TRADITIONAL VERSUS TECHNOLOGICAL APPROACHES TO TEACHING MATHEMATICS AND PHYSICS

by

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Abstract

The use of technology in the classroom can be an integral part of the learning process. It allows the instructor the freedom to explore a broader range of problems, concepts, or activities. The technology can reduce the long "busy work" problems to a few minutes without diminishing any of the concepts. The problems may be real without the "nice" numbers to make the calculations easier. The student and instructor may explore several variations of the problem in a short time with little effort. The laser disk opens other possibilities to bring in examples too costly for many laboratories or classrooms. The inclusion of technology in the classroom presents many interesting challenges to the instructor and student.

Introduction

The students and classroom has changed significantly over the past two decades. The method of instruction must also be changed to adapt to the changing times, students, technologies and job opportunities.

Traditionally mathematics has been a rather boring subject for most students. The ones who enjoyed it either found it easy or enjoyed the challenge of solving the problems. The rest of the students tolerated it long enough to get the credit for the course. The technology can increase the interest for the later group and even create some excitement while being successful with some of the problems.

The teaching of mathematics and physics has several levels of technology that may be used in the classroom or by the student. The first level being the chalkboard, overhead projector with transparencies, and models of the various curves or solids. This is the main support for the traditional methods. The instructor lectures on the concept, possibly aided with overhead transparencies and/or models. The students questions are addressed at the appropriate time or as time allows. The class period is dominated by the instructor with the majority of the feedback coming from test results. The instructor is very much in control of what is happening in the classroom all the time. The students may use their calculators on the homework and/or test.

The second level of technology is using the graphing calculators and/or other student affordable electronic devices. These devices may be used for classroom demonstrations purposes or by the student to explore the properties of functions. They can supply the student with a lot of support as he/she explores the patterns of mathematics and collected data. The graphing calculator will give the student a chance to start exploring the patterns of mathematics and/or analyzing data.

The third level is to make full use of the computer and other hardware with the various mathematics and physics software programs that are available on the market. These programs will do various things from collecting data, graphing it, fitting a curve to it and rotating the curve for different views. They will integrate, differential, and solve various types of equations as examples of their capabilities. The statistical software will give plots of the data to show distribution and also have curve fitting and analysis capabilities. The classroom will become a mathematics laboratory part of the time while studying and analyzing the real life data. These projects may be complex enough to require several days work and or the effort of several students working together. The instructor's role as the focal point of the class is diminished, the technology and what can be done with it starts controlling the direction of the class.

To feel comfortable using any or all of the possible technology in the mathematics and physics classroom, one must move away from the traditional meaning of mathematics. The average person will define mathematics as a lot of numbers and/or letters (variables) that created confusion they didn't understand

(and probably could care less about). Unfortunately their mathematics definition and experiences didn't include anything about reasoning, real problem solving, patterns, data collection and analysis. These are the areas that the student really needs to have some skills upon completing the mathematics sequence. The reasoning is short circuited with ideal problems in which a pattern or sequence of steps are memorized. The problem solving amounts to learning the methods for solving equations in algebra and/or the related simple word problems. No real life problems from outside of the textbook are ever explored. The use of technology will allow the student to move beyond the simple problems, with all the ideal numbers, that can be worked on paper in a few minutes.

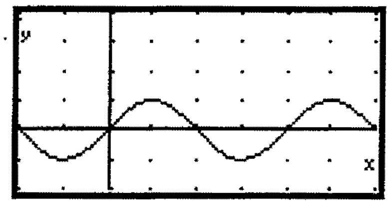
Using technology allows and encourages the student to explore different approaches (graphical, numerical, symbolic, etc.) The calculator and computer are very obedient. They do what they are told. The student must still be able to reason through the process of what they are trying to find and be able to recognize a reasonable answer when it occurs. Technology can't be a substitute for not knowing anything. Most still require knowing the general procedure of solving the problem.

Application of Technology

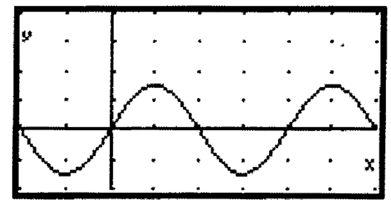
The amount of technology used in the classroom varies with the instructor and/or the amount available. I use the Texas Instrument - 85 graphing calculator, the Macintosh computer (*Theorist®* and *Maple®* software), and data sensors and collectors in the classroom.

The TI-85 can be purchased with a view screen that will fit on the overhead projector. Anything that is displayed on the calculator's screen is also projected by the overhead. The hardware and software is also available to connect the calculator to either an IBM/compatible or Macintosh computer. The two pieces of technology can exchange data, graphs, etc. to extend the applications or extend the memory of either. I have drawn graphs on the calculator and transferred them to the computer to be pasted into a test or problem exercise. They can also be enlarged and printed to make permanent transparencies for the overhead. Two TI-85 calculators can also "talk" to each other and exchange programs, data, etc. This has proved to be a useful "tool" for sharing information with the students who may also have TI-85 calculator.

