Technology in Mathematics Education: Preparing Teachers for the Future

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Abstract

The preparation of preservice teachers to use technology is one of the most critical issues facing teacher education programs. In response to the growing need for technological literacy, the University of Northern Colorado created a second methods course, Tools and Technology of Secondary Mathematics. The goals of the course include (a) providing students with the opportunity to learn specific technological resources in mathematical contexts, (b) focusing student attention on how and when to use technology appropriately in mathematics classrooms, and (c) giving opportunities for students to apply their knowledge of technology and its uses in the teaching and learning of mathematics. Three example activities are presented to illustrate these instructional goals of the course.

The preparation of tomorrow's teachers to use technology is one of the most important issues facing today's teacher education programs (Kaput, 1992; Waits & Demana, 2000). Appropriate and integrated use of technology impacts every aspect of mathematics education: what mathematics is taught, how mathematics is taught and learned, and how mathematics is assessed (National Council of Teachers of Mathematics [NCTM], 2000). Changes in the mathematics curriculum, including the use of technology, have been advocated for several years. The Mathematical Sciences Education Board (MSEB) and the National Research Council maintain that "the changes in mathematics brought about by computers and calculators are so profound as to require readjustment in the balance and approach to virtually every topic in school mathematics" (MSEB, 1990, p. 2). Future mathematics teachers need to be well versed in the issues and applications of technology.

Technology is a prominent feature of many mathematics classrooms. According to the National Center for Education Statistics (NCES, 1999), the percentage of public high school classrooms having access to the Internet jumped from 49% in 1994 to 94% in 1998. However, the use of computers for instructional purposes still lags behind the

integration of technology in the corporate world and is not used as frequentlyor effectively as is needed. One way to close the gap and bring mathematics education into the 21st century is by preparing preservice teachers to utilize instructional tools such as graphing calculators and computers for their future practice.

In the past at our campus, technology issues and "training" in mathematics education were addressed within the confines of a regular three-semester-hour mathematics methods course, taught by a professor of mathematics education within the College of Arts and Sciences. With increasing demands placed on the teacher preparation program by state legislation, which has become common throughout all of education, the amount of content in the methods course was becoming overwhelming. As a result, little time was available to address the issue of the technology required for effective mathematics instruction.

Even before the additional state requirements, relatively little time was spent providing preservice teachers with hands-on experience using graphics calculators and mathematics software. Secondary mathematics majors occasionally used a computer algebra system (CAS) for different projects within their calculus courses, as well as spreadsheets and software applications in their statistics course. Additionally, most teacher candidates have had experience using graphics calculators at different points within various mathematics courses. However, little time was spent preparing preservice mathematics teachers to use technology in their future classrooms. Our program has required all secondary education majors to take two one-credit general education technology courses that address spreadsheet, word processing, and Web-page development, but none of these college technology experiences provided them with content specific or classroom specific experiences they will need as future mathematics teachers.

Our response to the growing need for technological literacy was to create a second methods course entitled, Tools and Technology of Secondary Mathematics. This course supplements the content and methods of our existing methods course, but focuses on the utilization of technology in secondary mathematics classrooms. In keeping with the philosophy of our Secondary Professional Teacher Education Program, the course has three broad aims. First, teacher candidates receive hands-on training in using software tools, graphing calculators, and the Internet for mathematics instruction focused at the secondary school level. Second, they learn how and when to use appropriate technology to enhance their mathematics instruction of topics that are taught at the middle and high school grades. Third, they develop and teach lessons to their peers with equipment available to a typical public school mathematics classroom, using the technology learned in this course.

One purpose of the technology methods course is to provide the opportunity for preservice teachers to use specific technological resources in mathematical contexts. That is, teacher candidates are presented with a task involving some mathematical problem or situation and are required to learn to use and apply an appropriate piece of technology in completing the task. For example, one activity used in the methods course is found on the NCTM (2004) *Illuminations* Web site (available at http://illuminations.nctm.org/lessonplans/9-12/webster/index.html). The activity, titled "The Devil and Daniel Webster" and adapted from Burke, Erickson, Lott, and Obert (2001), has teacher candidates explore recursive functions using technology. The undergraduates are presented a scenario in which each person earns an initial salary of $1,000 on the first day, but pays a commission of $100 at the end of the day. On subsequent days, both amount earned and commission are doubled. Preservice teachers complete a chart using either handheld or computer technology to determine if it is

profitable to work for one month under these conditions. Additional questions require the undergraduates to graph the data from the chart. In this way, teacher candidates not only learn to use the kinds of technological tools that are available for use in instruction, but also learn them in the context of examining mathematics, which helps increase their content knowledge.

