rubric, questions remain about the ability of students to independently engage in active scientific inquiry. They are more skilled at reporting their inquiry, and are likely better at the inquiry itself, but becoming more skilled at scientific inquiry seems mostly due to increased practice.

Contents

Chapter 1

Introduction

This study was conducted with tenth grade general biology students in a small, rural high school. The Wabasha-Kellogg school, a K-12 facility and site of this study, had approximately 780 students enrolled in kindergarten through twelfth grade at the time of this study. Class sizes in the study were in the middle twenties or smaller, with approximately 75 students in each grade. Much of the diversity in this area is socioeconomic rather than cultural.

Comparisons were made to past students of the same age, in the same school, and in the same course engaging in similar learning activities. Some additional research was conducted with eleventh and twelfth grade students enrolled in my chemistry and advanced biology courses; students who had completed my general biology course as tenth graders. The assessment format for student work remained largely the same as previous years, involving checklists, portfolios, and the state rubric for scoring work on the Concepts in Biology standard.

Need for the Study

Standards for science education call for students to engage in scientific inquiry. The National Academy of Sciences states about the National Science Education Standards.

> In the vision presented by the *Standards*, inquiry is a step beyond "science as a process," in which students learn skills, such as observation, inference, and experimentation. The new vision includes the "processes of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. *Engaging students in inquiry* (emphasis mine) helps students develop understanding of scientific concepts, an appreciation of "how we know" what we know in science, understanding of the nature of science, skills necessary to become independent inquirers about the natural world and the dispositions to use the skills, abilities, and attitudes associated with science.

> Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities. The standards on inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (National Academy Press 1996).

The science related standards, Concepts in Biology, Chemistry, Physics, Earth Science and Environmental Systems, in the Minnesota Profile of Learning state a student shall

> C. design and conduct an experiment to investigate a question and test a hypothesis by:
> (1) formulating a question and hypothesis;
> (2) designing and conducting an investigation;
> (3) recording relevant data;
> (4) analyzing data using mathematical methods;
> (5) constructing reasonable explanations to answer the question and supporting or refuting a hypothesis;
> (6) identifying and considering alternative interpretations of results; and
> (7) specifying implications for further investigation; (MN CFL 2000).

The adolescent and young adult science standards of the National Board of Professional Teaching Standards say this about the role of science teachers in promoting active scientific inquiry, "VII. Science Inquiry - Accomplished science teachers involve students in inquiries that challenge and help them construct an understanding of nature and technology." (NBPTS 1997) The National Board of Professional Teaching Standards also promote the use of varied assessment and instructional tools.

> VIII. Fundamental Understandings - Accomplished science teachers use a variety of instructional strategies to expand students' understandings of the major ideas of science.
> X. Assessment - Accomplished science teachers assess student learning through a variety of means that align with stated learning goals.
> (NBPTS 1997)

The clear national trend is for students enrolled in science classes to engage in active scientific inquiry.

Rubrics have become very popular in current educational practice as a tool for helping students clearly understand expectations and to guide student progress toward mastery of expected outcomes. After conducting extensive searches of the available resources for rubrics, very few were found that related to science and almost no resources were found that were specific to scientific inquiry. The Chicago Public Schools Instructional Intranet and the Access Excellence web page did have rubrics that address scientific inquiry as small portions of larger rubrics designed to evaluate student performance at completing a predesigned lab or writing a lab report. (Access Excellence, Chicago Public Schools 2000)

Controlled studies, such as Heidi Goodrich Andrade's work with *Project Zero*, have clearly demonstrated the use of scoring rubrics increases student performance on stated learning goals. Exhaustive searching uncovered no published, controlled studies in which the effectiveness of rubrics in improving the scientific inquiry skills of students were conducted. Rubrics are one of the most effective and powerful tools available to educators today for helping their students improve performance on stated goals. However, very few resources and no controlled studies are available to the science teacher who wishes to incorporate this powerful tool in helping his/her students improve their performance at independent and active scientific inquiry; a very important part of the accepted standards in science education today.

Statement of the Problem

When students begin my general biology class in the fall of their sophomore year, very few are able to independently engage in active scientific inquiry. Their educational experience has rarely offered the freedom to actively and independently explore scientific inquiry. The students are dependent on myself as their teacher to provide structure and focus to all learning activities and to affirm they have found the "correct" answer. A genuine scientific experience has no "correct" answer or predetermined learning objective; rather it seeks to answer a question or solve a problem.

Developing scientifically literate persons who are able to independently engage in scientific inquiry is the hoped for goal of the science education standards of the Minnesota Profile of Learning, the National Science Education Standards, and the Project 2061 Benchmarks for Science Literacy. (AAAS 1993, MN CFL 2000, NRC 1996) With that goal, a tool to help my students engage in and master this learning objective was needed. Rubrics have been clearly demonstrated to help students improve their performance on both content and performance learning goals, but none existed to help my students with scientific inquiry.

Statement of the Question

Rubrics can be constructed for many purposes; general vs. task specific, formative assessment vs. summative assessment, and as instructional tools that clarify expectations and describe the desired product. Because they clearly define the expectations and describe the desired product, rubrics can also be used to create scoring uniformity among those who examine student work. (Arter and McTighe 2001) In this study, my focus was the use of scoring rubrics as an instructional tool. Will providing my students with a scoring rubric, to use in self-evaluation, increase their ability to independently engage in active scientific inquiry?

Terms

Analytical Trait Rubric: A rubric that divides a product or performance into essential traits or dimensions so that they can be judged separately. (Arter and McTighe 2001)

Checklist: A list of the components that must be present in a product or performance, provides no judgment of quality. (Arter and McTighe 2001)

Holistic Trait Rubric: A rubric that gives a single score or rating for an entire product or performance based on an overall impression of a student's work. (Arter and McTighe 2001)

Minnesota Profile of Learning: Legal name for the standards for graduation produced by the Minnesota Department of Children Families and Learning (CFL) and passed into law by the Minnesota legislature in 2000.

MN CFL: Minnesota Department of Children Families and Learning. The state agency in charge of public education in Minnesota.

National Science Education Standards: National standards for science education published by the National Resource Council (NRC 1996). Contain standards for teaching, professional development, assessment, and content.

NBPTS: National Board of Professional Teaching Standards. The 13 science standards, which are a more specified version of the 5 Propositions, were used to help refine and improve the instruction and climate of this classroom during the same time the action research was being performed.

Portfolios: A collection of student work used to assess student performance.

Reflection: Students were provided with questions to focus their thoughts, generally used to compare new learning to prior learning or to organize and incorporate new learning. Also used to explore understanding and focus student questions.

Scoring Rubrics: Specific sets of criteria that clearly define for both student and teacher what a range of acceptable and unacceptable performance looks like. Criteria define descriptors of ability at each level of performance and assign values to each level. Levels referred to are proficiency levels which describe a continuum from excellent to unacceptable product. (Downing, Chuck 2001)

Unifying Concepts and Processes: The primary goals for literacy from which the National Science Education Standards and the science standards of the Minnesota Profile of Learning are derived.

Limitations of the Study

My study was attempting to evaluate the success of implementing a new instructional/assessment tool. I analyzed the data collected to look for improvement in the current test group as compared to past groups. There are several potential factors that limited the validity of the data I collected. The data collected is largely subjective;

"are the students more independent?" and comparison to past groups was also therefore subjective. Unrelated improvements I made in my curriculum and instruction as well as the difference in abilities and personalities inherent in different groups were additional factors that limited the validity of my data and any conclusion(s) I reached based on that data. However, as this research is measuring the success of an instructional/assessment tool, the data collected through reflection and assessment of student work should be a valid tool for answering my question.

Chapter 2

Literature Review

Chuck Downing, in writing for the Access Excellence collection, defined rubrics as "specific sets of criteria that clearly define for both student and teacher what a range of acceptable and unacceptable performance looks like. Criteria define descriptors of ability at each level of performance and assign values to each level. Levels referred to are proficiency levels which describe a continuum from excellent to unacceptable product." (Downing 2001) A rubric is a scoring guide used to evaluate the quality of students' constructed responses on work like written compositions or science projects. (Popham 1997) Heidi Goodrich Andrade, in her writing for Educational Leadership and her work on the Harvard Graduate School of Education's *Project Zero*, describes rubrics as authentic assessment tools that support self-regulated student learning and the development of sophisticated thinking skills. She goes on to say that when rubrics are used correctly they serve the purposes of learning, evaluation, and accountability and like other approaches to authentic assessment, blur the line between instruction and assessment. (Andrade 2000, Andrade 2000) Properly constructed rubrics act as both instructional and assessment tools, describing for the student what high and low quality work look like and allowing the student, the parent, and the teacher to clearly understand expectations and evaluate the resulting work.

The definition of a rubric provided by Judith Arter and Jay McTighe in their book "Scoring Rubrics in the Classroom", define a rubric by what it is rather than what it does.

> A rubric is a particular format for criteria - it is the written-down version of the criteria; with all score points described and defined. The best rubrics are worded in a way that covers the essence of what we, as teachers, look for when we're judging quality, and they reflect the best thinking in the field as to

> what constitutes good performance. Rubrics are frequently accompanied by examples (anchors) of products or performances to illustrate the various score points on the scale. (Arter and McTighe 2001)

This excellent resource for teachers interested in rubrics explores the purpose, construction, use, and evaluation of rubrics. Like Andrade, Arter and McTighe describe a rubric as "a perfect example of integrating assessment and instruction." (Arter and McTighe 2001) There are countless resources available for understanding rubrics that are very consistent in their description of the important components of a rubric; a list of the criteria, descriptions of quality, and a scale of "scoring points" used to identify the level of quality a piece of student work represents. Quite often, rubrics are accompanied by examples of products that represent a range of quality work to better help students understand the descriptions of quality in a rubric.

The basic purpose in using a rubric is the clarification of expectations for all parties involved, "Providing more specific information or feedback to students, parents and teachers about the strengths and weaknesses of a performance." (Arter and McTighe 2001) Teacher's expectations are very clear, students receive more informative feedback, the development of skills and understanding is supported, and the explanation of grading criteria and student performance on those criteria is easily accomplished. (Andrade 2000) Rubrics are the most powerful when used as instructional tools rather than exclusively assessment tools. Clearly articulating desired skills in the criteria of a rubric provides the student with a clear picture of what is expected and the ability to continually monitor the quality of their own performance. For this reason, Heidi Andrade prefers to use the term "instructional rubric". (Andrade 2000)

Choosing the correct rubric to use is one of the first choices a teacher must make. There are many prepared rubrics available to the interested teacher. One Internet search I conducted using the "Google" search engine yielded more than

177,000 links to webpages with rubrics. Many of these sites, including "Kathy Schrock's Guide for Educators", "The Staffroom for Ontario's Teachers", "Chicago Public Schools, Instructional Intranet", "Education World" and many others provide free samples of rubrics that have been prepared commercially or by other teachers. The Chicago Public Schools website and the Access Excellence website both had examples of science related rubrics. Both free and fee-based Internet sites exist that offer teachers online software tools to develop their own rubrics. "Rubrics.com" is a web site that offers teachers rubric software on a fee basis while "Rubistar", "Teachnology", and 'The Landmark Project" are websites that offer free online rubric construction software.

When choosing a prepared rubric, or beginning the process of developing your own, Arter and McTighe explain three items on which to decide; do you want a holistic or analytic trait rubric, a task specific or general rubric, and the number of score points you want to use. Analytic trait rubrics allow the teacher to break down a complex performance into it's traits and better evaluate the quality of those traits. Analytic traits provide more specific feedback to students, parents, and teachers about the strengths and weaknesses of a performance, allow targeted instruction, and allow students to better understand the nature of quality work. (Arter and McTighe 2001)

> ...we generally recommend the use of analytical trait rubrics for day-to-day classroom use, where ongoing assessment is integrated with instruction and where specific feedback is needed to guide improvement of teaching and learning. (Arter and McTighe 2001)

Holistic rubrics provide an overall picture of student performance on the stated criteria, and are well suited for providing students with an overall sense of their performance and for determining a final score for a students work. Holistic rubrics, like the one for Scientific Applications, are provided by the Minnesota Department of Children Families and Learning for scoring student performance on the standards of the Profile of Learning. (MN CFL 2000) A general rubric is one that "can be used across similar performances. You'd use the same rubric for judging *all* open-ended mathematics problems, *all* writing, *all* oral presentations ..." (Arter and McTighe 2001) Whereas a task specific rubric is designed to assess student performance on one task. Most authors describe choosing a number of score points that strikes a balance between separating student work into obvious differences of quality without having too few or too many points to be cumbersome. Arter and McTighe "recommend from 3 to 6 points for rubrics". (Arter and McTighe 2001) Popham suggests using four, Andrade models the use of four, and the state model provided by the MN CFL uses four scoring points. (Popham 1997, Andrade 2000, MN CFL 2000)

A general consensus arises from the published resources on designing rubrics. Gather and sort student work by levels of quality, let the student work guide the description of scoring criteria, practice using and continuously refine the rubric. In addition to describing these steps in detail, Arter and McTighe recommend the following.

> Read the literature on what skilled people in your field are doing.
> Beg, borrow, and steal rubrics from your peers.
> Gather samples of student work and sort it into groups by quality.
> Score samples of student work, practice, practice, practice.
> Continuously refine the rubric as guided by student performance.
> (Arter and McTighe 2001)

David Lazear takes the development and use of rubrics a step further by incorporating considerations for student intelligence's in the scoring criteria. He discusses the lack of focus on intelligence's other than linguistic-mathematic intelligence. He describes the development of rubrics that consider multiple student intelligence's and provides many examples of "MI Rubrics." (Lazear 1998)

Regardless of how well designed a rubric may seem, there remain two main considerations; is the rubric understandable by students and have the students been provided with instruction on the use of the rubric? Both are important considerations. All the authors presented here mention the need for using language in rubrics that is student friendly. Popham even attacks the word "rubric", stating that it as "adequately opaque ... hence technically attractive" and suggests the more simple "scoring guide". (Popham 1997) David Lazear and Arter and McTighe stress the importance of instructing students on the meaning of the scoring criteria, providing examples of student work that represents each of the levels of quality, and providing students opportunit*ies* to practice applying the criteria in a rubric to their own work. (Arter and McTighe 2001, Lazear 1998) Arter and McTighe describe several important factors for student success at using scoring rubrics.

