THE USE OF DATA COLLECTION ACTIVITIES IN THE SECONDARY

MATHEMATICS CLASSROOM

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Abstract

Many high school students find mathematics to be difficult and irrelevant to their lives. The focus of this project was to survey high school math teachers to find out how often they use scientific data collection activities in their classroom in order to make real world connections. The survey also explored teacher attitudes about the use of data collection and teachers' reasons for not incorporating more data collection activities into their curriculum. The analysis of the survey data showed that a little more than half of the teachers who completed the survey have used data collection and that the greatest factor limiting the use of data collection activities was time. This project provides some recommendations for math teachers and includes some examples of data collection activities that are appropriate for use in secondary mathematics classrooms.

THE USE OF DATA COLLECTION ACTIVITIES IN THE SECONDARY

MATHEMATICS CLASSROOM

Incorporating scientific data collection activities into math curriculum is a teaching approach that should be considered by mathematics educators. Likewise, science educators should also look for ways to highlight mathematical models during the analysis of scientific data. Making changes in the way we teach our subjects and organize our curriculum is always a challenge. However, there are benefits for students and teachers to finding the areas where connections can be made between math and science curricula, and these benefits make the challenges that must be worked through worthwhile. Why collect data in math classes? Making connections is one of the five process standards recommended by the National Council of Teachers of Mathematics (NCTM). NCTM encourages teachers to apply math in contextual situations so that it will be more likely students will not forget the math skills they have learned in class. NCTM expectations for math programs at the high school level include designing studies, collecting and organizing data, developing models for the data, and making inferences using the models (NCTM, 2000). The NCTM *Principles and Standards for School Mathematics* (2000) states:

> The kinds of experiences teachers provide clearly play a major role in determining
> the extent and quality of students' learning. Students' understanding of
> mathematical ideas can be built throughout their school years if they actively
> engage in tasks and experiences designed to deepen and connect their knowledge.
> (p. 21)

The National Research Council (NRC) also states that science educators should be connecting science to other school subjects like mathematics (NRC, 1996). The book *How People Learn (2000)* which was co-written by a committee from the NRC, states:

> Students develop flexible understanding of when, where, why, and how to use their knowledge to solve new problems if they learn how to extract underlying themes and principles from their learning exercises. Understanding how and when to put knowledge to use –known as conditions of applicability-is an important characteristic of expertise. Learning in multiple contexts most likely affects this aspect of transfer. (p. 236)

Using scientific data collection activities in math classes is a simple way to connect separate courses that high school students attend in their daily school routine.

Students do not easily make the connections between their individual courses on their own, and a traditional high school does not offer integrated curriculum. Beane says "students as though piecing together a jigsaw puzzle, must rely on their own intuition to piece together fragmentary pieces of knowledge obtained separately from different subjects" (as cited in Jang, 2006, p. 615). Jeff Marshall and Bob Horton, educators involved in math and science education at the college level, feel that students want learning to be meaningful and relevant, and math and physical science courses are most often taught as separate subjects, limiting the cohesiveness of the learning (Marshall, Horton, & Austin-Wade, 2007). Students need to see math and science as relevant parts of their world. Math should not be taught just for the sake of learning math but to make sense out of the world (Davison, Miller, & Metheny, 1995). Berlin and White said "There

are times when the concepts of science and the concepts of mathematics have enough in common for it to be more meaningful to the student and more efficient to connect the learning of these concepts" (as cited in Roebuck & Warden, 1998, p. 329).

We can make our subjects more interesting for our students and hook them on math and science by tweaking our teaching methods to promote connections between the two subjects. In a paper presented at a conference for Integrated Science and Mathematics Teaching and Learning, Lynn A. Steen (1994) recommended that math and science teachers learn from each other by incorporating some of the ways each other teaches in their own classroom. For instance, math teachers should include more observation and data collection of real world situations which would lead to long-term retention of information by students. Science teachers should include more activities to promote inference and deduction skills instead of just dictating to students what science says is going to happen in certain situations. Steen wrote, "Active, exploratory learning works as well in mathematics as it does in science" (p. 12).

Teachers would also benefit from integrating math and science curricula through data collection activities in their classrooms. Because of the design of school schedules, teachers spend most of the school day in their own classrooms focused on their own students and individual subjects. There is very little opportunity during the school day to communicate with other teachers other than through short e-mail messages. By incorporating integrated data collection activities in the curriculum, teachers would need to have conversations with teachers in other subject areas to ask them for clarification on points related to their subjects. The other teachers in our buildings are our best resources

for help and talking with them will give us insight into what our students are learning in their other classes. Lisa Schmidt and Sam Horton, high school teachers who have taught interdisciplinary math and science courses, report that courses that require you to work with members of other departments lead to "a high level of collegiality that is both exciting and rewarding" (2003, p. 51).

Some documentation on educators making connections between math and science has been reported and the feedback is positive. Mike Smith, a Physics teacher who began integrating algebra concepts and technology into his curriculum, has found that he has changed the way he assesses his students and his students reap the benefits. He now appreciates the importance of algebra to science (Nicol, 1997). Robert Horton, an assistant professor of mathematics education, and William Leonard, a professor of education and biology, have worked on projects with their students to gather data and develop mathematical models to fit their data. They say that:

> In our experience, students not only enjoyed what they were doing but also surprised us with how quickly they mastered the techniques, which allowed us to focus on the connections between the mathematical models and scientific ideas they were investigating. The process goals in math and science standards have much in common. Teachers must take advantage of this and the power of modern technology to make learning as rich as possible. (Horton & Leonard, 2005, p. 45)

Why then are not all math teachers taking advantage of the opportunity to bring real world scientific data collection activities into their classroom? The national standards say to do it. The students would enjoy the hands-on activities, be more likely to retain

information, and develop higher-order thinking skills like application and inquiry.

Teachers would get the opportunity to work with colleagues and unite to achieve the

common goal of making learning meaningful.

In order to discover more about the use of data collection in math classes, a

survey was administered. The survey included questions to learn about the following: the

frequency in which secondary mathematics teachers have their students take experimental

data, the teacher perceptions of the value of data collection and analysis, and the

limitations that keep mathematics teachers from doing more experiments in their classes.

Survey

The survey consisted primarily of multiple choice questions and statements with a

Likert rating scale. Several free response questions allowed teachers to post their own

comments. The survey was sent to an Indiana math teacher listserv database and also to

individual high school math departments in Indiana. It was also sent to a small number of

math contacts in Texas. The survey was administered through Ball State University's

inQsit system and was open for responses for a period of approximately seven weeks.