In addition to learning to use the technology, pedagogical issues associated with the instructional tools are emphasized. Specifically, the course focuses attention on how and when to use technology appropriately in mathematics classrooms. Misuses of technology are discussed and discouraged, such as using calculators as a way to avoid learning multiplication skills and using computers to practice procedural drills rather than to address conceptual understanding. Rather, preservice teachers discuss the uses and benefits of commercial software and handheld devices to explore different content topics that have become possible with technology and consider pedagogical issues. Some time is also spent previewing national curriculum projects that have a high involvement with technology (e.g., Key Curriculum Press, 2002). As a result, preservice teachers address and discuss issues of teaching prior to their clinical experience, which helps these students focus attention on these matters when participating in their practicum.

Teacher candidates in the technology methods course apply their knowledge of technology and its uses in the teaching and learning of mathematics. These future mathematics teachers create several lesson plans using technology as an instructional tool. Lesson plans center around concepts and skills found in pre-algebra, algebra, geometry, precalculus and calculus that are enhanced using technology. Once a topic is selected for the lesson plan, preservice teachers determine an appropriate piece of technology that facilitates instruction. They develop and write instructional lessons using graphing calculators, an interactive mathematics computer environment, an interactive geometry application, computer spreadsheets, and the Internet. However, based on a selection of specific mathematics topics, each teacher candidate creates lessons using additional forms of technology examined in the course, including dynamic statistical software and a CAS. As a result, each teacher candidate has a unique experience of using technology to enhance mathematics instruction at the secondary school level.

Depending on time constraints, preservice teachers teach at least one of their lessons with their peers as students. Our course ensures that these future mathematics teachers are able to write and deliver lesson plans that incorporate appropriate technology for mathematics courses at the level for which they are seeking licensure.

It is important that teachers are able to develop well-conceived lesson plans that are structured and detailed, focusing on specific mathematics topics and using multiple representations, such as the examples in the appendices. Open-ended exploration and inquiry-driven mathematics lessons using such software as interactive, dynamic geometry or algebra software are also developed after the teacher candidates are able to develop a detailed lesson that explores the topic with some depth. For students to experience a mathematics topic in depth, specific "guided" discovery lesson planning is required. Part of the objective is to counter a pervasive disposition of the mathematics curriculum in this country as being a mile wide and an inch deep.

Since the creation of the technology methods course, we believe that our program adequately addresses the needs of many preservice teachers to be competent at integrating these instructional tools for teaching and learning mathematics. The growth of future teachers' ability to use technology appropriately in the mathematics classroom during the course becomes evident in observations. The following illustrations provide detailed descriptions of the process in which preservice teachers engage as they learn, analyze, and apply a particular piece of technology in the course.

Interactive Computer Environment

One important feature of the course is to introduce future teachers to the world of possibilities open to instruction when computers are used effectively. The vast majority of our preservice teachers have had some experience using computers within and outside their high school mathematics courses, but few have had the opportunity to learn mathematics in an interactive computer environment. Providing this experience for our teacher candidates has created a template on which they can draw as future teachers.

For one activity, the preservice teachers use an interactive mathematics computer environment as an electronic textbook. Embedded in the text is the derivation, using calculus, of the velocity of an object under the influence of earth's gravity as a function of time (i.e., $v(t) = gt + v_0$). Through this interactive environment preservice teachers manipulate parameters and see, in real time, the effects of those changes on the graphs and data tables of the function. For example, after explaining that the value of the gravitational constant, g, is 9.8 meters per second per second, teacher candidates integrate the gravitational constant with respect to time, t, to obtain the velocity function: $v(t) = -gt + v_0$. This function illustrates the physics principle that the velocity of an object is the integral of its acceleration. In Figure 1, the result of changing the initial velocity from 49 meters per second to 4.9 meters per second is apparent by the graphs and tables. After completing this assignment, preservice teachers learn how to create an activity using the interactive computer environment.