> Being exposed to scoring criteria from the beginning of instruction.
> Having terms defined.
> Having examples of strong and weak performance illustrated by teacher modeling, student work samples, videos, etc.
> Practicing feedback using vocabulary of the criteria to suggest to students how to improve a piece of work.
> Having opportunities for self- and peer-assessment using the vocabulary of the criteria.
> Practicing articulating the vocabulary for quality and applying it to many situations.
> Having instruction focused on subparts of the criteria.
> (Arter and McTighe 2001)

Why use rubrics? Several authors discuss problems that arise from the improper design and or use of rubrics. Evaluative criteria can become to specific or too general to provide valuable instruction and feedback to students, they can become too lengthy, and there is a danger of getting lost in the testing of a skill as the skill itself. (Popham 1997) David Lazear discusses the dangers of poorly constructed rubrics and the need for developing rubrics that allow assessment of all of a student's multiple intelligence's in his book "The Rubrics Way". (Lazear 1998)

> "Analytical trait systems are not worth the effort in the classroom if all they are to be used for is putting grades on student papers. If, however, they are used as an instructional methodology - to focus instruction, communicate with students, allow for student self-evaluation, and direct instruction of traits - they are very powerful." (Arter and McTighe 2001)

But as Arter and McTighe state at the end of that last passage, rubrics can be powerful tools and they provide this example.

> "At Aurora's (CO) Wheeling Elementary School, for example, the percentage of students writing at or above standard between 1997 and 1998 rose from 13% to 36%; at Leroy Drive Elementary in Adams County, from 13% to 45%; at Bessemer Elementary School in Pueblo - a school with an 8% minority population - from 2% to 48% . . . . Why are these schools experiencing such exceptional improvement in this area? George Hillocks . . . . found that one of the most powerful interventions was using what he dubbed "scales" - his word for rubrics or scoring guidelines." (Arter and McTighe 2001 as excerpted from NSDC's *Results*, December/January 2000, pp. 1, 6)

They go on to describe the benefits of using performance criteria in the form of rubrics.

1. To help educators clarify the nature of complex learning targets so that they feel comfortable teaching to them
2. To assess student progress and status in ways that are consistent across students, assignments, and time.
3. To improve student achievement by letting students in on the secret of the nature of quality.
4. Through all these things, to integrate assessment and instruction and grasp the essence of standards-based instruction.
(Arter and McTighe 2001)

In a controlled study as part of *Project Zero*, Heidi Andrade found a one-half point (12.5%) difference on a four point scale for students taught to use a rubric for self-evaluation of writing. This was a statistically significant effect and resulted from only forty minutes of instruction on the use of the rubric. (Andrade 2000) When students receive direct instruction on the use of rubrics for self-evaluation, research indicates student performance on stated standards does significantly improve. Rubrics clarify expectations and describe quality, allow students to monitor their progress and the quality of their work, and help teachers apply grading criteria consistently across students and time.

Chapter 3

Data Collection

"Will providing students with a scoring rubric, to use in self-evaluation, increase their ability to independently engage in scientific inquiry?"

Participants

Wabasha-Kellogg High School, the location of my study, is a small, rural high school. My research was conducted primarily with my tenth grade general biology students and my classes were all in the middle twenties or smaller and met for 50 minutes every day. I collected data from students who had taken general biology with me during the previous two years and who had engaged in similar learning activities providing baseline data against which the data I collected from the experimental group was compared. I also conducted some additional comparisons to eleventh and twelfth grade students enrolled in my chemistry and advanced biology courses to allow for identification of growth in inquiry skills due to more practice over a longer period of time.

Group A: Students who completed my general biology course during the 1999-2000 school year. These students were provided with a checklist and very basic rubric (Appendix A) to guide their work.

Group B: Students who completed my general biology course during the 2000-2001 school year. These students were provided with a revised checklist and rubric I had prepared to guide their work.

Group C: Primary Study Group. Students who completed my general biology course during the 2001-2002 school year. Based on information gathered from the literature review process, especially "Scoring Rubrics in the Classroom" (Arter and

McTighe 2001), I greatly revised the rubric and checklist for lab reports before providing it to the students. See "Rubric for Scoring Investigations" Appendix B. An additional rubric and checklist for assessing student inquiry skills was also constructed based on the same criteria and provided to the students. See "Rubric for Assessing Scientific Inquiry" Appendix C.

Group D: Students taking my chemistry and or advanced biology courses during the study period. These students had completed my general biology course during the 1999-2000 or 2000-2001 school years. Due to their previous completion of general biology and their enrollment in more advanced science courses, these students, especially those in chemistry, had more practice planning and conducting experiments and writing lab reports. During the study period, I provided these students with the "Rubric for Scoring Investigations".

Data Collection Tools

"Rubric for Scoring Investigations" See Appendix A for a sample of this rubric.

"Rubric for Assessing Scientific Inquiry" See Appendix B for a sample of this rubric.

Procedure

Development of Scoring Rubrics

I developed analytical trait rubrics with four score points for this investigation. (see Appendix B and C). The analytical trait rubric was chosen because of recommendations made by Arter and McTighe in their book, "Scoring Rubrics in the Classroom. Part of the Experts in Assessment Series", that this type of rubric was best suited for the instructional purpose I intended. (Arter and McTighe 2001) The actual scoring criteria within the rubrics were collected from a wide variety of sources throughout my career and represent my best understanding of the accepted format for a scientific paper and what is involved in scientific inquiry.

I chose to use four score points from a desire for all rubrics used in my classes to model the scoring criteria of the state scoring rubrics produced by the Minnesota CFL. (MN CFL 2000) Throughout the year, I work to educate the tenth grade general biology students about the criteria that will be used to score their performance on the Concepts in Biology standard. The rubrics developed for this investigation played a role in that process by providing the students experience with how work at each of the scoring levels 4, 3, 2, 1 looks.

Setting a Baseline

I generated baseline data by scoring lab reports written by students in Group A and Group B as part of their coursework in general biology. These papers had been saved as part of the student's portfolios, which I have kept. I used the revised "Rubric for Scoring Investigations", which was different from the materials provided to these students, to re-score their work. This provided me data on the scores achieved by students who had no or little use of a scoring rubric to assess their own work or for receiving feedback from me as their instructor. Re-scoring the papers with the revised rubric allowed a direct comparison in the scores of the control group to the experimental group.

I scored the papers by applying the criteria in the rubric to each portion of the checklist to determine a score point (4, 3, 2, 1). I combined the scores for all portions of the checklist to create a numerical score for each paper. This was done only for the purpose of data collection in this study and allowed mathematical comparisons of the students work. Arter and McTighe describe this method of converting an analytical trait rubric score into an overall score as inappropriate and they provide suggestions for converting to a grade that are based on the overall number of each score point (4, 3, 2, 1) rather than adding them together. (Arter and McTighe 2001)

I generated additional baseline information in the same fashion by scoring papers from students in Group D as a regular part of grading their papers. However, no formal collection and analysis of their scores was conducted for this investigation.

Why score student lab reports as a tool for measuring their independence at conducting independent scientific inquiry? I had several reasons, the most important of which is my goal to make the work of my students more authentic. The format I have developed for lab reports is nearly identical to the accepted format for published scientific papers which is the accepted format for conveying ideas in the scientific community. Within the lab report, as I have set it up, there is opportunity to get a sense of a student's inquiry abilities. A complicating factor in measuring scientific inquiry is that so much of the process occurs within the students mind, beyond observation. Short of working individually with each student for a long period of time, or having students record every idea they have and all the reasons for rejecting, modifying, and or accepting them, I know of no way to assess their thinking.

Collecting Data from the Primary Study Group

An important part of this study was instructing my students on the use of scoring rubrics to evaluate work. All work the students completed during the study was necessary for completion of the Concepts in Biology Standard (MN CFL 2000). Following the recommendations of Arter and McTighe and David Lazear_about the importance of instructing students on the use of scoring rubrics (Arter and McTighe 2001, Lazear 1998), I spent much time instructing the students in the primary study group on the use of scoring rubrics to evaluate and improve their work.

I designed scoring rubrics with similar criteria for several major projects completed by the students (See Appendix D). This provided my students with experience using scoring criteria to guide, evaluate, and assess their own work. It also provided the students familiarity with the scoring criteria that would be used to assess their overall performance on the standard at the end of the year.

I provided the students with anonymous examples of strong and weak lab reports written by previous students from groups A, B, and D (See Appendix H for copies of the papers used.) as part of their instruction in and practice with the scoring criteria specific to a lab report. Each student read the reports and scored them using the "Rubric for Scoring Investigations". The students were then provided time to discuss the scoring of the papers with their peers. Finally, I led the students in a discussion of each portion of each paper. Time was taken to discuss the strong and weak points of each section of the papers, how the scoring criteria applied, and what score such work would receive. The goal was to have the students reach a clear understanding of how the criteria were applied and what work at each level looked like. Most students were applying the scoring criteria consistently the same as myself by the end of this process.

The most important part of the study was engaging the students in a process of active scientific inquiry. Prior to beginning this process, I introduced the second data collection tool, "Rubric for Assessing Scientific Inquiry", to the students. As this tool had not been used with my previous students in any form, no work from previous students was available for comparison. I spent time discussing the criteria in the rubric and the levels of achievement. Once I felt the students were familiarized with this scoring tool, they were introduced to the inquiry lab that would be used for their first assessment.

To begin the inquiry process, I presented a demonstration related to cellular chemistry that created a discrepant event. See Appendix E for a complete description of this lab. The students were then allowed to choose a partner, discuss what may have happened, and developed a hypothesis and test of their hypothesis. Each team presented their hypothesis and testing plan to me; an opportunity I used to gather information on the inquiry ability of each team. The teams then performed their tests, gathered data, and in many cases adjusted their ideas and performed new tests. Finally they wrote formal lab reports following the criteria in the "Rubric for Scoring Investigations".

When the lab reports were finished, anonymous copies were prepared and handed out to other students. Each student had the opportunity to read the work of at least two other students, and each student's paper was read by at least two classmates. I also read and scored each student's paper. During this process, the papers were scored using the "Rubric for Scoring Investigations". For the purposes of data collection, the scores were added up in the same fashion used in scoring the papers from groups A, B, and D when creating the baseline.

A second inquiry lab was performed by the students based on their study of ecosystem structure and function. I reviewed and discussed the criteria in the "Rubric for Assessing Scientific Inquiry" in terms of the previous experience. Based upon the model of a pond ecosystem in a jar (See Appendix F for a more complete description of this lab), the students prepared and submitted questions individually with no opportunity for collaboration. I designed teams for this inquiry based on similarity of student questions. Each team designed a pond setup that would test a hypothesis they developed based on their question. I observed the students while they were working on designing, setting up, and gathering data from the pond model and made comments based on the criteria of the "Rubric for Assessing Scientific Inquiry".

At the end of this inquiry lab, each team prepared a formal lab report following the criteria of the "Rubric for Scoring Investigations". Due to these reports being turned in at the end of the school year, their was no time for peer review. I read and scored the papers using the criteria of the "Rubric for Scoring Investigations". For the purposes of data collection, the scores were added up in the same fashion used in scoring the papers from groups A, B, and D when creating the baseline.

Chapter 4

Analysis of Data

The goal of my investigation was to determine if providing my students with a scoring rubric to guide their work would increase their ability to perform scientific inquiry. To determine if the rubric I provided was successful, I compared lab report scores of students in group C to the scores of students in groups A and B. I had saved the lab reports written by the students in groups A and B as part of their portfolios for the biology standard.

As explained in Data Collection, the lab reports of students in groups A and B were re-scored using the "Rubric for Scoring Investigations" developed for this investigation. Each part of each lab report was scored using the criteria in the rubric and the scores for all parts were combined to generate an overall score for each paper. Using the same process, I scored the lab reports written by the students in group C, the primary experimental group. The goal of using this approach was to score all papers in the investigation against the same criteria and in the same way. This process generated a data set composed of scores from all the papers written by my students over the past three years. See Appendix G for the complete set of data.

One difficulty with this approach resulted from the students in all three groups, A, B, and C, receiving slightly different instructions. While the overall format of the lab reports remained consistent for all three groups, the specifics for each part of the report varied slightly. However, my goal was to determine how effective the use of a rubric was as an instructional tool. For that reason, I feel any difference that I observed would support my conclusions about the effectiveness of these rubrics as instructional tools.

Using Microsoft Excel, I calculated the average, standard deviation, and sample size for the control group, groups A and B, and the experimental group, group

C. (See Table 1) Based on instruction I received from Paul Gustafson during a presentation to our learning community, I compared the resulting data using statistical formulas in Excel for effect size, standard error, t test, and probability. (See Table 2) (Gustafson 2002)

Table 1	Control Group	Experimental Group
Average	25.626	28.957
Standard Deviation	5.3771	7.4551
Sample Size	131	70

Table 2	
Effect Size	0.6195
Standard Error	0.891
t test	3.7385
Probability	0.0004

In addition to explaining how to use Microsoft Excel to analyze our data, Paul Gustafson explained how to interpret the resulting numbers. (Gustafson 2002) The effect size is a statistical measurement of the impact of the independent variable, in this case the use of a rubric, on the results. He provided our community with a table for interpreting effect size that was based on published sources. (See Table 3)

Table 3	
Effect Size Interpretation	
0.00 - 0.20	Small
0.21 - 0.50	Medium
0.51 - 0.80	Large
0.81 +	Very Large
Gustafson 2002	

The standard error and t-test were both calculated to allow calculation of the probability, a measure of the likelihood that these results were achieved through random chance. This measurement takes into account the size of the sample used;

probability ranges from one (1), completely random, to zero (0), completely non-random.

Analysis of my data suggests that the use of a scoring rubric had a "large" effect on student performance in writing a lab report. Further, it is extremely unlikely, the probability is 0.0004, that this was the result of random chance. These results support my hypothesis that using a scoring rubric as an instructional tool, to make clear my expectations and teach my students how to independently monitor the quality of their work, is effective. But, does this indicate the students are "more independent at active scientific inquiry? Unfortunately, I must concede that scoring a student's lab report does not directly measure her/his independence or competence at engaging in scientific inquiry.

This type of report is the accepted format for reporting the results of scientific research in the scientific community. Does that mean it is an acceptable format for measuring a students ability to conduct such research? If reporting one's work in the accepted format is considered an important part of the inquiry process, then I feel this is an acceptable format. If the focus is on the inquiry itself, this tool fails to measure the necessary skills with that tool. For that reason, I monitored student progress using the "Rubric for Assessing Scientific Inquiry." As my investigation progressed, I had difficulty measuring the students inquiry skills. The only skills I was able to observe were their abilities to ask clear, testable questions and to design and carry out tests to answer those questions. As the student's questions, hypotheses, and plans for testing their hypotheses were all reported in their lab reports, I was brought back to using their lab reports as a measure of their science inquiry skill.

One interesting result of this study was a measurement of the effects of spring on student performance. The experimental group, group C, wrote two lab reports during this investigation with the second report being completed very near the end of the school year. My sense of student performance while conducting the lab was a lack of focus on their part. When I read and scored their papers that feeling was strengthened; but was my instinct accurate or misplaced? When comparing the average scores of the second lab report to the first, I was surprised to see how much better the students did on the first one. I would have expected scores on the second report to be higher due to more practice with the rubric, the lab report format, and the scientific inquiry process. Clearly, any resulting improvement of student understanding was overwhelmed by the time of year. How to keep students focused until the end of school is a problem I struggle with, as do all teachers. An editorial comment, perhaps this lends support to my long held belief that we need to strongly consider changing to all year school with more frequent, short breaks throughout.