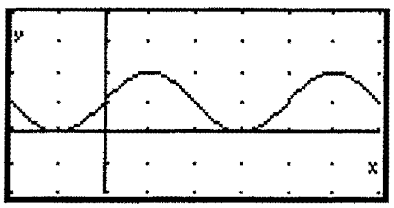
I have used the graphing calculator in all of the classes that involve the sketching of graphs. The MA-111, College Mathematics for Aviation I, involves sketching graphs of the various trigonometry functions and some polynomial functions. The graphs below, produced by the TI-85 calculator are an example for the sine function. All of the graphs involving the sine function are variations of the graph of $y = \sin x$. They are just shifted up or down, right or left, and either stretched or compressed horizontally or vertically.



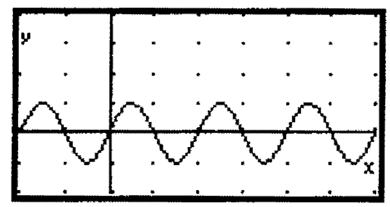
y = sin x



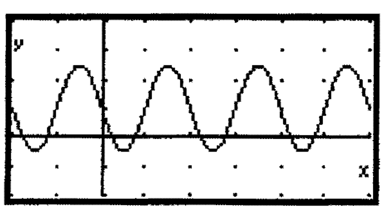
y = 1.5 sin x



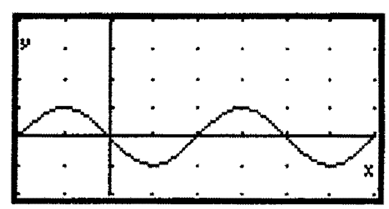
y = 1 + sin x



y = sin (2x)



y = 1 + 1.5 sin (2x + π)

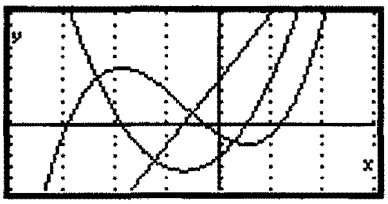


y = sin (x + π)

A rule from the sequence of graphs: The "1.5" changed the amplitude by a factor of 1.5 (stretched the graph vertically), the "1" shifted the graph up one unit vertically, the "2" was the number of cycles in 2π radians or 360° (compressed the graph horizontally or the period is $2\pi/2$) and the "π" shifts the graph left one half a cycle (horizontal shift in the opposite direction of the sign).

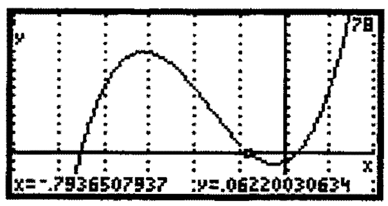
The patterns can be demonstrated in a few minutes using the calculator. I really prefer letting the students "discover" the affect of each of the various numbers in the function and the resulting affect on the graph. They can then formulate and check their own rules for future use. This is particularly nice when projected on a white board so comments may be added to the graphs along with the rules. This process can be done with any of the trigonometry functions, polynomial functions, or rational functions.

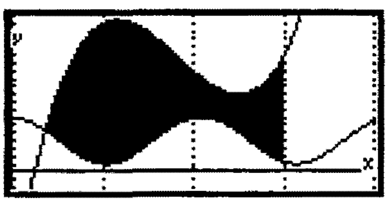
In the MA-112, College Mathematics for Aviation II, the graphing calculator is used to show the limits, local maximums, local minimums, zeroes of the function, etc. that the student has struggled to find with the calculus. The calculator will sketch a graph of the curve and shade the area that is found by the integration process. It will also do the integration by a numerical process to provide a value for the amount shaded. Examples of these graphs are shown below.



Polynomial max/min, relationship of derivatives
$y = x^3 + 2x^2 - 3x - 1$

Zero of the function
$y = x^3 + 5x^2 + 2x - 1$





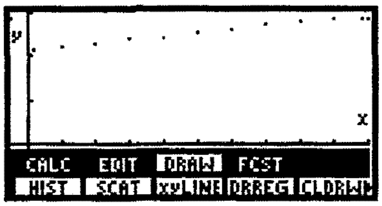
Integration
$x = .7421$ to $x = 6$
$y = 3 \cos (1.5x) + 4$
$y = x^3 - 11x^2 + 35x - 15$

Other models, such as the HP-48G, will draw 3-D graphs for used in the rotation of a solid and volume problems or other applications in Multivariable Calculus.