The potential of such an instructional tool is readily apparent to teacher candidates. Instead of using a static textbook in which authors determine examples and illustrations, using an interactive computer environment in instruction allows the preservice teachers to choose their own examples and participate in dynamic illustrations. Additionally, the undergraduates can type and check spelling, as in any common word processor, respond to problems and questions embedded in the computer application, and print copies for classroom use or assessment purposes by the teacher.

Teacher candidates then develop lessons or activities using this technology that are appropriate for their future middle school or high school students. One possible activity applies the knowledge gained in the initial experience with the interactive computer environment. Appendix A contains an example of one such activity used in our program as a guide for preservice teacher generated work that uses the height of an object acted upon only by the force of gravity as an application of quadratic equations. The scenario involves the launch of a model rocket into the air and requires high school students to model the height of the object as a function of time in tabular and graphical form. Such an activity demonstrates the multiple uses of important components of the interactive computer environment within an appropriate context of secondary mathematics.

Interactive Geometry Application

One way to introduce teacher candidates to a particular piece of technology is through classroom-ready, published materials. This is particularly useful when the software is well established and used regularly in classrooms, because teachers could adopt the activity for future classroom use. In one case, we use Bennett (2002) to introduce undergraduates to interactive geometry software on the computer. For example, the following problem could be posed at the beginning of a class session: How could you determine the height of a tree without measuring it directly? At the time they take the technology methods course, teacher candidates typically have an extensive cache of techniques to solve such a problem from prior geometry and trigonometry courses. Bennett (2002) utilizes interactive geometry software to find such indirect measures using lengths that are easy to measure and proportions in similar triangles. Specifically, the worksheet directs the learner to create line segments to represent the tree's height and the learner's height in the application; then learners construct parallel lines to simulate the rays of the sun. Finding the tree's height is a matter of calculating the unknown length (tree's height) in the proportion of ratios of object height to shadow length. Although preservice teachers often know this technique, constructing the solution in the interactive environment helps clarify concepts and procedures learned in prior courses.

After becoming familiar with the software from the activity, discussions take place on the appropriate uses of the technology. In the case of the interactive geometry software, teacher candidates should recognize several potential uses of the software in a high school geometry course. For example, appropriate use of the software can reinforce properties of similar triangles in students' minds. The preservice teachers should also recognize that the interactive component of the software allows their students to see that corresponding angle measures remain equal and that corresponding ratios of sides remain equal during actions that change the dimensions of the similar triangles. Preservice teachers reflect on the ability of the software to have students discover these properties, rather than simply telling their students, thus creating a more student-centered classroom environment. These future teachers should also recognize the need to transfer the knowledge gained from the interactive domain to problem situations away from the technology, which leads to discussions of how this might be accomplished.

As a culminating experience with the technology, preservice teachers create lessons using the software that are applicable to a secondary mathematics course. Often, ideas for these activities are generated by recognizing alternative solution methods for problems already considered. After exploring the interactive geometry software while solving the tree problem, teacher candidates are encouraged to develop alternative solution methods for solving indirect heights. Appendix B presents a follow-up activity for finding indirectly unknown heights of objects. The problem involves finding the height of a flagpole when a mirror is placed on the ground between an observer and the flagpole. The activity leads learners to find an indirect height using similar triangles formed by the reflection in the mirror because the angle of incidence equals the angle of reflection for light. Additionally, the solution plan requiring learners to reflect a ray across a line demonstrates the principles involved, as well as a more sophisticated feature of the interactive geometry environment.

Handheld Data Analysis

One of the easiest technologies for preservice teachers to learn, and yet one of the most adaptable for classroom instruction, is graphing calculator technology. Still, too few secondary school mathematics teachers are comfortable using graphing calculators or

know how to use them effectively for classroom instruction. A primary goal of the technology methods course is to provide instruction and experience with handheld technology. Utilizing graphing calculators in a statistical application is one way to meet this goal.