Chapter 5

Conclusions and Action Plan

Will providing my students with a scoring rubric, to use in self-evaluation, increase their ability to independently engage in active scientific inquiry? Answering this question with the data I collected requires a decision on exactly how a student's ability to conduct scientific inquiry is conducted. By choosing to use the student's lab reports to measure their inquiry skill, I may have been measuring the wrong skill. Did the use of a scoring rubric as I have describe improve my student's ability to prepare a properly written report of their efforts to answer a scientific question? Absolutely, the data shows the rubric had a large effect on the results and that the probability this happened through random chance was negligible. Are my students more independent at conducting active scientific inquiry? I am unsure how to measure independence, but I was unable to use the "Rubric for Assessing Scientific Inquiry" while observing students because I found many students needed my guidance and support. Are my students better at conducting scientific inquiry? The only measure I know for this is judging the student's questions and ability to test ideas, which I did not directly measure in this investigation.

Are scoring rubrics an effective tool for teaching scientific inquiry? Properly constructed and used rubrics act as instructional tools as much as assessment tools. As stated by Arter and McTighe a rubric is "a perfect example of integrating assessment and instruction. (Arter and McTighe 2001) Based on my results, I feel they are a very effective instructional tool. Based on my experience with students, my experience with designing and conducting experiments, and mostly my experience in a cancer genetics research lab at the Mayo Clinic, I have come to feel the only real way to improve the ability of students to conduct scientific inquiry is to frequently engage them in the process and give them many opportunities. A conclusion that fits nicely with the goals of the standards for science education.

I am confident the use of the rubrics, within the instructional process I described in the Procedure, helped my students better understand what is involved in conducting scientific inquiry, especially in reporting their work. The background research into the published literature combined with my own experience with instructional rubrics has convinced my of their effectiveness as an instructional tool. Like most teachers, my goal is for all my students to become independent, engaged learners. Rubrics help promote this by allowing the students to take ownership of their work and the assessment of their work. I will be developing rubrics for all the performance based assessments I have my students complete.

One change I intend to make is in the format of my rubrics. The rubric + checklist format I developed for this investigation was based on a model I received from a science teacher I respect. In the future, I plan to reformat that document to have quality criteria specific to each section of the paper. That would generate a rubric that is more closely modeled on a traditional rubric.

Few quality rubrics are available for the science teacher who wants to use them to measure scientific inquiry. I have been unable to uncover a published, controlled study of the effectiveness of scoring rubrics for this purpose. My research suggests rubrics may be effective tools for promoting quality student performance at scientific inquiry. Although poorly constructed, or improperly used, rubrics do not offer much help, well constructed and used rubrics are one of the most powerful instructional tools available to teachers today.

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Appendix A

Minneapolis Public Schools
Science Rubric

Rubric for Assessing Investigations

Meaning of Scores

4.0	Exceptional Work:	Ideas and work exceed requirements listed below.
3.0	At Standard Level	All aspects of the rubric are addressed and completed well.
2.0	Approaching Standard Level:	All aspects of the rubric are addressed but work quality is inconsistent.
1.0	Below Standard Level:	Parts of the rubric are not addressed and work done is not at standard level.
0	Investigation is not turned in or is copied from another source.	

A. Introduction

(1X) _____ The Title
Clearly identifies the purpose or problem to be investigated.

(1X) _____ Background Discussion
Provides information that clarifies the question to be investigated.

(1X) _____ The Question/Purpose/Problem
1. Is relevant to the topic, concise, and testable.
2. Leads directly to predictions.
3. Suggests the important variables.

(1X) _____ Variables
1. Reflect accurately the goals of the investigation.
2. Are identified correctly as independent, dependent, or controlled.

(2X) _____ The Hypothesis
1. Makes a prediction of the results.
2. Is based upon scientific concepts clearly stated in the background discussion.
3. Is clearly testable by the student with the equipment available.

B. Designing & Conducting an Investigation

(1X) _____ A Materials List
1. Includes all relevant materials for testing the hypothesis.
2. Does not include extra materials.
3. Clearly identifies materials with their scientific names and/or concentrations. (Ex. 2.0 M HCl)

(2X) _____ A Diagram of Experimental Set-up
1. Is neat and presentable.
2. Is drawn to scale.
3. Clearly labels items from the materials list.

(2X) _____ The Procedure
1. Tells sequentially how and when all materials are used.
2. Treats all variables correctly.
3. Indicates when data is to be recorded in the data table.
4. Includes safety & clean up procedures.
5. Uses appropriate methods to collect and analyze data.
6. Is clearly written and can be repeated by others.

Minneapolis Public Schools

C. Laboratory Work & Data Table

(1X)______ Laboratory Technique

1. Follows all safety procedures.
2. Conducts only the procedure authorized.
3. Uses all equipment appropriately.
4. Cleans lab materials properly.

(2X) ______ Data Table

1. Collects and clearly identifies all required data.
2. Records measurements that reflect the accuracy of the instruments used.
3. Uses proper significant figures.
4. Provides data from all trials.

D. Analyzing Data

(2X) ______ Calculations

1. Clearly states algebraic equations used.
2. Shows substituted values from the data table.
3. Calculates correctly.
4. Records units of measurement.

(2X) ______ Graphs

1. Writes variable names & units on all axes and includes a title.
2. Clearly indicates the significance of graphs. For example, identifies and labels the slope and intercepts.
3. Correctly labels scaling intervals.

E. Conclusion

(2X) ______

1. Identifies and explains patterns in the graphs.
2. Restates the question or problem.
3. Compares the results to the hypothesis.

F. Alternative Explanations

(1X) ______

1. Identifies areas where error may have occurred.
2. Explains differences between the results and the hypothesis.
3. Introduces new scientific concepts when appropriate to help explain the results.

G. Further Research

(1X)______ Lists at least two testable questions the investigation has raised.

Appendix B

Rubric for Scoring Investigations

Rubric for Scoring Investigations

General Biology, Advanced Biology, Chemistry, Environmental Systems
Mr. Tony McGee
Wabasha-Kellogg High School

Description of Scores:

4.0 - Exemplary Work — ***Work Exceeds "Standard" or Expected Level***
- All work exceeds the criteria listed below, *and*
- Accurate, original, unguided insight is shown in the application of scientific concepts.

3.0 - Proficient Work — ***Work is at "Standard" or Expected Level***
- All required components are completed, *and*
- Work is organized properly &/or logically, *and*
- All information is clear and accurate, *and*
- Work is free of extra information, *and*
- A consistent level of high quality is present throughout the work.

2.0 - Novice Work — ***Work is Approaching "Standard" or Expected Level***
- *All required components are completed, *and*
- Work is organized improperly &/or poorly, *or*
- Information is either unclear or inaccurate, *or*
- Work contains some extra information, *or*
- Quality of work is inconsistent.

1.0 - Emerging Work — ***Work is Significantly Below "Standard" or Expected Level***
- Some required components are missing or incomplete, *and*
- Work is poorly &/or improperly organized, *&/or*
- Information is neither clear or accurate, *&/or*
- Work contains some extra information, *&/or*
- Quality of work is poor or inconsistent.

0 ~ Work is either not turned in or is copied from another source.

(___X) _____ ***Abstract***
A clear, concise summary of the investigation is provided in less than 150 words.

(___X) _____ ***Introduction***

_____ A. Background Information
- Explains why the question or problem is of interest.
- Presents what is already known about the question or problem.
- Properly cites sources of factual information.

_____ B. Question or Problem
- Clearly Stated
- Is testable and leads directly to predictions.

_____ C. Variables
- Are correctly identified as independent, dependent, and controlled.

_____ D. Hypothesis
- A clear statement that predicts the results.
- Based on scientific concepts clearly stated in the background information.
- Directly related to the question or problem.

(___X) _____ ***Methods and Materials***

_____ A. Materials and Equipment List
- Provides a complete and accurate list of materials and equipment used in the investigation. List includes sizes and concentrations of all materials and equipment.

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***Methods and Materials* Continued**

_____ B. Diagram of Experimental Set-Up
- May include a diagram of the experimental set-up that clearly depicts and accurately labels the important variables and items from the materials and equipment list.
- Is drawn to scale.

_____ C. Description of Experimental Design
- Provides a clear and accurate description of the testing environment including descriptions of the...
  - control group,
  - experimental group,
  - environmental conditions,
  - sampling/ data collection procedures, *and*
  - data recording procedures.

_____ D. Procedure
- Provides a clear, accurate, step x step procedure that ...
  - tells when and how all materials are used,
  - indicates when and where data is to be recorded,
  - includes safety and clean up procedures, *and*
  - includes sufficient detail to be repeated by others.

(__X) _____ ***Results***

_____ A. Raw Data
- Raw data is included with the report, typically attached to end.

_____ B. Graphs &/or Tables
- Data is clearly and logically organized in appropriate tables.
- Data is presented in a properly constructed graph when appropriate.
- All data in tables and graphs clearly and accurately labeled.
- Reports measurements that reflect the accuracy of the instruments used.
- Provides organized data from all trials.

_____ C. Calculations
- Clearly states algebraic equations and statistical techniques used.
- Shows correctly performed calculations.
- Correctly labels all data used in calculations.

_____ D. Summarization of Data
- Clearly explains the data presented in tables &/or graphs.
- Identifies and describes trends that appear in the data, tables, &/or graphs.

(__X) _____ ***Discussion***

_____ A. Conclusion(s)
- Restates the hypothesis.
- Identifies data from the results that support &/or refute the hypothesis.
- Clearly states if the data supports or refutes the hypothesis.

_____ B. Interpretations and Explanations
- Uses scientific concepts to explain the results obtained.
- Explains differences between the hypothesis and the results.
- Identifies areas where error(s) may have occurred.

_____ C. Questions for Further Research
- Suggests at least two testable questions that could be investigated to ...
  - clear up problems with your results, or
  - further support your explanations, or
  - help explain unexpected results, or
  - explore thoughts or questions you had while conducting the investigating.

Appendix C

Rubric for Assessing Scientific Inquiry

Rubric for Assessing Scientific Inquiry

General Biology, Advanced Biology, Chemistry, Environmental Systems
Mr. Tony McGee
Wabasha-Kellogg High School

Name: ____________________

4.0 – Exemplary Describes a student who is able to engage in the process of scientific inquiry with minimal or no guidance, demonstrates superior techniques of good scientific practices, accurately applies scientific concepts in original and unguided ways, and is able to communicate work and findings with exceptional clarity and insight using the accepted format.
Student work exceeds all or most criteria listed.

3.0 – Proficient Describes a student who is able to engage in the process of scientific inquiry with minimal guidance, demonstrates techniques of good scientific practice, and is able to effectively communicate work and findings in the accepted format.
Student work satisfies all criteria listed.

2.0 – Novice Describes a student who is able to engage in the process of scientific inquiry with some guidance and structure provided, demonstrates few or poor techniques of good scientific practice, and/or is unable to effectively communicate work and findings in the accepted format.
Student work completes all criteria listed, but satisfies only some.

1.0 – Emerging Describes a student who is unable to engage in the process of scientific inquiry without continual guidance and structure provided, demonstrates poor techniques of good scientific practice and is unable to communicate work and findings in the accepted format.
Student work completes all criteria listed, but satisfies few or none.

0 – Student fails to engage in process of scientific inquiry and/or fails to report work.

Criteria for Assessing Scientific Inquiry

- ☐ Performs and describes clear and accurate ***observations*** that are free of inferences.
- ☐ Develops a clear, testable ***question*** based on observations and/or information.
- ☐ Makes a definite prediction (***hypothesis***) about the outcome that is directly related to the question, is accurately based on scientific principles, and leads to a test.
- ☐ Designs a "good" ***test*** of the prediction.
  See description of a "good" test.
- ☐ Designs a plan for collecting data that is accurately aligned to the test design, organized logically, and provides space for interesting observations not directly related to the prediction.
- ☐ Sets up test exactly as described in the test design (***procedure***).
  Notes any changes made to the test design and why they were made.
- ☐ Collects and records all data called for by the test design in the pre-designed data tables.
  Also notes and records interesting observations not directly related to the prediction.
- ☐ Analyzes and organizes data (***results***) in a clear and logical fashion.
  Correctly uses proper mathematical and statistical analysis techniques when appropriate.
- ☐ Uses collected data to reach and support a clear ***conclusion*** about the prediction.
- ☐ ***Reports*** question, hypothesis, test, results, conclusion, and ideas in the accepted format.
  See Rubric for Assessing Investigations form.

Appendix D

Other Miscellaneous Rubrics

2001-2002 Genetic Engineering Instructional Rubric

Genetic Engineering

An Exploration of the Techniques, the Products, and the Debate.

Description of Scores:

4.0 ~ Exemplary Work — *Work Exceeds "Standard" or Expected Level*
- All work exceeds the criteria listed below, *and*
- Accurate, original, unguided insight is shown in the application of scientific concepts.

3.0 ~ Proficient Work — *Work is at "Standard" or Expected Level*
- All required components are completed, *and*
- Work is organized properly &/or logically, *and*
- All information is clear and accurate, *and*
- Work is free of extra information, *and*
- A consistent level of high quality is present throughout the work.

2.0 ~ Novice Work — *Work is Approaching "Standard" or Expected Level*
- *All required components are completed, *and*
- Work is organized improperly &/or poorly, *or*
- Information is either unclear or inaccurate, *or*
- Work contains some extra information, *or*
- Quality of work is inconsistent.

1.0 ~ Emerging Work — *Work is Significantly Below "Standard" or Expected Level*
- Some required components are missing or incomplete, *and*
- Work is poorly &/or improperly organized, *&/or*
- Information is neither clear or accurate, *&/or*
- Work contains some extra information, *&/or*
- Quality of work is poor or inconsistent.

0 ~ Work is either not turned in or is copied from another source.

Goals of this Task

- Demonstrate understanding of genetic engineering as a branch of science.
- Demonstrate understanding of how various genetic engineering techniques are performed and used.
- Identify products that have been created or altered through the use of these G.E. techniques.
- Explore the debate surrounding the development and use of these G.E. techniques.
- Present and defend your own position on the development and use of these G.E. techniques.

Description of the Product(s)

The criteria presented above will be used to assess your performance on satisfying the listed goals. Your primary method of demonstrating your performance will be in the form of one or more papers that provide the things explained on the back of this page. Consider developing an alternative format for demonstrating your performance. Papers are a traditional format, can you think of something more innovative? I will always encourage you to **BE CREATIVE** and to do the best work you know how.

You should use the description on the back of this page as a guide to creating your work. Combined with the criteria above, you can use this form as a checklist to ensure your work is complete and a tool to measure your performance on this task. These are the same criteria and checklist I will use to assess your work.