Teacher background information requested included the number of years of math

teaching experience, number of years of science teaching experience, highest education

level, and math courses taught. Background information was looked at for correlation to

use of data collection.

One survey question directly asked if math teachers had ever used data collection

in their classes. The response to this question then routed the respondents to answer a set

of specific questions. If the respondents answered "no," then the respondents answered

questions about reasons for not using data collection and opinions of the use of data collection. If the respondents answered "yes," then the respondents answered questions about the types of equipment used in their activities, the frequency of use of activities, reasons for not using more data collection activities, and their opinions of the use of data collection. The survey questions can be found in Appendix A.

Survey results

One hundred and twenty-three math teachers responded to the voluntary electronic survey. Of those, 16 respondents' answers were deleted because they answered questions in both sections of the survey for teachers who said they did use data collection and for teachers who said they did not use data collection. One hundred and seven teachers' responses were then analyzed. The majority of the teachers who responded were from schools across Indiana with more than 1200 students. The number of male and female respondents was almost even. Thirteen of the respondents had some experience as science instructors. Almost half of the respondents had more than 12 years of teaching experience. There were an undetermined number of teachers who responded from Texas. Complete results of the survey can be found in Appendix B.

Sixty-one math teachers (57%) responded that they have had students use data collection in their classes and 46 math teachers (43%) responded that they have not had students use data collection. Time perceptions seemed to be the greatest concern for those who did not implement data collection activities. Of the 46 teachers who have never had students perform data collection activities, 38 teachers either agreed or strongly agreed that they did not have time to implement this instructional practice because there were too

many standards to cover, and 31 either agreed or strongly agreed that they did not have

time to gather materials (Figure 1).
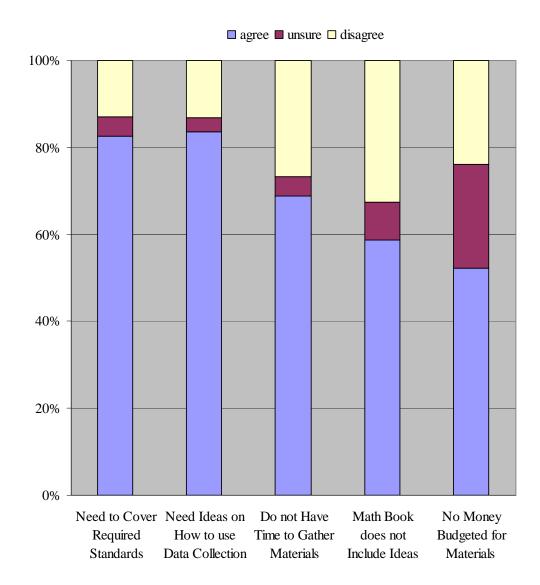

Figure 1. Top five reasons teachers do not use data collection

Thirty-six teachers would like more ideas on how to incorporate data collection

activities into their lessons. Twenty-seven teachers do not have math textbooks that

provide data collection ideas. Seventeen teachers thought that class periods were too

short to use data collection. Fifteen teachers indicated that they did not have access to

materials needed for experiments. Only 15 teachers said that they felt that they knew how

to use equipment currently available for use in data collection activities. Seven teachers

indicated that they believed their students understanding of math concepts would not be

improved by data collection activities. Only three teachers believed that their students do

not have the ability to collect and analyze data. See Table 1 for more detail of this data.

Table 1.

Reasons Teachers Do Not Use Data Collection Activities. Data Given as a Percentage of

the 46 Respondents.

Belief	Response				
	strongly agree	agree	unsure	disagree	strongly disagree
Don't have time because standards must be covered	45.7%	37.0%	4.3%	8.7%	4.3%
Need ideas on how to use data collection in classroom	17.4%	60.9%	4.3%	13.0%	4.3%
Don't have time to gather materials	15.6%	53.3%	4.4%	26.7%	0.0%
Don't have a math book with data collection ideas	8.7%	50.0%	8.7%	30.4%	2.2%

Table 1 (continued).

Belief	Response				
	strongly agree	agree	unsure	disagree	strongly disagree
Don't have money budgeted for materials that are needed	19.6%	32.6%	23.9%	23.9%	0.0%
Don't know how to use some of equipment	4.3%	47.8%	15.2%	32.6%	0.0%
Never been encouraged to do experiments in class	6.5%	43.5%	10.9%	37.0%	2.2%
Don't have time because class periods too short	10.9%	26.1%	2.2%	54.3%	6.5%
Don't have access to materials	2.2%	30.4%	17.4%	45.7%	4.3%
Don't want the classroom chaos	8.7%	21.7%	13.0%	47.8%	8.7%
Don't believe data collection will improve math understanding	2.2%	13.0%	26.1%	50.0%	8.7%
Don't believe students have the ability to collect/analyze data	2.2%	4.3%	21.7%	58.7%	13.0%

Of the 61 math teachers who indicated that they do have their students perform

data collection activities, 32 teachers said they have students use this learning method

once or twice per semester (Figure 2). Only 15 teachers indicated that they have their

students perform a data collection activity once every two to three weeks.
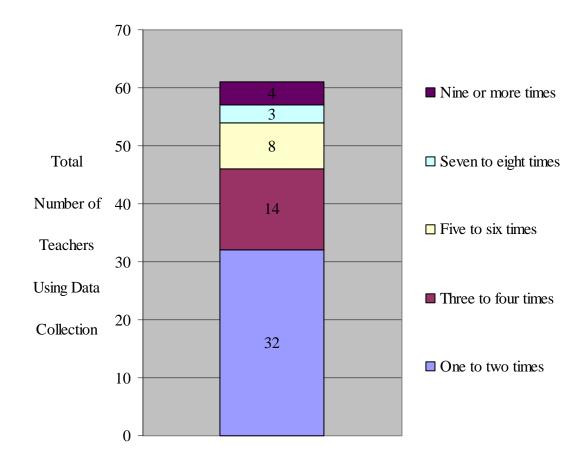
Figure 2. How many times per semester teachers use data collection

Not only did the majority of these 61 respondents feel very comfortable using the

equipment, they indicated that their students enjoyed the activities, and believed that their

students understood the math concepts better because of the data collection activities.

Fifty-one teachers would like to use data collection more in their lessons. Forty-three

teachers indicated they do not have more time to do so because they have too many

standards to cover. Fifty-one teachers would like additional ideas on how to

incorporate more activities into their lessons. Twenty-eight teachers do not have math

textbooks that provide data collection ideas. Twenty-four teachers felt that the length of

their class periods prohibits the inclusion of more activities. Twenty-five teachers do not

have the time to collect the needed materials for the activities. See Table 2 for more detail

of this data.