Recording, graphing, and analyzing data are important skills in mathematics, as well as in everyday life. The notion that data exist everywhere in the world is important for students to realize. Additionally, the ability to organize data provides a person with quick numerical and visual representations of the data and the power to predict, to within a predetermined degree of accuracy, future related events based on the data. An introductory lesson for managing data using handheld technology is to enter and graph party affiliations of the presidents of the United States. Two common representations of the data are bar graphs and circle graphs (see Figure 2).
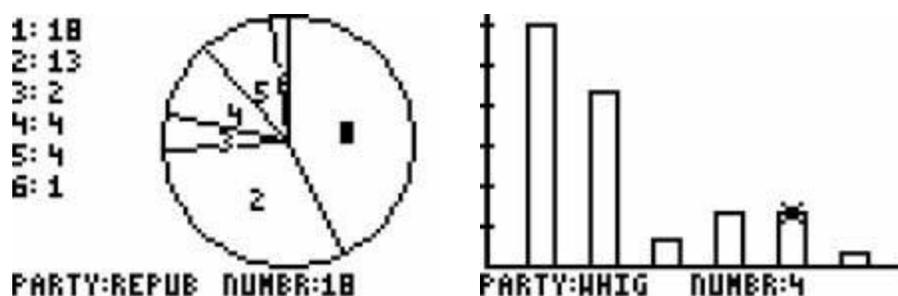

Figure 2. Circle graph and bar graph of presidential party affiliations in TRACE mode.

One of the issues that should be raised by preservice teachers involves the best visual representation of the political parties of the presidents. They should discuss the advantages and disadvantages of their bar graphs and circle graphs, as well as other common graphical representations. Although the graphs can be obtained from computer spreadsheet technology, students must recognize the importance of being familiar with handheld technology as well. We want our teacher candidates to be capable and experienced with various technological tools so that they are comfortable using the technology available to them in the schools in which they will be teaching.

One required activity of the course is to develop a problem involving the collection, graphing, and analysis of data for middle school or high school mathematics students to complete. Appendix C contains an authors' example of one such activity used in the technology methods course but applicable for a high school class. This activity uses presidential data, similar to the introductory activity, but involves the ages of the presidents at the time of inauguration. The activity extends the relatively simple task of representing data using handheld technology and includes more statistically rigorous analysis of the presidential ages. The activity highlights the mathematical power available to most students to make sense of the world around them using statistical analysis.

Conclusion

Teachers will use technology appropriately and effectively in their mathematics classrooms if they are familiar and comfortable with the technology and, especially, if

they have had successful experiences with the technology in an instructional environment. Additionally, teachers who are able to use today's technology in the classroom will be prepared to learn and utilize tomorrow's technology. This core course for the secondary teacher education program provides that experience. After this course, the teacher candidates integrate the technology in their field experiences conducted in one of the university's partner schools. In one instance, preservice teachers use technology during their first clinical teaching experience. At another time, during their semester-long student-teaching experience, host teachers and university faculty members evaluate student teachers on their ability to integrate technology in the classroom. Upon graduation, these future teachers should not only be knowledgeable as to which mathematics concepts are best learned through technology, but also will have had many successful experiences in developing and carrying out lesson plans that involve a variety of different technologies.

Since the creation of our technology-based methods course, its need is apparent. Although technology in typical secondary schools is sparse, several of our partnership schools are dedicated to utilizing technology in mathematics education. From interactive chalkboards to data-sharing hubs for handheld devices, our preservice teachers are beginning to experience these instructional tools during their field experiences. Consequently, we think it is important to prepare them for these eventualities. Our preservice teachers' experience with technology in our program makes them attractive to secondary school selection committees.

The quality of our preservice teachers since our program emphasized technology in the mathematics classroom is apparent. As university supervisors, we often hear from the host teachers that our graduates are highly knowledgeable in dealing with technological instructional tools. Many host teachers admit to learning valuable teaching strategies using technology from individuals in our program. Although most of our preservice teachers receive favorable technology evaluations, we think we can do better. Our preservice teachers continue to think pedagogically in ways that they were taught rather than to think of the potential learning gains using technology. This course does lay the foundation for these teachers as they become more comfortable with their teaching practices and different ways to educate their students.