Description of the Topics you will Include in your Work

Student Evaluation of Performance

(____X) _____ ***1. Introduction to genetic engineering as a field of science.***

_____ A. Clearly and accurately identifies and describes at least the topics discussed in class.

_____ B. Provides a clear and accurate history of genetic engineering.

(____X) _____ ***2. Explanation of how genetic engineering is done.***

_____ A. Clearly and accurately explains how each of the most commonly used genetic engineering techniques are performed.
Including at least explanations of...

- controlled breeding,
- recombinant DNA,
- genetic screening, *and*
- DNA fingerprinting.

_____ B. Uses appropriate scientific concepts as a part of these explanations.

(____X) _____ ***3. Identifies products that have been created &/or altered through the use of the genetic engineering techniques you described previously.***
*Note that this could be included with your descriptions of how the products are created.

(____X) _____ ***4. Identifies the groups involved in the debate and their arguments.***

_____ A. Clearly identifies the groups that have become part of the debate over one or more uses of genetic engineering techniques.

_____ B. Accurately describes each of these groups by explaining their ...

- position,
- arguments, and
- evidence they use to support their arguments.

_____ C. Accurately compares and contrasts the arguments and evidence of each group.

(____X) _____ ***5. Presents original research on the debate surrounding genetic engineering.***
*You will receive a second form that will help you conduct your research and organize your data.

(____X) _____ ***6. Presents your own opinion.***

_____ A. Clearly identifies and describes your position on one or more of the types of genetic engineering you described earlier.

_____ B. Uses evidence from primary research and print sources to support your position.

____ C. Properly cites sources of information.

2002-2003
Genetic Engineering
Instructional Rubric

"Should we . . . ?"

Genetic Engineering and DNA Technologies
Exploring the Techniques, Technologies and Issues

The standard says a student shall:
design and conduct one investigation through a problem-based study, service learning project or field **study by identifying scientific issues based on observations and the corresponding scientific concepts; analyzing data to clarify scientific issues or define scientific questions; and comparing results to current models, personal experience or both; and**

use scientific evidence to defend or refute an idea in a historical or **contemporary context by identifying scientific concepts found in evidence; evaluating the validity of the idea in relationship to scientific information; and analyzing the immediate and long-term impact** on the individual, society or both, in the areas of technology, economics and the environment.
Bold Items Apply to this Task.

Products:

- Team Concepts Map
- Knowledge and Opinion Surveys
  Incorporated into Debate Paper
  Instructions and Scoring Criteria Provided Separately
- Presentation on the issues and science related to one genetic engineering or DNA technology topic. May be in the form of a paper or other presentation type.

Expectations:

Exemplary: Describes a quality product that completes all required components in a unique fashion, explores issues in depth, and demonstrates a deep understanding of the science involved.

- ❑ Explains the history of the question in terms of scientific advances and social perspectives.
- ❑ Provides a detailed, accurate explanation of the science related to this question.
- ❑ Explains how this question is related to others through the science.
- ❑ Clearly describes all points of view and provides analysis that demonstrates clear understanding of the root causes for disagreement.
- ❑ Questions used in the survey reflect a clear understanding of the issues and science involved as well as public perception of the science.
- ❑ Results of the survey are used to answer the question and support your opinion.
- ❑ Demonstrates a deep understanding of how this and related questions will impact you, society, and the environment.
- ❑ Your opinion is explained and defended using material from published sources, and your survey, and demonstrates a complete understanding of the issues and science.

Expected Performance: Describes a quality product that completes all required components in a logically organized and nicely presented format.

- ❑ An historical context for the question is provided that explains how the question originated and why it is important to answer.
- ❑ A scientifically accurate explanation of how all techniques and/or technologies related to the question is clearly presented.
- ❑ Examples of products that are and/or could be produced using this technique and/or technology are provided.
- ❑ The questions used in the survey are presented along with the results. The results are clearly explained and used to answer the question.
- ❑ Information from published sources is used to describe all points of view related to the question.
- ❑ Scientific evidence is used to explain all points of view described.
- ❑ The potential impact of the use of this technique and/or technology on society and/or the environment is clearly explained.
- ❑ Your opinion is clearly presented and defended using scientific evidence previously explained in your product.

Good Performance: Describes a product that completes all required components. Overall quality is good, but some areas have room for improvement.

- An historical context is provided, but does not clearly explain how the question originated or why it is important that it be answered.
- The explanation of the techniques and/or technologies related to the question is either incomplete or has minor inaccuracies.
- Few examples of products that are and/or could be produced using this technique and/or technology are provided.
- The questions used in the survey are presented along with the results. The explanation of the results is either unclear or is not used to answer the question.
- Information from published sources is used to describe all points of view related to the question. However, the explanation lacks clarity or has minor inaccuracies.
- Scientific evidence is provided to explain all points of view described, but is either not explained or is used incorrectly.
- The potential impact of the use of this technique and/or technology on society and/or the environment is explained, but the explanation lacks clarity or has minor inaccuracies.
- Your opinion is presented, but is not clearly defended using scientific evidence previously explained in your product.

Poor Performance: Describes a product that does not complete all required components. Overall quality is poor because several areas have room for improvement.

- Either an historical context is not provided or it does not clearly explain how the question originated or why it is important that it be answered.
- The explanation of the techniques and/or technologies related to the question is either incomplete or has major inaccuracies.
- No examples of products that are and/or could be produced using this technique and/or technology are provided.
- The questions used in the survey are not presented along with the results. The explanation of the results is either missing, unclear, or is not used to answer the question.
- Information from published sources is not used to describe all points of view related to the question. Additionally, the explanation lacks clarity or has major inaccuracies.
- Scientific evidence is not provided to explain all points of view described or the evidence provided is not explained or used correctly.
- The potential impact of the use of this technique and/or technology on society and/or the environment is not explained or the explanation lacks clarity and has major inaccuracies.
- Your opinion is not presented or it is not defended using scientific evidence previously explained in your product.

2002-2003
Classroom Expectations Rubric
Performance Feedback Form

Classroom Expectations Rubric *Performance Feedback*

Biology, Experimental Science,
Environmental Systems, Study Skills

Name: ______________________

Use the descriptors in this rubric to evaluate your recent performance in this class. Be honest with yourself, not overly harsh or generous. When you have completed this form, you will turn it in to me and I will provide you with feedback on how I view your performance. Complete this form by choosing one category that you feel best describes your performance, circling those items in that category that you feel apply, then circle items in other categories that you also feel apply.

I feel my recent performance has been __________________ because ______________________

____

____

I will work to improve my performance in the following way(s) before the next feedback time.

____

Exemplary Performance – Describes a student who consistently provides more than is expected to the learning process and enhances the learning of others through doing so. (4)

In addition to *Expected Performance* ...

- ☐ Often helps individual classmates better understand concepts, material, and/or instructions.
- ☐ Provides a great deal of positive input during whole class and group activities that helps all classmates better understand concepts, material, connections, and/or instructions.
- ☐ Provides only positive support and leadership for classmates.
- ☐ Actively works to promote a safe, positive learning environment in the classroom.

Expected Performance – Describes a student who is an active, supportive member of the learning process. (3)

- ☐ Attends class ***every*** day.
- ☐ Arrives in class ***on time*** and with all needed materials every day. Includes ...
  - *Completed* Assignment(s)
  - Notebook and Writing Utensil
  - Other Requested Materials
- ☐ Active, positive, participation in all classroom activities.
  - Asks and answers questions.
  - Provides input for solving/completing problems/tasks.
  - Provides input during group/team tasks.
- ☐ Interacts with everyone in the classroom in a positive and respectful manor.
  - Says only positive things about others, never degrading or hurtful.
  - Provides helpful support to classmates when working on assignments.
  - Completes all assigned tasks independently and on time.
- ☐ Follows all directions the first time they are given.
- ☐ Uses equipment and materials with care and according to provided instructions.

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Growing Performance – Describes a student who generally participates in a manor consistent with the *Expected Performance*, but needs improvement in one or two areas. (2)

- ☐ Misses at least one day of class. *or,*
- ☐ Arrives in class *late* or without all needed materials at least one time. *or,*
  - Incomplete Assignment(s) *or,*
  - Does not have notebook and/or writing utensil and/or other requested materials
- ☐ Participates little in classroom activities. *or,*
  - Asks and answers few or no questions. *or,*
  - Provides little or no input for solving/completing problems/tasks. *or,*
  - Provides little or no input during group/team tasks.
- ☐ Interaction with classmates is sometimes disrespectful or negative. *or,*
  - Sometimes says degrading or hurtful things to or about others. *or,*
  - Rarely or never provides helpful support to classmates when working on assignments. *or,*
  - Occasionally disrupts the work or attention of classmates through behavior. *or,*
  - Assigned tasks are not completed on time.
- ☐ Does not consistently follow all directions the first time they are given. *or,*
- ☐ Uses equipment and materials improperly or carelessly.

Poor Performance – Describes a student who does not participate or does not participate in a manor consistent with the *Expected Performance*. (1)

- ☐ Misses at least one day of class. *and/or,*
- ☐ Arrives in class *late* or without all needed materials at least one time. *and/or,*
  - Incomplete Assignment(s) *and/or,*
  - Does not have notebook and/or writing utensil and/or other requested materials.
- ☐ Little or no participation in classroom activities. *and/or*
  - Asks and answers few or no questions. *and/or,*
  - Provides little or no input for solving/completing problems/tasks. *and/or,*
  - Provides little or no input during group/team tasks.
- ☐ Interaction with classmates is sometimes disrespectful or negative. *and/or*
  - Sometimes says degrading or hurtful things to or about others. *and/or,*
  - Rarely or never provides helpful support to classmates when working on assignments. *and/or,*
  - Occasionally disrupts the work or attention of classmates through behavior. *and/or,*
  - Assigned tasks are not completed on time. *and/or,*
  - Assigned tasks are copied from another source.
- ☐ Does not consistently follow all directions the first time they are given. *and/or*
- ☐ Uses equipment and materials improperly or carelessly.

Teacher Feedback: I have circled items that I feel apply to your recent performance and may provide further feedback in the space below.

____

____

____

____

Appendix E

Diffusion Lab

Diffusion Lab

The purpose of this lab was to provide the students with a discrepant event, an event that would challenge their first impressions of a situation. This lab is designed as an open inquiry lab in which the students determine their own questions, hypothesis, and testing plans based on observations made during a demonstration.

In this example, I set up a demonstration using a material called dialysis tubing, a synthetic material that is semi-permeable. I mixed solutions of starch and iodine in front of the students, answering questions and encouraging clear observations while doing so. A single piece of dialysis tubing was prepared for the students to see, and filled with iodine solution just prepared as part of the demonstration. A beaker of starch solution had previously been prepared in the demonstration; a small amount was placed in a second beaker and combined with iodine for the students observation.

With all the materials prepared, the students were encouraged to record any information they thought would be useful before anything was done. One important piece of information was the color of the solutions, a second was the mass of the tube containing the iodine solution. With all observations recorded, the tube of iodine was placed in the starch solution for the student to observe.

The results were the starch solution turned blue and a change in mass of the tube filled with iodine. The students were allowed to discuss the results and compare them to predictions made before the demonstration and their recorded observations. This led to the development of questions by pairs of students related to what had happened. I read each team's question, either approving it or suggesting clarification. Once their questions were approved, each team developed a hypothesis and testing plan which were also submitted for my approval.

With an approved question, hypothesis, and testing plan, each team moved into the lab to test their hypotheses. Results were gathered and discussed as whole class. Each team was to use data collected by all students to help defend the conclusion they reached regarding their hypothesis.

Appendix F

Pond Lab

Pond Lab

The pond lab was developed to provide the students with an inquiry experience related to ecosystem ecology. The students engaged in this activity following the completion of a classroom project related to ecology and ecosystem structure. The primary goal was to provide the students to apply their understanding of ecosystem structure in another format.

In preparation for the construction of their test models, the students were provided samples I had collected from a local pond ecosystem. Over a couple of class periods, the students observed samples from the pond water to identify as many living and non living components of this system as they were able. This information was then used to create a simple food web for this ecosystem and to help the students construct their questions.

The students were provided with a list of the materials available for this investigation and asked to write questions about the function of one aspect of pond ecology they would each like to try and answer with this simple set up. The students wrote their questions with no opportunity for collaboration with peers. I then paired students based on similarity of their questions.

Once paired, the students worked with their partners to refine their questions, develop hypotheses, and design a test for their hypotheses. Each team had to have their final hypothesis and testing plan approved by me before they received materials. Each team set up their "pond" by adding all the same materials as the control plus one more variable, the removal of just one component, or in a few cases the addition of only limited materials to test their hypotheses. Except for those students whose questions were related to environmental variables, the experimental "ponds" were set outside in the same location as the control "pond".

The control pond was set up in a large glass jar with rocks, sediment, water, and vegetation from the pond site where supplies were collected. The control was designed to mimic as closely as possible the natural conditions of the real pond. For the duration of the experiment, the control "pond" was set outside of the building to receive natural sunlight.

Appendix G

Raw Data

Baseline Data

Group A: 1999 - 2000 General Biology
Lab Report Scores By Class Hour

Hour 1	Hour 2	Hour 3	Hour 4
32	31	18	23
19	29	28	27
19	20	28	32
24	22	25	29
27	27	35	30
29	31	26	24
31	22	28	25
6	30	22	25
27	36	27	40
21	30	29	24
32	25	21	25
31	26	13	25
22	28	24	26
26	23	27	28
28	28	29	16
18	24	21	27
24	20	26	23
	26	24	26
	28	25	33
	27	21	23
	35	31	

Class Average = 25.861
Standard Deviation = 5.1559

Baseline Data

Group B: 2000 - 2001 General Biology
Lab Report Scores By Class Hour

Hour 1	Hour 2	Hour 3
24	30	31
27	23	14
26	22	30
25	26	23
20	12	27
23	32	34
9	19	32
24	30	32
20	35	26
29	25	27
32	16	26
23	26	28
23	16	29
14	22	28
	27	21
	25	31
	29	25
		33
		29
		29
		25

Class Average = 25.269
Standard Deviation = 5.7296

Experimental Data

Group C: 2001 - 2002 General Biology
Lab Report Scores By Class Hour
Dialysis Tubing Experiment

Hour 1	Hour 2	Hour 4
34	25	39
42	24	31
27	24	31
29	24	32
23	28	32
35	28	37
35	22	37
27	22	42
27	25	33
44	21	33
44		
21		
30		

Class Average = 30.545
Standard Deviation = 6.792

Experimental Data

Group C: 2001 - 2002 General Biology
Lab Report Scores By Class Hour
Pond Study Experiment

Hour 1	Hour 2	Hour 4
25	16	29
35	34	33
23	23	21
24	16	37
24	21	39
25	11	33
24	21	38
39	21	37
30	28	44
28	16	31
24		24
20		31
23		
32		
39		

Class Average = 27.086
Standard Deviation = 7.7512

Data Analysis

Control Group	
Average =	25.626
Standard Deviation =	5.3771
Sample Size =	131

Experimental Group	
Average =	28.957
Standard Deviation =	7.4551
Sample Size =	70

Effect Size and Probability	
Effect Size =	0.6195
Standard Error =	0.891
t test =	3.7385
Probability =	0.0004

Effect Size Interpretation	
0.00 - 0.20	Small
0.21 - 0.50	Medium
0.51 - 0.80	Large
0.81 +	Very Large

Appendix H

Selected Student Written Lab Reports

"Starch and Iodine"
Student Work Example
Prepared by students conducting the diffusion lab during this capstone investigation.