Table 2

*Reasons Teachers Do Not Use **More** Data Collection Activities. Data is Given as a*

Percentage of the 61 Respondents.

Belief	Response				
	strongly agree	agree	unsure	disagree	strongly disagree
Students enjoy taking data	31.1%	55.7%	11.5%	1.6%	0.0%
Data collection in math will improve math understanding	37.7%	45.9%	13.1%	3.3%	0.0%
Would like to use more data collection in class	34.4%	49.2%	9.8%	6.6%	0.0%
Need ideas on how to use data collection in classroom	16.4%	67.2%	3.3%	13.1%	0.0%

Table 2 (continued).

Belief	Response				
	strongly agree	agree	unsure	disagree	strongly disagree
Don't have time because standards must be covered	37.7%	32.8%	9.8%	14.8%	4.9%
Don't have money budgeted for materials that are needed	19.0%	32.8%	15.5%	27.6%	5.2%
Don't have a math textbook with data collection ideas	11.5%	34.4%	9.8%	39.3%	4.9%
Don't have time to gather materials	1.7%	40.0%	6.7%	46.7%	5.0%
Don't have time because class periods too short	13.6%	27.1%	10.2%	40.7%	8.5%
Don't want the classroom chaos	6.6%	21.3%	8.2%	39.3%	24.6%
Don't know how to use some of equipment	3.4%	25.9%	24.1%	39.7%	6.9%
Don't have access to materials	0.0%	28.8%	8.5%	54.2%	8.5%

The findings from this survey demonstrate that math teachers believe that data collection activities do help students with their understanding of math concepts. Time is the factor that limits the use of this teaching method. Teachers feel the pressure to cover a greater number of standards than can be taught in the length of their courses. One teacher

commented, "The main reason that I do not incorporate data collection activities is that I feel like I am always pressed for time because of class length and state standards that need to be covered." Data collection takes time to complete and if technology is involved, extra time will be needed to become proficient with the equipment. Also, teachers do not always have the time to gather the materials and do activity set-up, evidenced by one teacher who commented that "I don't have time to search out activities and plan out the activity."

Math teachers would like more ideas and examples of data collection activities they can use. One respondent noted, "If I had an experiment that was already set up for me, I would at least try it to see how it worked, even if it put me behind a couple of days." Fifty-one percent of all the teachers surveyed indicated that their textbooks do not include examples of data collection activities. Appendix C includes comments from teachers who do not use data collection activities in their lessons. Appendix D includes comments from teachers who do use data collection activities in their lessons.

The survey provides evidence that math teachers with more years of teaching experience may be more likely to include data collection in their classes, although a more scientific polling method would be necessary to substantiate this claim. Sixty-four percent of teachers with 12 or more years of teaching experience stated that they do use data collection compared to 47% of teachers with one to three years of teaching experience who said that they included data collection in their teaching methods. Those with a bachelor's degree who responded to this survey were more likely to include data collection in their classes when compared to those who responded with a master's degree.

Although 61% of teachers with a bachelor's degree use data collection compared to 55% of teachers with a master's degree, these numbers likely indicate that there is no statistical difference, but again, a more scientific survey would be needed. Also, the survey showed that 47% of the female teachers used data collection compared to 66% of the male teachers surveyed.

Recommendations

One recommendation for math teachers would be to begin by including one data collection activity every nine weeks or two per semester for each math class. Work together with other math teachers to develop activities and organize the materials. At the beginning, choose activities that use simple, low-cost materials that your department can keep boxed up in a labeled container. The most common equipment used by the math teachers who already use data collection were rulers, timers, mass scales, and motion sensors. Enlist the help of a science teacher to learn how to use science equipment and to find science concepts that use specific mathematical functions. Start by asking questions such as "Do you ever take data in your science class that result in linear graphs or relationships among the variables?" There are math textbooks companies that include experiments in their texts. Look through the books left behind from your last textbook adoption. I found many algebra based activities in *Discovering Advanced Algebra: An Investigative Approach* published by Key Curriculum Press. There are activity workbooks for purchase that use simple equipment, such as *Algebra Experiments 1: Exploring Linear Functions* published by Addison-Wesley. Articles in the *Mathematics Teacher* also frequently include data collection activities.

As far as the issue of using classroom time to collect data, consider carefully whether it is more important to cover as many topics as possible with minimal real world application, or to cover fewer topics in more depth and emphasize process skills like collecting data and making deductions? A recommendation for national and state standard boards would be to indicate in the standards a "core" group of standards that must be covered and lighten the pressure on teachers so they can pick and choose from the other standards to cover in a course. Then teachers would have the flexibility to teach process skills along with concept standards.

Data collection activities

There are three algebra based activities included in the appendices that serve as models of the types of activities that students could and should perform in their mathematics classes. These activities were chosen because they used the equipment that was indicated in the survey as the most often used by teachers already using data collection in their classrooms. The *Free Fall* lab is appropriate for a second year algebra course (Appendix E). This lab requires motion sensors (which are commonly used in physical science classes) and graphing calculators. This lab will require about 20 minutes of class time to take the data and five minutes to gather the equipment. Teachers who have never used motion sensors before would want to practice with the equipment before doing the *Free Fall* activity. This activity reinforces the concepts of quadratic equations and system of equations. Science connections made are free-fall and gravitational acceleration. This activity meets the needs of teachers who do not have a lot class time to

spend taking data and for teachers who have used motion sensors before, the preparation time will be minimal.

The *Skittlelium Decay* lab is also appropriate for a second year algebra course (Appendix F). This lab requires inexpensive Skittles® candies and graphing calculators. The activity will require about 10 minutes of class time to collect the data and approximately 10 minutes per class to sort the candies into piles of 50 for each lab group. Student helpers could be utilized ahead of time to perform the sorting. This activity reinforces the concept of exponential decay. Science connections made are radioactivity and half-life. This activity meets the needs of teachers who do not have a lot of class time to spend taking data. There is no equipment required to gather or understand how to use.

The *Comparing Pennies* lab (Appendix G) is appropriate for a first year algebra course, but could easily be modified for a second year course. This activity requires electronic balances, graduated cylinders, water, old and new pennies, and graph paper. The activity will require about 20 minutes of class time to take the data and 20 minutes to collect the materials. This activity reinforces the concepts of graphing skills, y-intercept form of equations, and best line of fit. The science connection made is density. This activity meets the needs of teachers who do not have a lot of class time to spend taking data. The equipment is simple to use. A science teacher can demonstrate how to use the electronic balances in one minute.