Today's middle school and high school students were born into a world with technology. Using technology during mathematics instruction is natural for them, and to exclude these devices is to separate their classroom experiences from their life experiences. One objective in preparing teachers for the future is to ensure that their classrooms will include the technology that will be commonplace for a future generation of mathematics learners, thus ensuring that the mathematicians, mathematics educators, and citizens of tomorrow experience harmony between their world of mathematics and the world in which they live.

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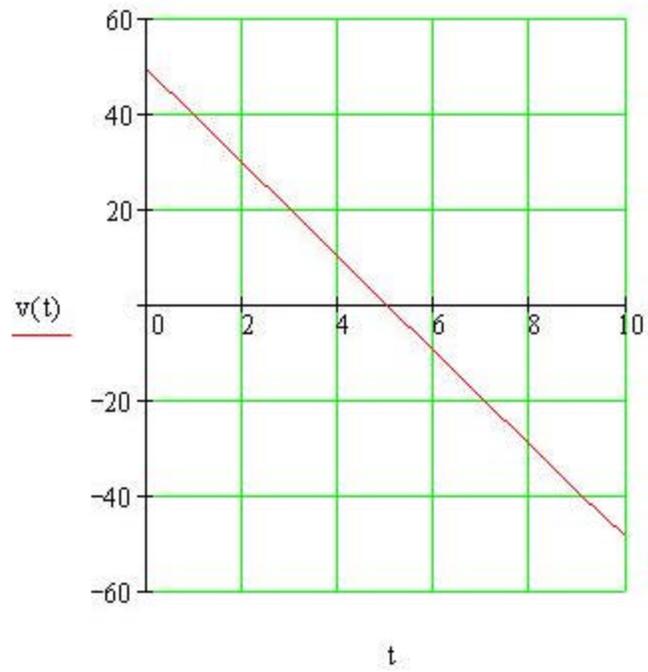bill.blubaugh@unco.edu

$g := 9.8$

$v0 := 49$

$t := 0, 1 .. 10$

$v(t) := -g \cdot t + v0$

t =	v(t) =
0	49
1	39.2
2	29.4
3	19.6
4	9.8
5	0
6	-9.8
7	-19.6
8	-29.4
9	-39.2
10	-49

$g := 9.8$

$v0 := 4.9$

$t := 0, 1 .. 10$

$v(t) := -g \cdot t + v0$

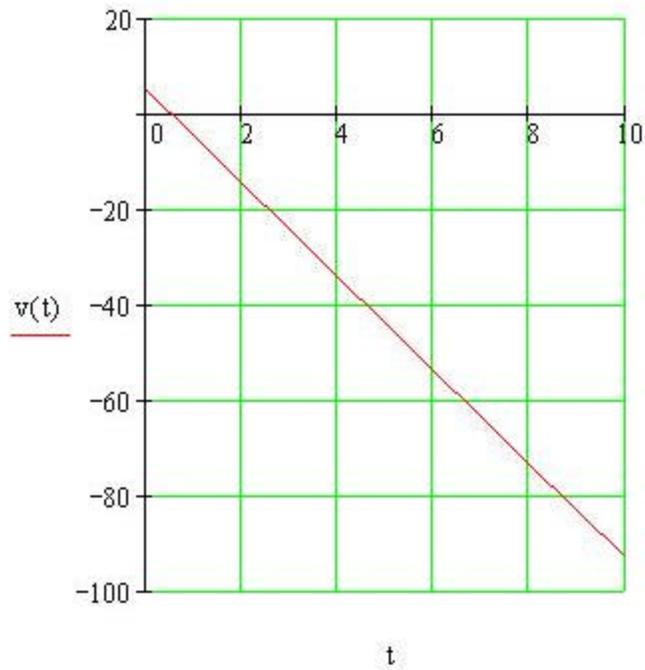| $t =$	$v(t) =$
0	4.9
1	-4.9
2	-14.7
3	-24.5
4	-34.3
5	-44.1
6	-53.9
7	-63.7
8	-73.5
9	-83.3
10	-93.1

Figure 1. Changing the value of v_0 in the function $v(t)$ is apparent in the graphs and tables.