Starch and Iodine

Abstract:

In a recent science class we saw an experiment conducted in which a strip of dialysis tubing was filled with starch solution and placed in a beaker of iodine solution. A chemical reaction occurred and turned the starch solution to a blue color. We were then asked to design an experiment to further study this. Our experiment involved changing the membrane in which the starch solution was enclosed. First we did the same experiment to check the results. We then went on to switch the dialysis tubing with a freezie pop tube, a test tube, and no membrane to further study the diffusion of the iodine into the starch.

Background Information:

We saw this demonstration performed to our class and wondered what the significance of the dialysis tubing was. We were also shown a similar demonstration where the dialysis tubing was not present. The iodine solution was directly placed into the starch solution. The iodine appeared not to diffuse throughout the starch solution to create a state of equilibrium as it did in the demonstration with dialysis tubing. (Modern Biology, 95-96) The cell membrane of an animal can be compared somewhat to dialysis tubing. The cell membrane is selectively permeable because it controls the substances that pass through it. The cell membrane is composed of lipids and proteins. The lipids have a head, which is attracted to water and a tail, which is not. The cell membrane has two layers of these lipids. Nothing can pass through this part of the cell wall but things can pass through proteins. However the proteins do not allow everything through. The cell membrane allows molecules to be transported through them by the means of special proteins like carrier molecules and gated channels. (Modern Biology)

Question

This leads us to our question of: Does the dialysis tubing help the chemical reactions occur between the two solutions?

Variables

Independent variable: membrane in which the starch solution is enclosed. The different membranes we will use are dialysis tubing, a test tube with a cork, a freezie pop tube, and no membrane.

Dependent variable: The rate of reaction, the concentration and diffusion of blue-like color.

Controlled variables: the amount of time between checks-5 minutes-2 times, 100mL or 10mL of iodine Solution, 10mL or 100mL of starch solution, the size of beaker (150mL), similar size of Membrane, same balance, and same observer.

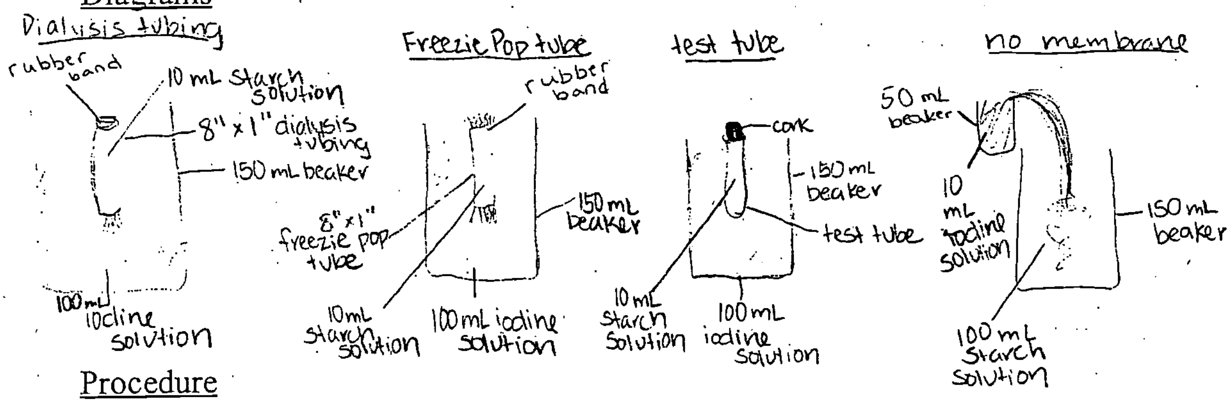
Hypothesis

The dialysis tubing will help the chemical reaction occur between the iodine and starch solutions. It will help by diffusing the iodine solution into the starch solution to create a state of equilibrium. The dialysis tubing allows the chemical reaction to occur from all sides of the membrane.

Materials and Equipment List

2 150mL beakers
1 50mL beaker
3x 10mL starch solution
100mL starch solution
3x 100mL iodine solution
10mL iodine solution
1 1"x8" strip of dialysis tubing
1 test tube capable of holding 10mL of solution
1 freezie pop container (aprox. 1"x8")
1 funnel
2 rubber bands
1 balance
1 cork (that fits the test tube)

Diagrams



Procedure

1. Prepare for experiment by tying back long hair and removing loose clothing. Put on safety goggles, apron, and gloves. Clear work area.
2. Collect needed supplies found in the materials and equipment list.
3. Take the mass of the test tube, the 150-mL beakers, the dialysis tubing, the freezie pop tube, the test

tube, and the 50-mL beaker. Record these measurements of the Mass Data Table.

4. Fill a 150mL beaker with 100-mL of iodine solution. Record color and characteristics of the solution in the Observation Data Table.
5. Tie a knot in one end of the dialysis tubing as close to the end as possible.
6. Have your partner hold a funnel over the open end of the tubing. Pour in 10-mL of starch solution.
7. Tie the open end of the dialysis tubing with a piece of a rubber band.
8. Take the mass of the starch solution filled dialysis tubing. Record it on the Mass Data Table.
9. Place the Starch filled dialysis tubing into the beaker of iodine. Immediately record the colors and characteristics that result from the chemical reaction into the Observation Data Table.
10. Wait 5 minutes and record the colors and characteristics of both solutions into the Observation Data Table.
11. Repeat step 10.
12. Remove Dialysis tubing from iodine solution and find the tubing's mass, record on Mass Data Table.
13. Repeat step 4.
14. Have your partner hold the funnel over the open end of a freezie pop tube and pour 10-mL starch solution into the tubing, record the color and characteristics in the Observation Data Table.
15. Tie the open end of the tubing with a rubber band as tight as possible.
16. Take the mass of the starch filled freezie pop tube and record it on the Mass Data Table.
17. Repeat steps 9-12 substituting the dialysis tubing with the freezie pop tubing.
18. Repeat step 4.
19. Have your partner hold the funnel over the open end of the test tube and pour 10-mL of starch solution, record its color and characteristics of the Observation Data Table.
20. Place the cork over the open end of the test tube.
21. Take the mass of the starch filled test tube and record it of the Mass Data Table.
22. Repeat steps 9-12 substituting dialysis tubing with the test tube.
23. Fill a 150-mL beaker with 100-mL of starch solution and record its color and characteristics on the Observation Data table.
24. Take the mass of the starch filled beaker and record it on the Mass Data Table.
25. Fill the 50-mL beaker with 10-mL of Iodine solution and record its color and characteristics on the Observation Data Table.
26. Take the mass of the iodine filled 50-mL beaker, and record it on the Mass Data Table.
27. Pour the iodine solution into the starch solution and immediately record its color and characteristics on the Observation Data Table.
28. Repeat steps 10 and 11.

29. Mass 150-mL beaker with contents and record this weight on the Mass Data Table.

30. Clean up the lab station, wash and return all supplies.

Results

Tables:

Mass Data Table

Object	Weight Before Reaction	Weight after reaction
Dialysis Tubing	.95 g	
Test tube w/cork	24.31 g	
Freezie pop tube	1.21 g	
150-mL beaker	83.11 g	
50-mL beaker	48.30 g	
Dialysis tubing & starch sol.	7.12 g	7.09 g
Freezie pop & starch sol.	5.25 g	5.31 g
Test tube & starch sol.	28.75 g	28.90 g
150-mL beaker & starch sol.	163.45 g	167.91 g
50-mL beaker & 10-mL iodine	53.80 g	

Observation Data Table

Object	Before	Immediately After	5 Minutes After	10 Minutes After
Iodine	Brown-orange cloudy liquid	No apparent change	No apparent change	No apparent change
Tubing & Starch	White cloudy liquid	Slight blue tinge, iodine clings to outside	Dark blue coloration	Darker blue coloration than previous When taken out, the had a blue liquid on it.
Iodine	Brown-orange cloudy liquid	No apparent change	No apparent change	No apparent change
Freezie & Starch	White cloudy liquid	No apparent change	No apparent change	No apparent change
Iodine	Brown-orange cloudy liquid	No apparent change	No apparent change	No apparent change
Test Tube & Starch	White cloudy liquid	No apparent change	No apparent change	No apparent change
Iodine	Brown-orange cloudy liquid	Blue Medium blue in middle	Blue	Blue
Iodine & Starch	Dark blue, but uneven diffusion Bottom layer is still white, very dark on top	Blue, medium blue in middle	Same as Previous	Same as Previous

No leakage at knots and rubber bands.

Calculations

Mass changes after the chemical reactions.

Dialysis tubing & starch solution: 7.12g − 7.09g = -0.03g

Freezie pop & starch solution: 5.31g − 5.25g = +0.06g

Test tube & starch solution: 28.90 − 28.75 = +0.15

150-mL beaker & starch solution: = No mass change

Summarization of Data

It appeared that the dialysis tubing assisted in the diffusion of the iodine into the starch solution. It also appeared that the test tube and freezie pop tube did not allow the chemicals to penetrate the membrane. When we used no membrane the chemicals did not diffuse well. Also, most of the chemical filled membranes lost a small amount of mass beyond the margin of error.

Discussion

Conclusions

Our hypothesis was correct. The dialysis tubing helped the chemical reaction occur between the iodine and starch solutions. This is supported by some data on the observation table. When we directly placed the iodine solution into the starch solution it didn't diffuse evenly. The top turned dark blue while the bottom remained a cloudy white. When we used the dialysis tubing it was an even color of blue throughout the dialysis tubing. When we used other membranes there was no apparent diffusion through the membrane. From this we can see that the dialysis tubing helped with the diffusion of the chemicals.

Interpretations and Explanations

Through diffusion the chemicals go from a higher concentration to a lower concentration. The dialysis tubing aids the diffusion by allowing the chemical iodine to transfer through the iodine. Our hypothesis was very similar to our results; we could not find many differences between the two. However, now we have scientific evidence to back up our hypothesis.

We thought possibly the know may have leaked but during the lab we carefully observed this and found no leakage at the areas of the knots and rubber bands. One area of error could be the margin of error of the balance that we used. Our science teacher made a new batch of starch solution in the middle of our experiment. I observed and even aided in the mixing of the solution and saw that the ingredients were not precisely measured. This could have lead to a different chemical concentrations and made errors in our results (he he).

Questions for Further Research

Would it make a difference if we added starch solution to the iodine solution instead of adding iodine solution to the starch solution in the no membrane experiment?

If we set the dialysis tubing on top of the iodine solution would the diffusion still occur as quickly?

Overall score 3

Rubric for Scoring Investigations

General Biology, Advanced Biology, Chemistry, Environmental Systems
Mr. Tony McGee
Wabasha-Kellogg High School

Description of Scores:

4.0 ~ Exemplary Work — ***Work Exceeds "Standard" or Expected Level***
- All work exceeds the criteria listed below, *and*
- Accurate, original, unguided insight is shown in the application of scientific concepts.

3.0 ~ Proficient Work — ***Work is at "Standard" or Expected Level***
- All required components are completed, *and*
- Work is organized properly &/or logically, *and*
- All information is clear and accurate, *and*
- Work is free of extra information, *and*
- A consistent level of high quality is present throughout the work.

2.0 ~ Novice Work — ***Work is Approaching "Standard" or Expected Level***
- *All required components are completed, *and*
- Work is organized improperly &/or poorly, *or*
- Information is either unclear or inaccurate, *or*
- Work contains some extra information, *or*
- Quality of work is inconsistent.

1.0 ~ Emerging Work — ***Work is Significantly Below "Standard" or Expected Level***
- Some required components are missing or incomplete, *and*
- Work is poorly &/or improperly organized, *&/or*
- Information is neither clear or accurate, *&/or*
- Work contains some extra information, *&/or*
- Quality of work is poor or inconsistent.

0 ~ Work is either not turned in or is copied from another source.

(__X) 3 — ***Abstract***
A clear, concise summary of the investigation is provided in less than 150 words.

(__X) 11-12 — ***Introduction***

3 A. Background Information — Great Detail
- Explains why the question or problem is of interest.
- Presents what is already known about the question or problem.
- Properly cites sources of factual information.

2-3 B. Question or Problem
- Clearly Stated — I still feel, as written, it is hard to test.
- Is ~~testable~~ and leads directly to predictions.

3 C. Variables — well written
- Are correctly identified as independent, dependent, and controlled.

3 D. Hypothesis
- A clear statement that predicts the results.
- Based on scientific concepts clearly stated in the background information.
- Directly related to the question or problem.

You certainly had the most ambitious ideas & experiment. I think you tested exactly what you were thinking, but have struggled to explain it in writing.

(__X) 9 — ***Methods and Materials***

3 A. Materials and Equipment List
- Provides a complete and accurate list of materials and equipment used in the investigation. List includes sizes and concentrations of all materials and equipment.

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Methods and Materials Continued

3 B. Diagram of Experimental Set-Up Excellent!

- May include a diagram of the experimental set-up that clearly depicts and accurately labels items from the materials and equipment list.
- Is drawn to scale.

Procedure gets confusing with the use of Repeat step x. Very complete however. Would have gone faster if you hadn't done each separately.

1 C. Description of Experimental Design

- Provides a clear and accurate description of the testing environment including descriptions of the...
  - control group,
  - experimental group,
  - environmental conditions,
  - sampling/ data collection procedures, *and*
  - data recording procedures.

2-3 D. Procedure Very very close.

- Provides a clear, accurate, step x step procedure that ...
  - tells when and how all materials are used,
  - indicates when and where data is to be recorded,
  - includes safety and clean up procedures, *and*
  - includes sufficient detail to be repeated by others.

(__X) 12+

Results

3 A. Raw Data

- Raw data is included with the report, typically attached to end.

3 B. Graphs &/or Tables Lots of great info.

- Data is clearly and logically organized in appropriate tables.
- Data is presented in a properly constructed graph when appropriate.
- All data in tables and graphs clearly and accurately labeled.
- Reports measurements that reflect the accuracy of the instruments used.
- Provides organized data from all trials.

3 C. Calculations

- Clearly states algebraic equations and statistical techniques used.
- Shows correctly performed calculations.
- Correctly labels all data used in calculations.

3 D. Summarization of Data

- Clearly explains the data presented in tables &/or graphs.
- Identifies and describes trends that appear in the data, tables, &/or graphs.

(__X) 8

Discussion

3 A. Conclusion(s)

- Restates the hypothesis.
- Identifies data from the results that support &/or refute the hypothesis.
- Clearly states if the data supports or refutes the hypothesis.