Conclusion

While it is encouraging to find that many mathematics teachers are currently integrating data collection activities into their instructional practices, more teachers need

to incorporate this approach so students can develop a deeper understanding of

mathematical concepts. Using data collection in class does not have to be costly or take

much class time. It will require teacher preparation time to either find or write activities

and a willingness to try something new. We need to challenge ourselves as teachers in

order to improve the curriculum for students so that their learning is as meaningful as

possible.

References

Bransford, J., Brown, A., & Cocking, R. (Eds.). (2000). *How people learn: Brain, mind,*
    experience, and school Washington, D.C.: National Academy Press.

Davison, D., Miller, K., & Metheny, D. (1995). What does integration of science and
    mathematics really mean? *School Science and Mathematics, May, 95* (5), 226-
    230.

Horton, R.M, & Leonard, W.H. (2005). Mathematical modeling in science. *The Science*
    Teacher, July/August, 40-45.

Jang,S.-J. (2006). The effects of incorporating web-assisted learning with team teaching
    in seventh-grade science classes. *International Journal of Science Education,*
    May, 28 (6), 615-632.

Marshall, J., Horton, B., & Austin-Wade, J. (2007). Giving meaning to numbers. *The*
    Science Teacher, February, 36-41.

Murdock, J., Kamischke, E.,& Kamischke, E. (2004). *Discovering advanced algebra: An*
    investigative approach Emeryville, CA.: Key Curriculum Press.

National Council of Teachers of Mathematics (NCTM). 2000. *Principles and standards*
    for school mathematics. Reston, VA: NCTM.

National Research Council. (1996). *National science education standards.* Washington,
    DC: National Academy Press.

Nicol, M. (1997). How one physics teacher changed his algebraic thinking. *The*
    Mathematics Teacher, 90 (2), 86-89.

Roebuck, K.I., & Warden, M.A. (1998). Searching for the center on the mathematics-

science continuum. *School Science and Mathematics, 98* (6), 328-333).

Schmitt, L., & Horton, S. (2203). Smath. *The Science Teacher, December,* 46-51.

Steen, L. (1991, April). *Integrating school science and mathematics: Fad or folly.*

Paper presented at the NSF/SSMA Wingspread Conference, Racine, WI.

Winter, M.J. & Carlson, R.J. (1993). *Algebra experiments I: Exploring linear functions*

United States: Addison-Wesley Publishing Company.

Appendix A

Teacher Survey

1. How many years of mathematics teaching experience, including the current year, do you have?
a. 1-3
b. 4-6
c. 7-9
d. 10-12
e. more than 12
Pick one

2. How many years of science teaching experience, including the current year, do you have?
a. 0
b. 1-3
c. 4-6
d. 7-9
e. 10-12
f. more than 12
Pick one

3a. In what fields are you currently certified to teach? Check all that apply.
a. elementary mathematics
b. middle level mathematics
c. secondary mathematics
d. secondary life science
e. secondary physical science

3b. other

4a. What course(s) do you currently teach? Check all that apply.
a. algebra 1
b. algebra 2
c. geometry
d. trigonometry/precalculus
e. calculus
f. probability and statistics

4b. other

5. What is your highest education level?
a. undergraduate degree
b. masters degree
c. doctoral degree
Pick one

6. What is your gender?
a. male
b. female
Pick one

7. Estimate the number of Grade 9-12 students at your current school.
a. 0-300
b. 301-600
c. 601-900
d. 901-1200
e. more than 1200
Pick one

8. Do you and your students have easy access to computer workstations or computer laboratory facilities?
yes/no

9. Do you ever have students collect and analyze experimental data as a part of a math lesson?
yes/no

If your answer to the question above is NO, please respond to Questions 10 and 11, and then hit the Submit button at the bottom of the page. If your answer is YES, please skip Questions 10 and 11 and proceed directly to Questions 12-19.

Please rate your level of agreement or disagreement with these statements of reasons why you are NOT having your students perform any data collection and analysis activities in your mathematics classrooms.

Likert table range=1 to 5 "strongly agree" "agree" "unsure" "disagree" "strongly disagree"

10a. I don't have time to incorporate data collection activities because I need to cover other standards.

10b. I don't have time to incorporate data collection activities because our class periods are too short.

10c. I don't have access to any materials to use for data collection activities.

10d. I don't have money budgeted to purchase materials to use in data collection activities.

10e. I don't know how to use some of the equipment that is currently available for us to use in data collection activities.

10f. I don't have time to gather the materials to use in data collection activities.

10g. I don't want the chaos that might occur during data collection activities.

10h. I need ideas on how data collection activities could be used in my lessons.

10i. I don't believe that using data from an experiment will improve my students' understanding of math concepts.

10j. I don't believe my students have the ability to collect and analyze real laboratory data.

10k. I don't believe my students have the discipline to collect and analyze real laboratory data.

10l. I've never been encouraged to do experiments in my class.

10m. I don't have a math textbook that provides examples of data collection experiments that I can use with my lessons.

11. Please list any other reasons why you do not incorporate data collection activities into your mathematics lessons. Then hit Submit at the bottom of the page.

Only answer the remaining questions if you answered YES to question 9.

12a. What types of equipment have you had students use in data collection. Check all that apply.
a. rulers
b. timers
c. thermometers
d. chemicals
e. mass/weight scales
f. masses/weights
g. motion sensors
h. light sensors
i. pH sensors
j. sound meters
k. other sensors

12b. other

Please rate your level of agreement or disagreement with the statements below.

Likert table range=1 to 5 "strongly agree" "agree" "unsure" "disagree" "strongly disagree"
13a. I feel very comfortable having my students use equipment to collect data.

13b. My students enjoy taking data to use in math lessons.

13c. Using real data in a math lesson helps my students make better sense of the math concepts.

13d. I would like to use more data collection in the classroom than I currently do.

14a. What mathematics courses do you currently incorporate data collection activities into? Check all that apply.
a. algebra 1
b. algebra 2
c. geometry
d. trigonometry/precalculus
e. calculus
f. probability and statistics

14b. other

15. How many times in a semester would you say you have students collect data to use for a math lesson?
a. 1-2 times
b. 3-4 times
c. 5-6 times
d. 7-8 times
e. 9 or more times
Pick one

16. How much time on average would you say your students spend taking data for a lesson that involves data collection?
a. 5 minutes
b. 10 minutes
c. 15 minutes
d. 20 minutes
e. more than 20 minutes
Pick one

17. How much time do you spend to get equipment/materials ready for data collection?
a. 5 minutes
b. 10 minutes
c. 15 minutes
d. 20 minutes
e. more than 20 minutes
Pick one

Please rate your level of agreement or disagreement with these statements of reasons why you do not have your students perform any more data collection and analysis activities in your mathematics classrooms than you are presently.