Appendix A

Computer Algebra System: Rocket's Flight

Rocket's Flight

Statement of the Mathematical Situation

A model rocket blasts off from a position 2.5 meters above the ground. Its starting velocity is 49 meters per second. Assume that it travels straight up and the only force acting on it is the downward pull of gravity. Describe the rocket's flight path and any key aspect that may be significant or important to the problem. Also, note that the acceleration due to gravity is 9.8 m/sec².

Directions for Students

Analyze the above situation and describe it using tabular, graphical, and symbolic representations. After you have completely analyzed the situation in two different ways, describe in your own words the biggest challenge you had in analyzing and completing the task. You may choose (but are not required) to follow the steps below.

Step 1: What is the value of *h(0)?* What is the real-world meaning of *h(0)*?

Step 2: What is the initial value of the velocity, given by *v*(0)?

Step 3: What is the acceleration due to gravity, or *g*? How would any equation describing the rocket's flight show that this force is downward?

Step 4: Write the unique quadratic function that represents the height, *h(t),* of the rocket identified in the problem statement *t* seconds after liftoff. Hint below.

Remember that $h(t) = -\frac{1}{2} g \cdot t^2 + v(0) \cdot t + h(0)$

Step 5: In the space below: (a) Graph your function *h(t)* using the best viewing window that shows all important parts of the parabola. (b) Make a table of heights above the ground, for the first 10 seconds of flight, increment by 1 second.

Step 6: How high does the rocket fly before falling back to Earth? When does it reach this highest point?

Step 7: How much time passes while the rocket is in flight?

Step 8: Write the equation you must solve to find when *h*(t) = 50.

Step 9: When is the rocket 50 meters above the ground? Approximate your answer to the nearest tenth of a second.

Step 10: Describe in words and show graphically your answer to Step 9.

Related Online Resource:

Online Graphics Calculators:
http://www.scugog-net.com/room108/calculator99/ and
http://matti.usu.edu/nlvm/nav/frames_asid_109_g_4_t_1.html?open=activities.

Appendix B

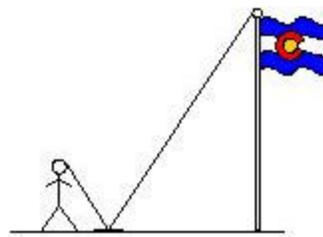**Geometry Application: Flagpole Problem**

Flagpole Problem

In this activity, you will solve the flagpole problem using an
interactive geometry application.

To find the height of a flagpole, a student placed a mirror on
the ground and stood so that she could look in the mirror
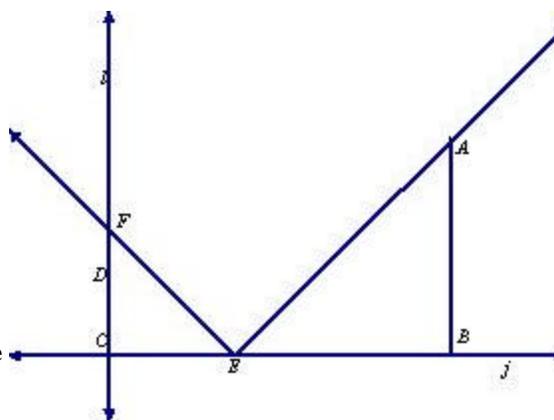and see the reflection of the top of the flagpole. See figure on
the right.

Sketch and Investigation

1. Construct line segment $\overline{AB}$ to
represent the flagpole.

2. Construct the line j perpendicular to
segment $\overline{AB}$ at point B to represent the
ground.

3. Construct point C on line j to
represent the location of the observer.

4. Construct line l perpendicular to line
j at point C.

5. Construct point D on line l to represent the eye level of the observer.

6. Construct point E between points C and B on line j to represent the location of the
mirror.

7. Construct ray $\overrightarrow{EA}$.

8. Construct the line m perpendicular to line j through E.

9. Mark line m as a mirror.

10. Reflect ray $\overrightarrow{EA}$ about line m.

11. Construct the intersection of the reflected ray and the line l. Label it point F.

12. Hide line m.

13. Measure the lengths of $\overline{CF}$, $\overline{CE}$, and $\overline{EB}$.

14. Measure angles $\angle FEC$ and $\angle AEB$.

Questions:

1. Drag point E between C and B. What do you notice about angles $\angle FEC$ and $\angle AED$? What does this imply about triangles $\triangle FEC$ and $\triangle AED$?