2-3 B. Interpretations and Explanations Could have explored the permeability of the other membranes

- Uses scientific concepts to explain the results obtained.
- Explains differences between the hypothesis and the results.
- Identifies areas where error(s) may have occurred.

3 C. Questions for Further Research

- Suggests at least two testable questions that could be investigated to ...
  - clear up problems with your results, or
  - further support your explanations, or
  - help explain unexpected results, or
  - explore thoughts or questions you had while conducting the investigating.

Student Work Example
Prepared by students conducting the diffusion lab during this capstone investigation.

*Abstract

Our question was "Why does a mass change occur when you place dialysis tubing filled w/ starch solution into iodine solution?" Our hypothesis was "Some of the starch solution soaked through into the iodine." After conducting the experiment, we found out our hypothesis was wrong.

*Introduction

In Biology class, we were learning about cell membranes. This experiment was supposed to mimmick how an actual cell membrane works.

Prior to conducting our own experiments, we observed that when you placed starch solution in dialysis tubing and then placed that in iodine solution for 10 minutes, the starch solution would turn from a white-ish color to a dark blue color, and the mass of the dialysis tubing decreased. (starch solution) The color also changed when there was no dialysis tubing. From this we concluded that the dialysis tubing must be atleast semi-permiable, meaning it allows some materials to pass through it. (Modern Biology, 73) This means that the dialysis tubing allowed the iodine solution to diffuse through it. Diffusion is the movement of molecules from an area of higher concentration to an area of lower concentration. Osmosis is the diffusion of water. Diffusion and osmosis are both types of transport. At this point, we weren't sure if osmosis was occuring or not. (Modern Biology, 73) Real cell membranes are made out of Lipids and proteins. Lipids have a head and 2 tails. The tails are hydrophobic and the heads are hydrophilic. Since the inside and outside the cell is surrounded by water, it causes the Lipids to form 2 layers, or a lipid bilayer. (Modern Biology, 73) In order for things to pass through the

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bilayer, we need proteins. Proteins control what gets in and out of a cell. (Modern Biology, 73)

Our question was: Why did the mass of the starch solution change? The independent variable was the iodine solution, the dependent variable was the starch solution, and the controlled variable was the dialysis tubing and the amount of solutions used.

Our hypothesis was "Some of the starch solution soaked through the tubing into the iodine."

*Materials & Methods

150 ML Beaker	Dialysis tubing
100 ML Beaker	Rubber band
10 ML Starch Solution	funnel
100 ML Iodine Solution	Balance

Procedure:

1 Put on gloves, goggles, aprons, pull back hair, clear work area.
2 Pour 100 ML of Iodine solution into the 150 ML Beaker.
3. Pour 10 ML of Starch solution into the 100 ML Beaker.
4. Record the color of the Iodine solution in your table
5. Take the dialysis tubing and securely tie a knot at one end, as close to the bottom as possible.
6. Using the funnel, pour the Starch solution into the dialysis tubing, and secure the top with the rubber band. (Make sure it's tight)
7. Take and record the mass of the dialysis tubing in your table.
8. Place the dialysis tubing in the iodine solution.

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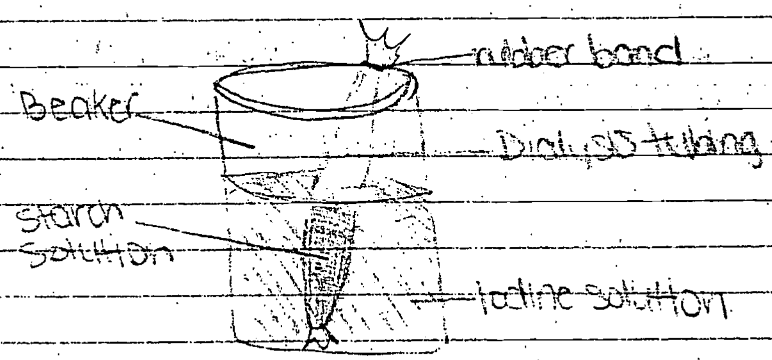
making sure that the top end (secured with rubber band) is not submerged.
9. Wait 10 minutes In your table ✓
10. Take and record the mass of the dialysis tubing, making sure to wipe off any excess solution on the outside before measuring.
11. Record the color of the iodine solution, noting any significant changes. in your table
12. Clean up work area, wash all beakers, and put everything back as you found it.

Diagram of Experimental set up:



*Results

TABLE A

	BEFORE	AFTER 10 MIN.	Changes
Description of Iodine solution	Rusty Orange in color, semi-transparent	rusty orange in color, semi-transparent	no apparent change
Mass of Starch solution	8.6 g	8.4 g	It lost .2 g

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Calculations: 8.6 g - 8.4 g = .2 g

Summary: Table A summarizes our results. We started with 8.6 g of starch solution and then 10 minutes later, after the reaction occured, the mass was reduced to 8.4 g. There was no change in the iodine solution throughout the experiment. This is what happened in the controlled experiment also. In our experiment though, the mass lost was a lot less (.2 compared to .9)

*Discussion

Our hypothesis was "Some of the starch solution soaked through the tubing into the iodine". The results of our experiment did not support our hypothesis. If this would have occured, the iodine solution would have changed color, and in our experiment the iodine solution never changed color. This happened because the dialysis tubing didn't allow the starch to pass through it. It did however let iodine pass through. This makes the tubing semi-permiable. So, our results were the exact opposite of what our hypothesis was. We believe that no errors occured because our results were confirmed by the first experiment that we observed. The same thing happened there.

The question that we still have is why did the mass change? Also, why doesn't the dialysis tubing change colors? Does the amount of time that the dialysis tubing is in the iodine solution affect the amount of mass lost?

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overall score almost a 3

Rubric for Scoring Investigations

General Biology, Advanced Biology, Chemistry, Environmental Systems
Mr. Tony McGee
Wabasha-Kellogg High School

Description of Scores:

4.0 ~ Exemplary Work — ***Work Exceeds "Standard" or Expected Level***
- All work exceeds the criteria listed below, *and*
- Accurate, original, unguided insight is shown in the application of scientific concepts.

3.0 ~ Proficient Work — ***Work is at "Standard" or Expected Level***
- All required components are completed, *and*
- Work is organized properly &/or logically, *and*
- All information is clear and accurate, *and*
- Work is free of extra information, *and*
- A consistent level of high quality is present throughout the work.

2.0 ~ Novice Work — ***Work is Approaching "Standard" or Expected Level***
- *All required components are completed, *and*
- Work is organized improperly &/or poorly, *or*
- Information is either unclear or inaccurate, *or*
- Work contains some extra information, *or*
- Quality of work is inconsistent.

1.0 ~ Emerging Work — ***Work is Significantly Below "Standard" or Expected Level***
- Some required components are missing or incomplete, *and*
- Work is poorly &/or improperly organized, *&/or*
- Information is neither clear or accurate, *&/or*
- Work contains some extra information, *&/or*
- Quality of work is poor or inconsistent.

0 ~ Work is either not turned in or is copied from another source.

(__X) 3 ***Abstract***
A clear, concise summary of the investigation is provided in less than 150 words.

(__X) 10 ***Introduction***

3-4 A. Background Information — very well written!
- Explains why the question or problem is of interest.
- Presents what is already known about the question or problem.
- Properly cites sources of factual information.

3 B. Question or Problem
- Clearly Stated
- Is testable and leads directly to predictions.

2 C. Variables — what did you change + predict?
- Are correctly identified as independent, dependent, and controlled.

3 D. Hypothesis
- A clear statement that predicts the results.
- Based on scientific concepts clearly stated in the background information.
- Directly related to the question or problem.

(__X) 7 ***Methods and Materials***

3 A. Materials and Equipment List
- Provides a complete and accurate list of materials and equipment used in the investigation. List includes sizes and concentrations of all materials and equipment.

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Methods and Materials Continued

2 B. Diagram of Experimental Set-Up Should have amounts

- May include a diagram of the experimental set-up that clearly depicts and accurately labels items from the materials and equipment list.
- Is drawn to scale.

X C. Description of Experimental Design

- Provides a clear and accurate description of the testing environment including descriptions of the...
    - control group,
    - experimental group,
    - environmental conditions,
    - sampling/ data collection procedures, *and*
    - data recording procedures.

2-3 D. Procedure

- Provides a clear, accurate, step x step procedure that ...
    - tells when and how all materials are used,
    - indicates when and where data is to be recorded,
    - includes safety and clean up procedures, *and*
    - includes sufficient detail to be repeated by others.

very-very close!

(__X) 8 *Results*

0 A. Raw Data

- Raw data is included with the report, typically attached to end.

2 B. Graphs &/or Tables what about change in starch color?

- Data is clearly and logically organized in appropriate tables.
- Data is presented in a properly constructed graph when appropriate.
- All data in tables and graphs clearly and accurately labeled.
- Reports measurements that reflect the accuracy of the instruments used.
- Provides organized data from all trials.

3 C. Calculations

- Clearly states algebraic equations and statistical techniques used.
- Shows correctly performed calculations.
- Correctly labels all data used in calculations.

3 D. Summarization of Data

- Clearly explains the data presented in tables &/or graphs.
- Identifies and describes trends that appear in the data, tables, &/or graphs.

(__X) 9 *Discussion*

3 A. Conclusion(s)

- Restates the hypothesis.
- Identifies data from the results that support &/or refute the hypothesis.
- Clearly states if the data supports or refutes the hypothesis.

3 B. Interpretations and Explanations

- Uses scientific concepts to explain the results obtained.
- Explains differences between the hypothesis and the results.
- Identifies areas where error(s) may have occurred.

3 C. Questions for Further Research

- Suggests at least two testable questions that could be investigated to ....
    - clear up problems with your results, or
    - further support your explanations, or
    - help explain unexpected results, or
    - explore thoughts or questions you had while conducting the investigating.

"Pond Lab"
Student Work Example
Prepared by students conducting
the pond lab during this
capstone investigation.

Pond Lab

[redacted]

Abstract:

We did an experiment on how the extreme temperature like freezing would affect the pond environment. We tested this through a matter of five days and gained results to help support our hypothesis. We collected data through slide samples and through observations throughout our experiment. In the end we found that the freezing of pond water (as in the winter) causes the organisms to begin to die out and to decompose most of the vegetation matter. We also found that not many organisms are apt to survive through such temperature changes.

Introduction:

Background Information:

We were asked to pose a question about the community interactions in a pond environment by our favorite science instructor Mr. McGee. We chose our question because both of were curious about what would happen to the organisms and the community if we froze the miniature pond ecosystem. We wanted to see of it would mimic the winter conditions of a pond. When affecting the ecosystem we were told to use a biotic or abiotic variable. We chose the abiotic variable of temperature which we feel would greatly have an affect of the environment. (Modern Biology) We are aware that when temperatures lower a lot the pond water will freeze. We also know that during the winter some organisms hibernate or may finish their lives, while some organisms only have a short life span in the first place. However, we also know that pond life resumes in the spring. So we wondered if this would happen in this situation.

Question:

How will these aquatic organisms react to an extreme temperature change? (cold)

Variables:

<u>Independent</u>: Temperature, (location of jar)
<u>Dependent</u>: Amount of organisms, movement of organisms, interaction among organisms, color of the water, density of the water, vegetation color, the smell of the environment
<u>Controlled</u>: Jar size, vegetation life, ecosystem, amount of water, amount of sediment, time allotted for temperature change, organism amounts, and location of samples taken.

Hypothesis:

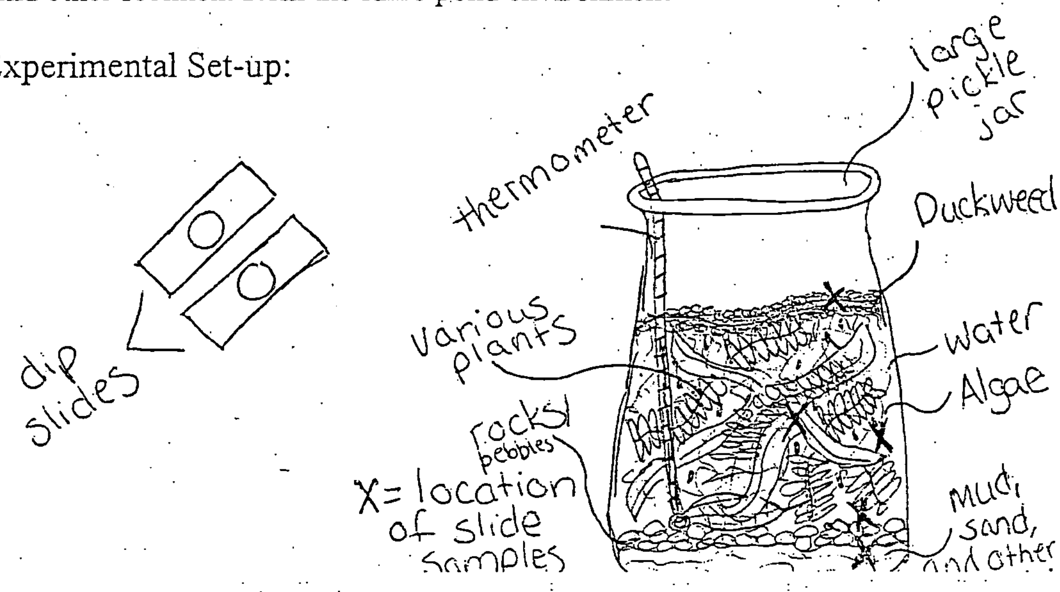
Aquatic organisms will react to an extreme temperature change in a natural way. We feel that when we expose the organisms in our pond ecosystem, they will react in a way that is similar to how they would react to a winter. We think that they will all probably die, but it is probable that if enough time is given, they will regenerate once the pond returns to its normal state, temperature wise. We also think that perhaps some organisms will try to hibernate in the sediment. Temperature change is an abiotic factor and thus it is natural to the environment. This made us feel that if a natural factor was change then the pond would react in a natural way and possible regenerate itself as if it would in the springtime. In the lab previous to the experiment we saw many different organisms, and it interested us into thinking "how would each of these organisms react to a temperature change such as freezing cold" and "would each organism react differently or the same".

Methods and Materials:

Material and Equipment List:

- ☆ Large pickle jar
- ☆ 2 Dip slides
- ☆ Microscope
- ☆ Squeeze dropper
- ☆ Dry erase marker
- ☆ 2 thermometers
- ☆ refrigerator
- ☆ freezer
- ☆ pond water
- ☆ various vegetation from the same pond environment
- ☆ duckweed from the same pond environment
- ☆ mud, rock, and other sediment form the same pond environment

Diagram of Experimental Set-up:



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Description of Experimental Design:

Control: environment- we chose this overall environment plan in order to have an environment very similar to a real pond environment. Vegetation- we chose no specific vegetation for this environment, except that they were natural to the environment we chose, however, we did choose duckweed for our experiment because we felt that it would make our environment more natural and that it could possibly help in the experimental process. Amount of water- (3/4 full) we chose this amount of water because we felt that that was appropriate amount of water for a realistic pond environment, and we never added or removed water from our jar for this same reason. Time allotted for temperature change- we aloud 24 hours for each individual temperature change we had, we did this to keep consistency in our experiment. Location of samples taken- we got samples of the pond environment from the same location each time, to also keep consistency in the environment. Sediment- we chose the natural layered sediment of a pond (rocks, then sand and mud), we wanted this not only to keep the consistency, but also to see if the organisms would try to "hid" in the sediment when the cooling temperature change occurred.