Likert table range=1 to 5 "strongly agree" "agree" "unsure" "disagree" "strongly disagree"

18a. I don't have time to incorporate more data collection activities because I need to cover other standards.

18b. I don't have time to incorporate more data collection activities because our class periods are too short.

18c. I don't have access to any more materials to use for data collection activities.

18d. I don't have money budgeted to purchase more materials to use in data collection activities.

18e. I don't know how to use some of the equipment that is currently available for us to use in data collection activities.

18f. I don't have time to gather the materials to use in additional data collection activities.

18g. I don't want the chaos that might occur during data collection activities.

18h. I need more ideas on how data collection activities could be used in my lessons.

18i. I don't have a math textbook that provides examples of data collection experiments that I can use with my lessons.

19. Please list any other reasons why you do not incorporate more data collection activities into your mathematics lessons.

Appendix B

Teacher survey results

Number	Type	Total	Right	Difficulty	Descrimination	Mean	St.Dev
1	MC	107	107	100.00%	-2		
2	MC	107	107	100.00%	-2		
3a	MR	107	107	100.00%	-2		
3b	Essay	107				0	0
4a	MR	107	107	100.00%	-2		
4b	Essay	107				0	0
5	MC	107	107	100.00%	-2		
6	MC	107	107	100.00%	-2		
7	MC	107	107	100.00%	-2		
8	Y/N	107	0	0.00%	0		
9	Y/N	107	0	0.00%	0		
10a	Likert	107				1.89	1.11
10b	Likert	107				3.2	1.21
10c	Likert	107				3.2	0.99
10d	Likert	107				2.52	1.06
10e	Likert	107				2.76	0.96
10f	Likert	107				2.42	1.04
10g	Likert	107				3.26	1.15
10h	Likert	107				2.26	1.03
10i	Likert	107				3.5	0.9
10j	Likert	107				3.76	0.81
10k	Likert	107				3.2	1.12
10l	Likert	107				2.85	1.06
10m	Likert	107				2.67	1.06
11	Essay	107				0	0
12a	MR	107	107	100.00%	-2		
12b	Essay	107				0	0
13a	Likert	107				1.88	0.8
13b	Likert	107				1.87	0.7
13c	Likert	107				1.84	0.79
13d	Likert	107				1.9	0.84
14a	MR	107	107	100.00%	-2		
14b	Essay	107				0	0
15	MC	107	107	100.00%	-2		
16	MC	107	107	100.00%	-2		
17	MC	107	107	100.00%	-2		
18a	Likert	107				2.16	1.22
18b	Likert	107				3.03	1.25
18c	Likert	107				3.42	0.99
18d	Likert	107				2.67	1.21
18e	Likert	107				3.21	1.01
18f	Likert	107				3.13	1.06
18g	Likert	107				3.54	1.25
18h	Likert	107				2.13	0.84
18i	Likert	107				2.92	1.18
19	Essay	107				0	0

Number	YES	NO	A	B	C	D	E
1			15	11	13	13	55
2			94	7	3	1	1
3a			5	61	103	2	6
3b							
4a			54	39	48	31	12
4b							
5			46	60	0		
6			56	51			
7			7	7	8	7	78
8	93	13					
9	61	46					
10a			21	17	2	4	2
10b			5	12	1	25	3
10c			1	14	8	21	2
10d			9	15	11	11	
10e			2	22	7	15	
10f			7	24	2	12	
10g			4	10	6	22	4
10h			8	28	2	6	2
10i			1	6	12	23	4
10j			1	2	10	27	6
10k			3	12	8	19	4
10l			3	20	5	17	1
10m			4	23	4	14	1
11							
12a			53	39	7	0	21
12b							
13a			23	28	8	2	
13b			19	34	7	1	
13c			23	28	8	2	
13d			21	30	6	4	
14a			23	13	18	15	6
14b							
15			32	14	8	3	4
16			0	15	16	9	21
17			9	12	11	10	18
18a			23	20	6	9	3
18b			8	16	6	24	5
18c				17	5	32	5
18d			11	19	9	16	3
18e			2	15	14	23	4
18f			1	24	4	28	3
18g			4	13	5	24	15
18h			10	41	2	8	
18i			7	21	6	24	3
19							

Number	F	G	H	I	J	K	nr
1							
2	1						
3a							
3b							
4a	17						
4b							
5							1
6							
7							
8							1
9							
10a							61
10b							61
10c							61
10d							61
10e							61
10f							62
10g							61
10h							61
10i							61
10j							61
10k							61
10l							61
10m							61
11							
12a	7	12	2	1	4	3	
12b							
13a							46
13b							46
13c							46
13d							46
14a	17						
14b							
15							46
16							46
17							47
18a							46
18b							48
18c							48
18d							49
18e							49
18f							47
18g							46
18h							46
18i							46
19							

Appendix C

Comments from teachers about why they do not incorporate data collection activities into their math lessons.

I actually used to do a fair amount of data collection in my geometry and precalculus classes. Since I have changed schools I have been under a lot of pressure to plow through the material. There doesn't seem to be time for much but lecture and homework. Sort of depressing. I think the students really enjoyed the activities we did and learned to make important connections. Maybe I can get back to that. A good source of prepared activities for calc and precalc would be wonderful

The main reason that I do not incorporate data collection activities is that I feel like I am always pressed for time because of class length and state standards that need to be covered. In addition, I feel like my students have a very hard time taking something they learned from data collection and generalizing it or applying it to abstract situations. Lastly, material preparation is very time consuming. IF I HAD AN EXPERIMENT THAT WAS ALREADY SET UP FOR ME, I WOULD AT LEAST TRY IT TO SEE HOW IT WORKED, EVEN IF IT PUT ME BEHIND A COUPLE OF DAYS.

Not sure how I can use data collection activities to make connections with factoring, polynomials, conic sections... There are topics that could benefit from these activities such as quadratic functions, but it does feel that we are under the gun to teach the standards, with little time to play. It's a shame.

Our curriculum is very structured. It is very difficult to deviate from the department standards.