2. Drag point E until point D and F coincide. What are the measures of $\overline{CF}$, $\overline{CE}$, and $\overline{ED}$? Describe these measures in the context of the flagpole problem.

3. Using the relation between triangles $\triangle FEC$ and $\triangle AED$, determine a formula for calculating segment $\overline{AD}$. What is the measure of $\overline{AD}$?

4. The student measured the distance from herself to the mirror to be 1.19 meters, from the mirror to the base of the flagpole to be 6.65 meters, and her eye level height to be 1.70 meters. How tall is the flagpole?

Related Online Resources:

Dynamic Geometry for the Internet:
http://www.keypress.com/sketchpad/javasketchpad/about.php

Appendix C

Data Analysis: The Presidency of the United States

The Presidency of the United States

1st: Using the Internet, school library, or a history book obtain the ages, at inauguration, of the presidents of the US.

Question: What do you initially observe about the ages of our presidents?

2nd: Using the statistical lists of your graphics calculators, enter the presidential order (1st, 2nd, 3rd, etc.) and the inauguration age for each president in "Order" and "Age" lists.

Question: To enter the data in the "Order" list, do you remember the quick way of entering an arithmetic sequence using the *seq(* command?

3rd: Construct and display a histogram of ages at inauguration on the screen of your calculator.

Question: From this graph, what do you notice about the inauguration ages of the presidents?

4th: Construct a box-and-whiskers plot of their ages at inauguration on the screen of your calculator.

Questions:

(1) What five-number summary is obtained from the box plot?

(2) What does the box plot reveal regarding the spread of the data?

(3) By looking at its shape and length, what else does the box plot reveal?

5th: Display your histogram and a box-and-whiskers plot of the above ages as two different plots, and display them on the same screen.

Questions:

(1) By looking at two different graphical representations at the same time, what additional information or reinforcing comments can you make?

(2) Which of the two graphs provide the more important information and why?

(3) Support your conclusions from Question 2 above by calculating *1-Var Stats* of the Presidents' ages.

6th: Now graph the ages at inauguration by the order of their presidency.

Questions:

(1) Describe any patterns that you see in the points.

(2) If we divide the presidency into three parts, say the first 14, the middle 15, and the last 14 presidents, how do the 3 parts compare with each other?

(3) Verify your observations, using the statistics available in your calculator.

(4) Based on the ages of the last 14 presidents, what "predictions" can you make regarding the next president?

7th: Knowing the inauguration ages and political party affiliation of each of our presidents, what questions were not asked that you would like answered?

Extension: If time permits, perform the additional analysis involving confidence intervals and tests of significance.

8th: Determine the Confidence Interval, at the 95% level for the mean, for the age at inauguration of our next president.

Questions:

(1) What does a 95% Confidence Interval mean?

(2) Would the 95% Confidence Interval be the same for the mean and the median of the ages? Elaborate.

(3) Based on the ages of all U.S. presidents at inauguration, what is the interval that will likely contain the age of the next president at the 95% confidence level?

(4) Using only the ages of the last 14 presidents, what is the 95% confidence interval that will likely contain the age of the next president?

(5) What is the difference between 3 and 4 above, and why?

9th: Suppose we were to randomly select the age of one of our past presidents to help determine the likely age of the next president.

Question: What is the probability that the next president would be between 40 and 46 years old (a) using the ages of all 43 presidents, and (b) using the ages of the last 14 presidents?

10th: Use a *t*-test of independent sample means available on your calculator to determine if the ages of the first 14 presidents at inauguration are significantly different from the ages of the last 14 presidents at inauguration.

Questions:

(1) What is the meaning of this calculator result?

(2) Why was this test used?

Related Online Resources:

Political Party Data: http://www.presidentsusa.net/partyofpresidents.html
Ages at Inauguration: http://www.campvishus.org/PresAgeDadLeft.htm
Data Plots/Graphs: http://matti.usu.edu/nlvm/nav/category_g_4_t_5.html