Experimental group: Temperature change, we changed the temperature from the natural outside environment to the refrigerator environment to the freezer environment and back again.

Environmental conditions: (see above, in controlled)

Sampling data collection procedures: (samples taken- in controlled, see above), Observation- we observed the organism that were visible from the outside of the jar and also the ones we took samples of, we looked at how they affected each other and at how they were affected by the cooling of the water, we looked at the water level, the smell of the water, sedimentation of the water, the color of the plants, and the ice color and location (after frozen).

Data recording procedures: We created two charts that we used to collect all of this data, one was for the slides we used, and the other was for observation recording, and also temperature recording.

Procedure:

1- Prepare for experiment by tying back long hair. Clear work area.

2- Collect materials needed for experiment.

3- Fill the bottom of your jar with the sediment, starting with the sand and mud, and then adding the small rocks.

4- Pour pond water into your jar so that it is ½ full.

5- Add vegetation to you jar by carefully setting 2 average size handfuls of plants into the water.

6- Pour more pond water into the jar so that the jar is now ¾ of the way filled.

7- Now add duckweed to the top of the jar so that it fully covers the top of the water.

8- Allow 24 hours outside for the pond environment to settle.

9- Take the temperatures of the "backyard" and the temperature of the pond environment and record it on you Observation Data Table.

10- Make visual observations of the plants, organisms, community interactions, and other observations (such as smell, water level, and sediment settlement) of the pond environment. Record this in the Data Observation table.

11- Take slide samples from the water: 2-3 from the top, 2-3 form the middle, (one in plants, one not), 2-3 from the bottom (one in sediment, one above it) record your observations onto the Slide Data Table.

12- Place the jar pond environment into the refrigerator for 24 hours.

13- Repeat steps 9-11, replacing the word "backyard" with "refrigerator".

14- Place the jar pond environment into the freezer for 24 hours.

15- Repeat steps 9-11, replacing the word "backyard" with "freezer".

16- Place the jar pond environment back into the refrigerator for 24 hours.

17- Repeat steps 9-11, replacing the word "backyard" with "refrigerator".

18- Place the jar pond environment back into the "backyard" for 24 hours.

19- Repeat steps 9-11.

20- Clean up the lab station, wash and return all supplies.

Results:

Tables:
(See next 2 pages)

Calculations: (Temperatures)

	Day 1: 27.8°C	Day 2: 4.2°C	Day 3: -11°C	Day 4: 6.1°C
	Day 2: - 4.2°C	Day 3: -(-11)°C	Day 4: -6.1°C	Day 5: -29.0°C
Temp. change =	23.6°C	15.2°C	17.1°C	22.9°C

Summarization:

Our tables show observations that we took in our experiment. We found that in general after freezing our pond environment a large majority of the organisms died. When looking at our Slide Data Table we saw that the algae was present in the environment all five days. Although we did see that the vegetation beginning to decomposing. During Day 1 of the experiment we found many larger organisms that were alive, but as our experiment progressed and the temperature changed we saw that the organisms size and number began to decline. The same thing began to occur within the community interaction of the environment. For example, we noticed that small water beetles seemed to have "disappeared" after the pond environment was frozen for 24 hours. Before they "disappeared", and the water was cooling in the refrigerator we noticed that the number of beetles began to decline. We also noticed that on Day 2, slide two, we discovered a small worm in the sediment at the bottom of the jar that was alive and covered in sediment. The vegetation in the pond environment stayed a greenish natural color until the fourth and fifth days when the water in the pond was beginning to thaw out after being frozen. On Day 4 and Day 5 we noticed that the duckweed was beginning to turn brown and white and began sinking into the water, and the other vegetation (plants) started turning darker and became becoming "limpy". Also on Days 4 and 5 we tended to find either dead organisms or we did not discover many organisms. Also as the days went on the sediment settled more to the bottom. Another thing that occurred as the time progressed was that in the beginning the water had no distinctive smell to it, but as the days went on and the water thawed out the pond environment expelled an odor that was quite distinctive. The water level of the pond environment stayed the same until Day 5, where it declined more than before.

Observation Data Table

Elements	Day 1	Day 2	Day 3	Day 4	Day 5
Temperature and Location of jar (pond environment)	27.8°C Outside Temperature	4.2°C Refrigerator over weekend	-11°C Freezer Temperature	6.1°C Refrigerator Temperature	29.0°C Outside Temperature
Plants	Fill most of the jar, greenish brownish natural color duckweed on top, dead leaf	fill most of jar, browner than before natural color, duckweed more spread out	Not Moving frozen still in water natural color duckweed on top, but ice layer above green	Same natural color duckweed on top, appear slightly darker	darker, "limpy" duckweed-way less, turned brownish white, sinking leaf darker algae still green
Organisms	small bugs crawling, water beetle in middle and bottom, blood worm, snail on rocks	way less bug movement, organisms floating not swimming, clear worm, a few organisms moving, snail dead	No visible movement, no sight of bugs, snail still dead	dead scud at bottom, no noticeable organisms lots of dead ones, snail still dead	dead bug floating on top, dead damsel fly nymph, no live organisms visible
Community Interaction	normal like creature eating algae, water bugs swimming around in middle, many on top on duckweed	few less bugs eating plants, less bugs swimming around, organisms in bottom sediment	no movement "preserved" environment, sediment settled all to bottom	a lot of dead organisms, little movement, small particle very small movement, plants in center in ice	no visible interactions, dead and decomposing organisms plants sinking and wilting water darkening
Other Observations	Sediment sunk to bottom, water mark water level cloudy	water seems little darker, fogged jar, sediment settled more, no distinctive smell	frozen solid, water level increased, expanded, ice is clear but white in middle, no bad smell	water is starting to thaw back only top center is left frozen little smell	Smells more, water is dark, water level down, sediment still on bottom

Slide Data Table

	Day 1	Day 2	Day 3	Day 4	Day 5
<u>Top</u>					
Slide 1	Lots of duckweed more plants than animals	lots of algae, moving organisms	algae, worm not moving	algae, organism moving, lots of dead organisms	dead brown organism, dead duckweed
Slide 2	duckweed, algae	duckweed dead organism, algae,	organism, red, not moving, algae, duckweed	dead organism, rotifer, algae	algae, brown and green organisms not moving
<u>Bottom</u>					
Slide 1	plants, algae, more plants	algae, lots of sediments	NOT AVAILABLE	algae, duckweed, sediment	algae, organisms, dead plants
Slide 2	larger organisms, algae	worm covered in sediment, small moving organisms	NOT AVAILABLE	Particle moving, algae, organism	duckweed slightly green
Slide 3	midge larvae, blood worm	clear small worm, organisms floating	NOT AVAILABLE	sand, duckweed dead, dead scud	lots of sediment and weeds
<u>Middle</u>					
Slide 1	less organisms algae, spirogyra	large dead plant, algae, duckweed	NOT AVAILABLE	duckweed, algae	algae, plant dead
Slide 2	algae duckweed	algae, few visible organisms	NOT AVAILABLE	organism, dead algae	algae, plants dead, discolored duckweed
Slide 3	water bug, spirogyra	organism dead not moving small	NOT AVAILABLE		algae, sediment dead blood worm dead plant

Discussion:

Conclusions:

Our Hypothesis was: Aquatic organisms will react to an extreme temperature change in a natural way. We felt that when we exposed the organisms in our pond ecosystem, they would react in a way that was similar to how they would react to a winter. For the most part our hypothesis was correct. We felt that the organisms would probably die out, and we noticed in our experiment that as we stated in our summarization that the number and size of the organisms decreased over the five-day span of our experiment. Also as we stated in our summarization the plant life: darkened after being frozen, became "limpier" after being frozen, and began to decompose after being frozen. The duckweed began sinking into the pond water and also began to become a whitish brownish color. We also found many dead organisms, which shows that part of our hypothesis was correct. The worm that we found buried in the sediment seems to have showed that perhaps it was trying to hide in the sediment to remove itself from the rapidly cooling environment. We believe that bacteria and fungi seemed to survive throughout the temperature change because we noticed our pond environment began to decompose and the environment also seemed to have created a lovely (horrible) smell. We were not able to see if the environment would regenerate itself once it was returned to it natural temperature state due to a limited time of 5 days for our experiment. But we feel that if enough time were allotted perhaps at least the plants would have regenerated and would have grown back into our pond environment.

Interpretations and Explanations:

The abiotic factor of temperature has a large impact on the environment around it. In the winter vegetation and/or organisms usually do "die out". So, our results have us assumed that the results occurred because we implemented winter like conditions into the pond environment. We feel that the freezing of the pond prevented the organisms from going about their regular life cycles and that this may have caused a rift in the food web. The loss of life in the environment probably caused a chain reaction in the environment that left the entire environment affect not only as a whole but also in each individual's distinct "responsibilities". For example, when the producers began to die and decompose the organisms that hid and fed off them also decomposed. Also we felt proper sunlight the plants may not have been able to perform photosynthesis properly. Thus another chain reaction was caused throughout the environment. As we stated earlier we feel that the bacteria and fungi that survived began to decompose the organisms as is natural in an environment/community. Although our hypothesis was well backed up by the results we found that there were still differences among the two. For example, we were incorrect in thinking that these organisms would have hibernated due to their short life spans. We also found that from our observations no non-vegetation organisms survived the environment while it was completely frozen. However this is only from what we observed. Although we tried very carefully to be consistent in our experiment we are aware that a few errors may have occurred. One very large error was the location of the jar and its affects on the experiment. When cooling our jar we placed it in the refrigerator and freezer unfortunately both of these environments were not lighted all of the time so we were not able to have "sunlight" in our environment at all times as would be natural. Another item that we may have changed if possible is the amount of slides, and placement of the samples taken. With more slides we would have been able to represent more of the environment and we would have been able to locate more organisms in the pond environment. However we feel with the time allotted and materials provided we did a rather adequate job.

Questions for Further Research:

☆ If we allowed the pond to stay in Mr. McGee's "backyard" for a longer amount of time would the pond have regenerated itself?

☆ If we had placed a light in the refrigerator and freezer would the results have varied?

☆ If we had allowed temperature changes to have occurred for longer than 24 hours would our results be different?

“Salt Lab”
Student Work Example
Used as an exemplar while instructing
Group C on lab report preparation.

Salt Lab

Abstract

Our team was given a value of 2.48 g of NaCl to produce. Using only this data, we used mathematical formulas to find how much of each reactant we would need to produce the desired amount of NaCl.

Introduction

We wanted to know if it would be possible to combine x amounts of $NaHCO_3$ and HCl and get an exact amount of NaCl as a product. Our group was given the task of producing 2.48 grams of NaCl. Our equation and data:

$NaHCO_3$ +	HCl -->	CO_2 +	H_2O +	NaCl	
3.56 g.	1.55 g.	1.87 g.	.764 g.	2.48 g.	grams
0.0424 mol	0.0424 mol	0.0424 mol	0.0424 mol	0.0424 mol	moles
2.55×10^{22}	2.55×10^{22}	2.55×10^{22}	2.55×10^{22}	2.55×10^{22}	molecules

First we needed to find out how many moles of each substance we needed. We used the following equation to determine that amount:

$$\frac{2.48 \text{ g. NaCl}}{1} \cdot \frac{1 \text{ mol NaCl}}{58.44277 \text{ g/mol}} = 0.0424 \text{ mol NaCl}$$

As you can see, we got the value of 0.0424 mol for our answer. Since the mole ratio of our equation was 1:1, the number 0.0424 applied to each of our reactants and products. Next we found the number of grams per mole for each of our compounds by adding by adding the mass of the elements that make up each individual compound. Our math:

$NaHCO_3$

22.98977 + 1.0079 + 12.011 + 15.9994 + 15.9994 + 15.9994 = 84.00687 g/mol $NaHCO_3$

HCl

1.0079 + 35.453 = 36.4609 g/mol HCl

CO_2

12.011 + 15.9994 + 15.9994 = 44.0098 g/mol CO_2

H_2O

1.0079 + 1.0079 + 15.9994 = 18.0152 g/mol H_2O

NaCl

22.98977 + 35.453 = 58.44277 g/mol NaCl

Using this data, we were then able to calculate how many grams of each substance we needed. Our math:

NaHCO$_3$

$$\frac{0.0424 \text{ mol } NaHCO_3}{1} \cdot \frac{84.00687 \text{ g/ mol } NaHCO_3}{1 \text{ mol } NaHCO_3} = 3.56 \text{ g } NaHCO_3$$

HCl

$$\frac{0.0424 \text{ mol HCl}}{1} \cdot \frac{36.4609 \text{ g/mol HCl}}{1 \text{ mol HCl}} = 1.55 \text{ g HCl}$$

CO$_2$

$$\frac{0.0424 \text{ mol } CO_2}{1} \cdot \frac{44.0098 \text{ g/mol } CO_2}{1 \text{ mol } CO_2} = 1.87 \text{ g } CO_2$$

H$_2$O

$$\frac{0.0424 \text{ mole } H_2O}{1} \cdot \frac{18.0152 \text{ g/mol } H_2O}{1 \text{ mol } H_2O} = .764 \text{ g } H_2O$$

NaCl

$$\frac{0.0424 \text{ mol NaCl}}{1} \cdot \frac{58.44277 \text{ g/mol NaCl}}{1 \text{ mol NaCl}} = 2.48 \text{ g NaCl}$$

We also had to convert moles to molecules. Our math:

$$\frac{0.0424 \text{ moles}}{1} \cdot \frac{6.022 * 10^{23}}{1 \text{ mol}} = 2.55*10^{27}$$

Since our mole ratio was 1:1, this value carried all across the table.

Our question for this lab was how do we produce 2.48 g of NaCl. For this experiment, the amounts of $NaHCO_3$ and HCl were the independent variables and the dependent variable was our given amount of NaCl (2.48 g). Our hypothesis stated that if we combined 3.56 g of $NaHCO_3$ with 4.71 mL of 9M HCl we would produce 1.87g of CO_2, 0.764 g H_2O and 2.48 g NaCl.