Time and lack of resources are key reasons for not utilizing data collection. Most statistical processes use previous data collected that exists elsewhere.

While I feel that such data collection labs would be helpful to the instruction of some math concepts, many of my students lack the skills necessary to be successful in carrying out such an activity. I feel that teaching these skills would require incorporating them into a routine that would be difficult to keep up with for chapters for which data collection laboratory assignments are less relevant. I also feel that other support systems need to be in place to help students understand the proper behavior during such activities.

Where I am cuirrently (sic) stationed at, we only have access to two computer labs. Due to the lack of resources that we have, I have avoided doing these types of activities.

I haven't had the opportunity to look and see how to incorporate data collection within my current classroom setting.

In the classes I teach it is not something that really relates to the topics. In our upper level classes most of the teachers do use them when appropriate.

Pressure of the trimester to complete material on time.

No time in class. I barely have enough time to get everything done now.

I have very little time to prepare such lessons with my current responsibilities.

Time is the biggest issue.

Basically it is an issue of time and covering the standards fully with as much comprehension as possible.

After 34 years in the classroom it's not as easy for me to change methods as many of my younger peers!

Appendix D

Comments from teachers about why they do not incorporate more data collection activities into their math lessons than they currently do.

I don't have time to search out activities and PLAN out the activity.

Students understand the concepts of the graphs, mean, median, mode, etc without having to take the time to get the data. I find other units need the extra time rather than the data chapter.

We are on a trimester schedule and are required to cover a specific amount of lessons in the 12-week period. It is a real challenge to get through the chapters and therefore the first things that is cut from my lessons are anything ivolving (sic) math manipulatives and data collection.

Doesn't always fit lessons. I would like more lessons available so that I don't have to make up so many from scratch.

I believe the primary reason teachers don't incorporate data collection in a math class is amount of material that must be covered. It is also important to have data collection mean something mathematically. Often the time spent collecting actual data can be bypassed if you want to simply analyze data in a mathematical manner. The scientific methods of collecting meaningful data put emphasis on science and technology as opposed to mathematical analysis. If the two subjects (math and science) were to be taught simultaneously one could justify taking the time to collect data in a meaningful way before analyzing it.

There is a difference in my schedule between MATH and STATISTICS courses. In my stats courses, I use data collection activities frequently. In Pre-calculus, I collect data only 1-2 times per year since the emphasis of the course is not on data and statistics, but more on functions and trigonometry.

Our statistics text has plenty of real data sets for use in various problems. Students collect data for the (sic) own end-of-course research project. Otherwise, data collection is not really relevant to geometry.

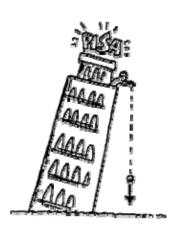Working on using Science class data at this time :)

You have to really keep the students on task when they are doing this kinds of activities and a lot of times one or two students end up doing all the work:)

Appendix E

Free Fall

Purpose: In this lab you will collect free fall data using a motion detector and your calculator. You will then look at the data to see what kind of mathematical function the data will model and write an equation.

Materials: motion sensor, graphing calculator, pillow

Pre-lab:

1. In Physics we use the equation $d = \frac{1}{2} gt^2$ to find the distances(d) that a free-falling object will drop in relation to the amount of time (t) that the object is in free-fall. Use $g = 10 \text{m/s}^2$ for acceleration due to gravity and neglect air resistance.

Time interval (sec)	Distance fallen (m)	D_1	D_2
0	0	-----------------	-----------------
1			-----------------
2			
3			
4			
5			
6			
7			
8			
9			
10			

2. In the D_1 column, find the common differences for the distance fallen. In the D_2 column, find the differences between the D_1 column. The D_2 column should be constant values if you've done your work correctly. Constant D_2 values indicate that the data represents a quadratic function like $y = ax^2 + bx + c$.

3. Explain why the distance fallen increases with each time interval?

4. On a piece of graph paper, make a graph of the distance vs time values from the table above.

5. When you find experimental data, would you expect your common differences to be perfectly constant? Explain.

6. To find the constant values "a, b, and c" for the quadratic function, you need a system of three equations. Practice writing these equations by choosing three of the data points from the table above and substituting them into the function $y = ax^2 + bx + c$.
Time = x point and distance = y point. Example, for x = 2 sec, y = 20 m, the equation is
    $20 = 4a + 2b + c$.

7. Use an algebraic method to solve for a, b, and c. (ideas include elimination, inverse matrices). Show work.

8. Substitute the values you found for a, b, and c into the equation $y = ax^2 + bx + c$. How does this equation compare to the formula $d = \frac{1}{2} gt^2$?

Procedure:

1. Using the ranger program, at the main menu go to **set up** and enter the following:

> real time: no
> time: 5
> display: dist
> begin on: (trigger)
> smoothing: light
> units: meter

The sensor will collect distance data every .053 seconds for 5 seconds.

2. Arrow up to **start now**. Place the sensor and calculator on the floor. Hold a soft object about 2 meters directly above the sensor. Press the trigger button, then release the object so it falls straight. Check your graph to make sure the sensor recorded your falling object correctly and the graph looks appropriate.

What should the graph look like?
Perform again if necessary.

3. Clean up materials.

Data:

1. Trace the points on the drop part of your graph and copy 10 sets of x and y data points onto your data table so that x is an arithmetric sequence.

2. Enter your time values(x) into L_1 on your calculator. Enter your distance values(y) into L_2.

3. Find the differences in your distances, D_1, and enter into L_4 on your calculator. Use your calculator to perform common differences for a list. With your lists displayed on the screen, arrow the curser so L_4 is highlighted. Then enter **2nd (List) OPS 7 ΔList L_2** . Copy these values onto your data table.

4. Enter your time values into L_3. Do not enter the first value so that you have the same number of entries as in L_4.

5. Stop if D_1 values are nearly constant. Continue if not.

6. Enter your time values into L_5. Do not enter the first two values. Use your calculator to find the second differences in your distances, D_2, and enter into L_6.

7. Stop if D_2 values are nearly constant. Continue this process as needed.

Time (sec)-x values	Distance (m)-y values	D_1	D_2
		----------------------	----------------------

Analysis:

1. Using data to support, does the free fall of an object model a quadratic function?

2. Choose 3 data points from your table and write three equations. (Should you choose data points close together or spread out?)
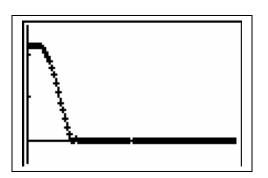
3. Solve for a, b, and c in your equations. Show work.

4. Substitute the values you found for a, b ,and c into the equation $y = ax^2 + bx + c$.
How does this equation compare to the formula $d = \frac{1}{2} gt^2$? Account for the differences
in the equation created by having the object fall toward the motion sensor instead of
away.

5. What should the graph of D_1 values compared to time values look like?

Using **StatPlot**, view the graph of L_3 and L_4 to see the graph. Show the shape of the
graph .

6. What should the graph of D_2 values compared to time values look like?

Using **StatPlot**, view the graph of L_5 and L_6 to see the graph. Show the shape of the
graph.

Teacher notes:

- Course level- This activity would be most appropriate for students in Algebra 2.

- Concepts covered- quadratic equations, system of equations, free-fall, gravitational acceleration

- This lab was based on an activity found in *Discovering Advanced Algebra*, 2004 published by Key Curriculum Press

- Set-up- I tried collecting data by having the object fall away from the sensor which was clamped to a ring stand resting on a lab table. The data was never as smooth as when the object fell toward the sensor.
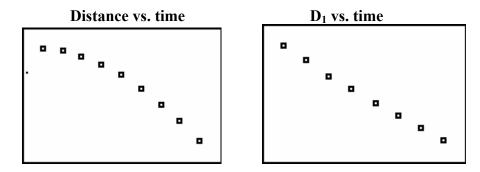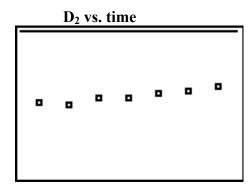
Data:

Original graph of distance vs. time

Sample data

L1 time	L2 distance	L3 time	L4 D1	L5 time	L6 D2
0.2688	2.22783	0.32256	-0.02723	0.37632	-0.02517
0.32256	2.2006	0.37632	-0.0524	0.43008	-0.0259
0.37632	2.1482	0.43008	-0.0783	0.48384	-0.0235
0.43008	2.0699	0.48384	-0.1018	0.5376	-0.0234
0.48384	1.9681	0.5376	-0.1252	0.59136	-0.0214
0.5376	1.8429	0.59136	-0.1466	0.64512	-0.0216
0.59136	1.6963	0.64512	-0.1672	0.69888	-0.0197
0.64512	1.5291	0.69888	-0.1869		
0.69888	1.3422				

Graphs

Distance vs. time

D$_1$ vs. time

I used the calculators **Zoom Stat** function to set the window for the first two graphs.

D$_2$ vs. time

I set my own window for this graph because of the closeness of the D$_2$ values.

Skittlelium Decay

Purpose: In this lab you will simulate radioactive decay using Skittles® candies to represent radioactive nuclei. You will graph class data and find an equation to model the data.

Materials: cup with 50 Skittles® candies

Pre-lab:
   1. What is radioactive decay?

   2. What is half-life?

Procedure:

1. Shake the 50 Skittles® in your cup and gently pour them on a paper towel. The Skittles® are the nuclei of a radioactive element called Skittlelium. Sort your Skittles® into 2 piles. One pile should have the "S" facing down and the other pile should have the "S" facing up. Those candies with the "S" facing down have just decayed and should be removed (and eaten immediately). Count those that remain and record your data for throw #1 on the data table.

2. Continue this process until all of the radioactive Skittlelium are gone.

3. Combine the class data for each trial on your data table.

Data:

Throw #	Number of radioactive nuclei	Class total of radioactive nuclei
0	50	
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Analysis:

1. Look at the column for class data. What is happening to the number of radioactive Skittlelium remaining each consecutive toss?

2. What type of function models this kind of data?

3. Write the general equation for this mathematical expression.

4. Make a graph of the class data on your calculator. Make the independent variable the # of tosses and the dependent variable the # of radioactive Skittlelium remaining.

   Draw what your graph looks like. Label the axis.

5. For each trial(throw), write an equation and solve for the rate. Show work.

   average rate =

   Write an equation using your average rate value.

6. Explain what the value of your rate means or indicates.

7. Use the calculator to fit your data to an exponential regression equation. Write the equation.

8. Copy this equation in your y= window and graph this equation with your experimental graph. Comparing the graphs, how does this graph fit your data?

Science connection:

The rate that you measured in this experiment is the half-life of your Skittlelium element. A better label for your x-axis on your graph would be "number of half-lives" instead of "toss #". Throughout radioactive decay the half-life or rate of decay for an element is constant. It is not affected by environmental conditions such as temperature and pressure.

Questions:

1. A radioactive nuclei has a half life of 4 days. If you start with a 500 gram sample, how much of the sample will you have in the following amount of time?

    4 days _____

    8 days _____

    10 days _____

    Write an equation for this data. Check your answers using the equation.

2. Thorium-234 has a half-life of 24.1 days. If you start with a 100 gram sample and you have 12.5 grams remaining, how many half-lives have passes? Write an equation to solve for # of half-lives.

Teacher Notes

- Course level- This activity would be appropriate for students in Algebra 2.

- Concepts covered-exponential decay, radioactivity and half-life

- Materials- 2 bags of Skittles® per class were enough if students work in pairs and are given 50 Skittles . I give my students a few extra credit points for bringing in candy for labs.
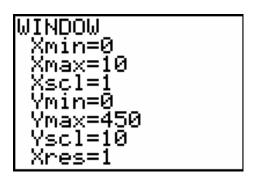
Answers to pre-lab questions

1. Radioactive decay is when the nuclei of unstable atoms break down into other particles in order to gain stability. Eventually, stable non-radioactive atoms are formed. The process is accompanied by the emission of energy.

2. Half-life is the amount of time it takes for half of the mass of a sample to decay. This time can be a fraction of a second or billions of years depending on the types of radioactive material.
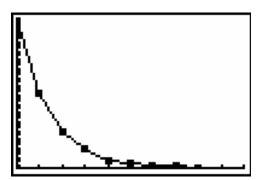
Sample data

throw #	class total of radioactive nuclei
0	450
1	223
2	111
3	56
4	24
5	12
6	7
7	5
8	3

Window

```
WINDOW
 Xmin=0
 Xmax=10
 Xscl=1
 Ymin=0
 Ymax=450
 Yscl=10
 Xres=1
```

Graph

Graphing instructions

- To enter data into lists, press **STAT, EDIT.** In List 1, input # of tosses and in List 2, input # of radioactive Skittlelium remaining.
- Set window.
- To turn on the graph, press **STAT PLOT** and turn on plot 1. For X List: L_1 and for YList: L_2.
- To fit an equation, press **STAT, CALC.** Arrow down to 0: ExpRegression. After you see ExpReg on the screen enter L_1, L_2 and enter. You will be given the values for the equation.
- To graph this equation with your experimental equation, after L_2 , enter **, VARS , Y-VARS, 1: Function, Y_1** then enter. Both graphs will be displayed together.