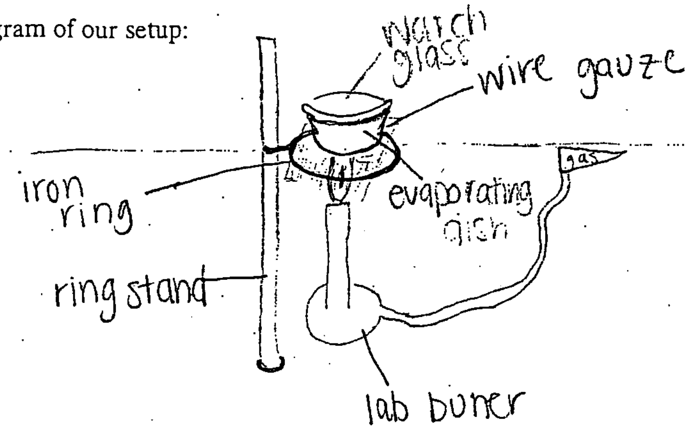
Methods and Materials

Our list of materials:

- 1 evaporating dish
- 1 watch glass
- 1 pipette
- 1 electronic balance
- 1 wire gauze
- 1 lab burner
- 1 ring stand
- 3.56 g $NaHCO_3$

- 4.71 mL 9M HCl
- 1 iron ring
- 1 sparker

A diagram of our setup:



Our procedure:

Step 1: Put on safety gear (goggles, apron, gloves). Remove loose clothing and tie back long hair. Clear your work area.

Step 2: Collect the supplies listed under the Methods and Materials section of this paper.

Step 3: Find the mass of the evaporating dish, the watch glass, and the evaporating dish with the watch glass using an electronic balance. Record this data in your data table.

Step 4: Place the evaporating dish on the electronic balance. 'Zero out' your scale. Add exactly 3.56 g $NaHCO_3$. Describe its appearance in your data table.

Step 5: Measure out exactly 4.71 mL of 9M HCl using the pipette. Observe the HCl and describe it in your data table.

Step 6: Add the HCl to the dish (that already holds the $NaHCO_3$). Place the watch glass on top of the evaporating dish. Observe what's happening and record it in your data table.

Step 7: Make sure all you reactants have reacted by carefully swirling the mixture in the evaporating dish. Record what your mixture look like in your data table.

Step 8: Place wire gauze on iron ring and attach the iron ring to the ring stand. Place the lab burner underneath the wire gauze. Turn on the gas and light the burner. Adjust the flame until you have a blue flame.

Step 9: Adjust the height of the iron ring so that the tip of the blue flame touches the bottom of the evaporating dish.

Step 10: Watch closely while water boils out and describe the process in your data table.

Step 11: Heat evaporating dish until all liquid has evaporated. Record what the substance looks like in your data table.

[redacted]

Step 12: Shut off the gas/flame and wait for the evaporating dish to cool.
Step 13: When the dish has cooled, weigh the evaporating dish on the electronic balance. Record weight in your data table. Subtract weight of watch glass and evaporating dish before the reaction (found in Step 3) from the mass you just found. Record what you found in your data table.
Step 14: Repeat steps 10 through 13 until 3 consecutive masses are within .01 gram. Record each of these masses in your data table.
Step 15: Wash and clean up all your supplies and put everything back where it was found.

Results

		Description of
Reactants	$NaHCO_3$	white powder, finely ground with some clumps
	HCl	clear liquid
Reaction	Right away	fizzing, bubbling, still white
	When you swirl	was white, then turned clear and stopped fizzing
Products	Before boiling	was clear, not fizzing
	During boiling	can start to see white crystal particles on side of dish
	After boiling	looked a little burnt, white crystals covering the insides of the dish and watch glass, crystals break apart easily

	Mass of...
evaporating dish	81.87 g
watchglass	35.93 g
dish and watchglass	117.80 g
dish and $NaHCO_3$	85.43 g
$NaHCO_3$	3.56 g
dry product 1	2.47 g
dry product 2	2.47g
dry product 3	2.47 g
final mass of $NaHCO_3$ alone	2.47 g

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	Volume of..
HCl delivered	not measured

Results

We found that the original mass of the dish was 81.87 g. The original mass of the dish and the watchglass together was 117.80 g. After our reaction occurred and we boiled away the remaining liquid the mass of the dish, watchglass, and final product was 120.27 g. After heating and cooling the dish twice more, we found that the mass stayed unchanged. The average of our three masses was 120.27 g, or 2.47 g of the final product. We calculated our percent of error by using the equation $\frac{|observed-expected|}{expected} = \%$ error

Our percent error turned out to be .4%. Our data shows that our final mass of 2.47 g was only .01 away from the amount we were supposed to produce.

Discussion

By looking at our data table, we made 2.47 g of $NaHCO_3$. By figuring out our percent of error we were within .4% of our expected result so our hypothesis was supported. Our reaction took place because when $NaHCO_3$ (the Na having a positive charge and the HCO_3 having a negative charge) is combined with HCl, (the H having a positive charge and the Cl having a negative charge), the Cl strips the Na and bonds with it (forming NaCl). The remaining HCO_3 and H combine to form H_2O and CO_2. The describes exactly what is happening during our reaction. We may have made errors in our expirment in several ways. We had originally planned to use 9M HCl but after trying it in class we found that the 6M was the only concentration causing the reaction we need to happen. Because of this problem we werent able to measure the exact amount of HCl delivered. Also, when we were boiling our substance to remove the liquid we had the burner on too high and so the liquid was coming out of our dish in little droplets. I would like to know if this type of expirment works for all chemical reactions. I am also curious about why only the 6M concentration seemed to work.

[redacted]

Data Table

		Description of....
reactants	$NaHCO_3$	white powder, finely ground w/ some clumps, doesn't smell
	HCl	clear liquid, no smell
reaction	right away	fizzing, bubbling, still white
	when you swirl	was white, then turned clear & stopped fizzing
	before boiling	was clear, not fizzing
Products	during boiling	can start to see white crystal [illegible]
	after boiling	looked a little burnt, white crystals covering the insides of the dish/watch glass, break apart easily

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"More Bugs in the Sun or Shade?"
Student Work Example
Used as an exemplar while instructing
Group C on lab report preparation.

More Bugs in the Sun or Shade?

[redacted]

Introduction

Does the amount of sunlight (sunlight or little or no sunlight) effect the amount of bugs in an area was the question that my partner and I decided to investigate. Even though it seems like there are more bugs in the shade, I think there are more in the sun. I think it is the type of bug that makes it seem if there are more or fewer bugs. For example, there are more mosquitoes in the shade that bother people; so many might think there are more bugs bothering them. We choose this question because we thought it would be interesting to find out where there are more bugs

The control model of our experiment is a 5'x5' area in the sun. The experimental model is a 5'x5' area without sun or a shaded area. The independent variable is the sunlight allowed (sun lighted area or shaded area). The dependent variable is the amount of bugs that results from each area.

Hypothesis

Our hypothesis is that we think that there will be more bugs in the sunlight area vs. the shaded area. I think this because it is warmer in the sun lighted area and most bugs like that or live in a warmer habitat. Also, many bugs seem to like flowers and many flowers are located in the sun. This is why I think there are more bugs in a sun lighted area.

Methods & Materials

Materials

String	2 5x5 plots of grass (1 in the sun & 1 in the shade)
Paper Clips	Sweep Net
Measuring Device	[redacted]

Procedure

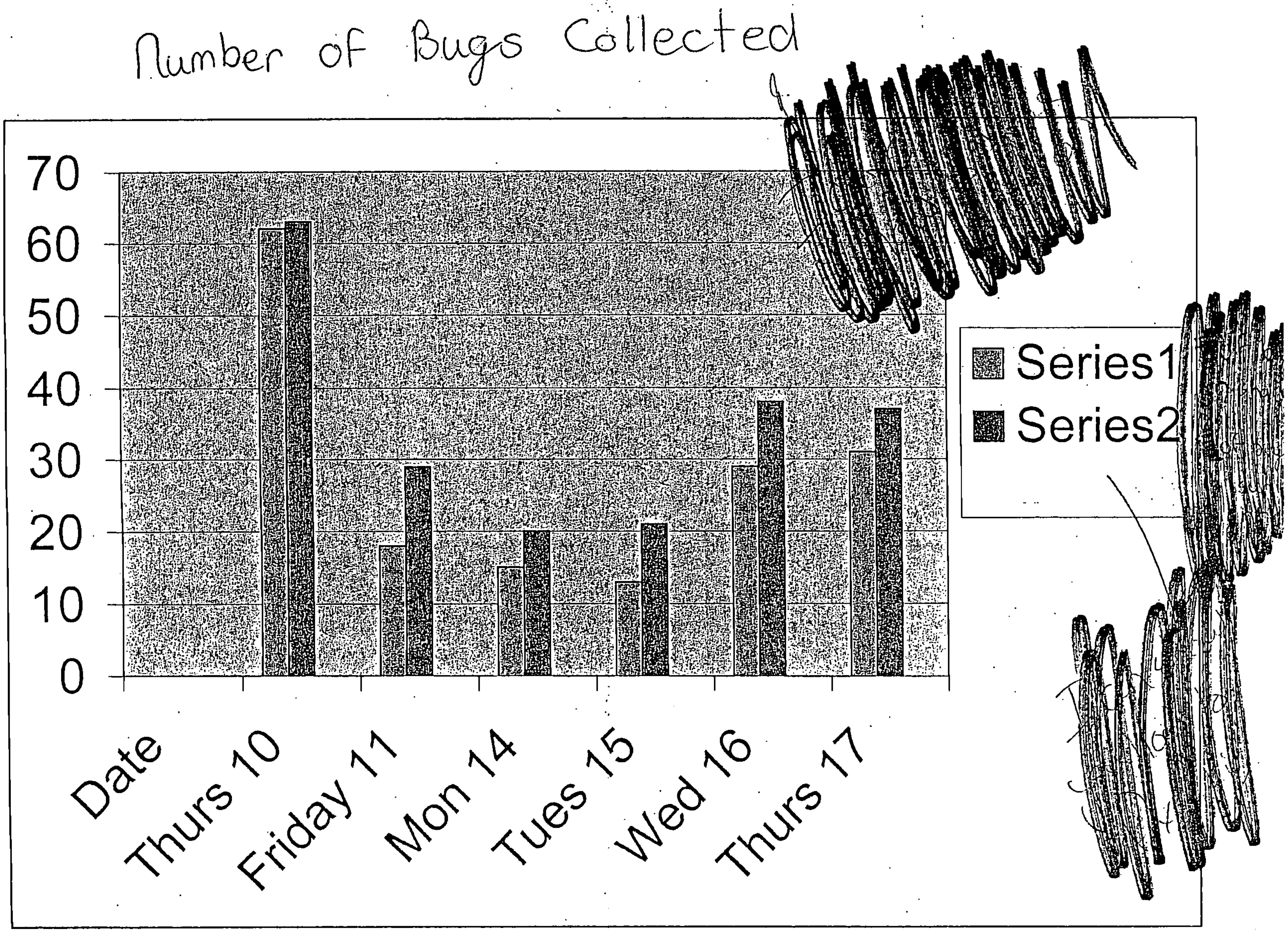
1. Take measuring device and measure out both a 5'x5' grass area in the sun and a 5'x5' grass area in the shade. *Try to keep both grass areas with the same length of grass.
2. Measure out 8 pieces of 5 feet long string.

3. Take paper clips and straighten them out and tie two pieces of string to each of them
4. Take each paper clip and put one of them on each corner of the 5'x5' areas.
5. Attach all of the strings so it is a border to each 5'x5' area.
6. Take sweep net and sweep it across each area close enough to the ground so you can collect the bugs in it and count them.
7. Next pick a random 1'x1' area in your 5'x5' area and count the bugs in that area and add them to the bugs you already counted.
8. Record your data in a data table, including the date you collected them.
9. After data is collected for enough days to get a conclusion from it-add up all the bugs and average them for both the sun and the shade.
10. Take the averages and compare them and see how they differ from one another and take the standard deviation and see how that compares with the control and experimental model.
11. Make a conclusion and tell if it supports or doesn't support your hypothesis.

<u>Results</u>

Data Table

Date	# of bugs in experimental model (and type)	# of bugs in control model (and type)
Thursday May 10	62 all gnats	63 variety of bugs
Friday May 11	18 all gnats	29 variety of bugs
Monday May 14	15 all gnats	20 variety of bugs
Tuesday May 15	13 variety of bugs	21 variety of bugs
Wednesday May 16	29 all gnats	38 variety of bugs
Thursday May 17	31 mostly gnats	37 variety of bugs



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Calculations

Average number of bugs in shade

62
18
15
13 168/6=28
29 Average=28
+31
168

Standard Deviation

Avg=28+-15
Range=13-62
Standard Deviation=13-43

Average number of bugs in sun

63
29
20
21 208/6=35
38 Average=35
+37
208

Standard Deviation

Avg=35+-15
Range=20-63
Standard Deviation=20-38

Our standard deviations of both are 13-43 & 20-38. These two standard deviations overlap a great deal or for most of the part.
Even though the bar graph shown on the previous page shows quite a difference in numbers between the control model and the experimental model, it is really not that big of a difference. It may look like a big difference because of the intervals used.

Conclusion

The information we found did not support my hypothesis to the question; Does the amount of sunlight (sunlight or little or no sunlight) effect the amount of bugs in an area?. I thought that there would be more bugs in the sunlight area vs. the shaded area. With the calculations that I came up with, using the standard deviation, it showed that there was not a big enough difference of the number of bugs between the sunlight area and the shade area to say they had an effect on the number of bugs in the areas. Even though the graph made it look like there was a noticeable difference between the two because everyday the control model had more bugs than the experimental model, there really wasn't that big of a difference. The averages only differed by 7 bugs. The standard deviations almost overlapped each other completely making the results show similarity between the two areas. I came up with the conclusion that the amount of sunlight (sunlight or little or no sunlight) does not affect the amount of bugs in an area. One thing that we did find though is that in the shaded area, we collected mostly gnats, but in the sunlight area we caught a variety of bugs.

Discussion

There are many alternative explanations or errors that could have caused a problem in our experiment and could of altered the results we came up with. One problem that probably played an important role was not catching all of the bugs in the 5'5' area. We could of very easily missed bugs while using the sweep net or very easily missed some when we were counting. Another problem that may have caused an error was that the bugs might have not had the chance to repopulate the whole way. This may be why we got 62 bugs the first day in the experimental model and only 18 the next day. A third problem that may have caused an error was the weather. This plays an important role on the bugs around. One of the days it was rainy, causing the grass to be wet which may have caused bugs to leave that area for a drier place. Another problem is that the grass in the shade was damper than the grass in the sun. A fifth problem was that the grass in the shade was longer than the grass in the sun, which may have caused a difference in the number of bugs collected. This may have altered the number of bugs and it might have not. With all of these errors that may have occurred, it is hard to say whether our results are accurate or not. If we could have somehow kept these from happening, our results may or may not have showed us different results.

One of my questions for further research is does an area by a tree have a different amount of bugs in it than an area not by a tree. My second question for further research is if the length of grass has anything to do with the number of bugs in an area (if there is more in long grass or shorter grass). A third question is if the temperature or wetness of the grass affects the number of bugs in an area.

Contents

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