Answers to questions

1. 4 days- 250 grams, 8 days-125 grams, 10 days-88 grams
   $y = 500 \, (.5)^x$

2. $12.5 = 100(.5)^x$
   $x = 3$ half-lives

Appendix G

Comparing Pennies

Purpose: In this lab you will measure the density of pre-1983 pennies and post-1983 pennies. You will graph your results and find an equation to fit the data.

Introduction: The U.S. government changed the composition of the penny throughout 1983 due to rising copper prices. Before 1983, the penny was made of copper. Following the change, the penny has been made with a zinc center and a copper coating.

Materials: 100 ml graduated cylinder, older and newer pennies, electronic balance

Pre-lab:
1. What is density?

2. What is the formula for calculating density of an object?

3. What kinds of objects have density?

Procedure:

1. Sort a handful of pennies into a pre-1983 pile and a post-1983 pile. You need 25 for each pile. Do not use 1983 pennies.
2. Mass 5 pre-1983 pennies with an electronic balance. Record.
3. Fill your 100 ml graduated cylinder with precisely 40.0 ml of water. Remember to read from the bottom of the meniscus and read to the correct precision which would be one tenth of a milliliter. **Record this as the initial volume for each set of data**. Carefully drop in the 5 pennies and read the new volume. Record. Subtract to find the volume of the 5 pennies.
4. Mass 5 more pennies. Record and then total the mass of the 10 pennies.
5. Add these 5 pennies to the graduated cylinder. Record the final volume of the 10 pennies.
6. Continue adding 5 pennies at a time until you reach 25 pennies.
7. Drain the water and pour your pennies on a paper towel.
8. Calculate the density of the pennies for each set of data using the formula from your pre-lab.

9. Repeat with post-1983 pennies   .

Data:

pre-1983 penny

# of pennies	Mass of 5 additional pennies (g)	Total mass of pennies (g)	Initial volume of H$_2$O (ml)	Final volume of H$_2$O (ml)	Volume of pennies (ml)	Calculated density (g/ml)
5						
10						
15						
20						
25						

post-1983 penny

# of pennies	Mass of 5 additional pennies (g)	Total mass of pennies (g)	Initial volume of H$_2$O (ml)	Final volume of H$_2$O (ml)	Volume of pennies (ml)	Calculated density (g/ml)
5						
10						
15						
20						
25						

Analysis:

1. Based on what happens to the mass and volume as 5 more pennies are added each time, what do you think the graph of your data will reveal?

2. Graph your data on one piece of graph paper. Use different colors for each set of data. The volume of the pennies should be on the x-axis and the mass of the pennies should be on the y –axis. Draw a best line of fit for each set of data.

   Which line has a greater slope?

3. Using your lines, write the equation for each set of data in y-intercept form. When finding slope, choose 2 data points that are spread apart. Show work.

   pre-1983   post-1983

Questions

1. Explain the meaning of your slope in this context?

2. Explain the meaning of the y-intercept in this context?

3. Use your equation for pre-1983 pennies to predict the volume of a handful of pennies that have a mass of 225.00 grams.

4. Which set of pennies has a greater density?
   What does this tell you about the density of copper compared to zinc? (Go back and read the introduction again.)

Science connection

For substances, the amount of the substance does not affect the density. For example, the density of helium gas in a little balloon will be the same as the density of helium in a very large balloon (think Hindenburg!)

5. Use your data to explain why the density of the pennies remains constant as you add more and more pennies.

6. Which will have a greater density? a small ice cube (1" x 1" x 1") or a large ice cube (1' x 1' x 1')

7. What can be done to an object that will change its density?

Teacher notes

- Course level-this activity is appropriate for Algebra I students. The difficulty of the lesson could be increased for Algebra II students by having them find the residuals and then the root mean square error.
- Concepts covered-graphing, y-intercept, line of fit, density
- To save time taking data, have students work in groups of four. Two students take the pre-1983 data and the other two students take the post-1983 data. The four students can share one balance.
- Show students how to read the meniscus of the graduated cylinder and emphasize reading the volume measurements with care to the nearest tenth of a milliliter. Volume measurements will be the largest source of error.
- Demonstrate how to use an electronic balance for those who have never used them in science class.

Sample data for pre-1983 penny

# of pennies	Mass of 5 additional pennies (g)	Total mass of pennies (g)	Initial volume of H_2O (ml)	Final volume of H_2O (ml)	Volume of pennies (ml)	Calculated density (g/ml)
5	12.50	12.50	40.0	41.8	1.8	6.9
10	12.51	25.01	40.0	43.5	3.5	7.1
15	12.51	37.52	40.0	45.2	5.2	7.2
20	12.51	50.03	40.0	47.0	7.0	7.1
25	12.48	62.51	40.0	48.8	8.8	7.1

Sample data for post-1983 penny

# of pennies	Mass of 5 additional pennies (g)	Total mass of pennies (g)	Initial volume of H_2O (ml)	Final volume of H_2O (ml)	Volume of pennies (ml)	Calculated density (g/ml)
5	15.40	15.40	40.0	41.9	1.9	8.1
10	15.50	30.90	40.0	43.8	3.8	8.1
15	15.43	46.33	40.0	45.7	5.7	8.1
20	15.36	61.69	40.0	47.5	7.5	8.2
25	15.40	77.09	40.0	49.3	9.3	8.3

Answers to pre-lab questions

1. Density is a ratio of an object's mass to volume.
2. Density = mass/volume
3. All objects whether solid, liquid, or gas have a density.

Answers to questions

1. The value of slope is equal to density because the rise/run is equivalent to mass/volume.
2. The y-intercept will be equal to the value of volume when mass is zero. This value should be zero as well because all substances that have any mass at all must have a volume.
3. Answers will vary depending on individual equations.
4. The density of the pre-1983 pennies will be greater which means that the density of copper is greater than the density of zinc.
   density of copper= 8.96g/ml   density of zinc=7.133 g/ml
5. Student's data should show reasonably well that the ratio of mass to volume remains constant as more pennies are added.
6. The same. Anything that will change the volume of the object without changing the mass- pressure and temperature changes will cause the atoms inside the object to compress or expand. Make sure students don't say something along the lines of breaking the object in half-the mass to volume ratio will remain the same.