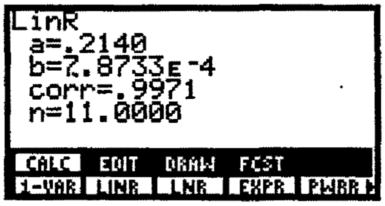
In Statistics classes, such as MA-211, Statistics with Aviation Applications, the statistics package on the TI-85 calculator may be used. The data may be entered into the calculator for analysis by any of the several programs. If there are a few data points the calculator can plot a histogram, a scatter diagram, and fit a curve (function) to the points, including the correlation coefficient to characterize how well it fits the data. The regression function may be up to fourth order polynomial function, a power function, an exponential function or logarithmic function. An example using the data from a gas law physics experiment to predict the value of absolute zero is given below.

Volume*	Temp
.289 m	98°C
.285 m	90°C
.279 m	80°C
.271 m	70°C
.259 m	60°C
.256 m	50°C
.242 m	40°C
.239 m	30°C
.230 m	20°C
.222 m	10°C
.215 m	2°C

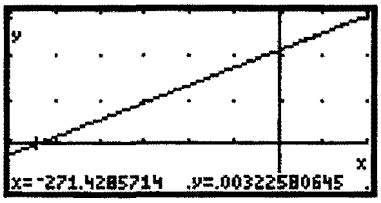
*Volume is proportional to the length of capillary tube.



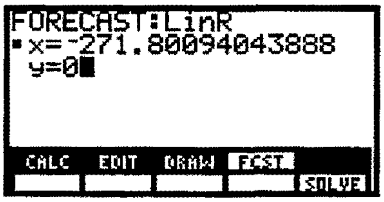
Graph of data



Regression equation and correlation coefficient
V = 0.00078733 + 0.2140



Linear regression equation



Predicted Absolute zero

This type of problem is often outside of the introductory statistics course due to the difficulty of making all of the calculations error free and possibly collecting the data itself. Without the help of the statistics software, this type of problem turns out to be "busy work" problems. More time is spent doing the calculations and graphs than is spent actually analyzing the data.

I also teach in the mathematics and physics departments at Centralia College, Centralia, WA. Most of the students, in the trigonometry course and above, have graphing calculators of some type. I used the calculator as mentioned above whenever possible. In addition to those examples, I also provide data or have the student collect data from physics experiments. This data is analyzed using the math concepts available to the student at that time. Few of the numbers are the "nice" numbers typically found in the textbook. They are closer to what the student may experience in the real world outside the classroom. The student will have few preconceived conclusions about the problem. Textbook problems are grouped together by type and method of solution. They are also ranked in order of difficulty. They are willing to tackle the problem to "play" with the calculator or computer. The student will work/struggle through it with the appropriate guidance when needed.

The calculus and physics students are stepped up to the next level of technology, the use of the computer. The computer is used to do some modeling of a physics experiment or its result. The spread sheet is a useful tool for that purpose. The data can be entered and various forms of a model tried. The results are compared to the theoretical and observed. The student can try small perbutation in the model/system to find optimum results. Sensor units are available in the physics lab to collect the data and enter it directly into the computer. The software provided with the sensors will provide graphs to help with the analysis of the data.

The Macintosh computer lab, at Centralia College, has the mathematics software *Theorist*® available on many of the computers. This software is a very powerful tool in demonstrating mathematical methods from elementary algebra to differential equations. It requires the student to know the procedure. When instructed, the computer obeys and makes whatever symbolic or numerical calculation. It will not solve the problem with out the step by step instruction from the student. It is a very good symbolic mathematical software. It is capable of sketching 3-D graphs, rotate the graphs in space, or resize them for a better view of a certain part.

Merely having the technology available is not sufficient. The instructor must use it in the classroom and in assignments whenever possible. Textbooks are available that have been revised to make use of the various technology, such as in the reform calculus. The "revisions" range from adding a few calculator problems to the traditional textbook to completely new textbooks that rely heavily on technology in the course. Workbooks or lab books are available in many subjects to supplement the present course or textbook.

The laser disc has also changed the environment of the classroom. The laser disc combines the best of the movies and slides. One can stop and view a particular frame without fear of destroying the film, may run the disc at various speeds to create the affect of slow motion, or go directly to a particular frame. They are bar coded to increase the ease of entering frame numbers. The quantity and quality of material on laser disc has greatly improved in recent years.

In the physics courses, I use the laser disc to show/demonstrate a number of the principles of physics or experiments in physics that I can't do with the equipment available in our physics lab. The demonstrations on the laser disc are about one minute in length. They require little time to setup and show. They are used to enhance or start a discussion of some particular concept. The sound may be turned off and the student is asked to explain the physics of the demonstration as a quiz/test question. They find them very stimulating and prompts them to start looking at the physics in their everyday life. The laser disc could be applicable to any subject area.

The use of the *Interactive Physics®* software is very nice to model concept of physics. It actually provides a computer simulation lab for the student to study the concepts in a trial and error atmosphere. It allows the student to change parameters and observe the results. For example, how does the muzzle velocity (angle and magnitude) affect the range of the projectile? a lab can be designed to allow the velocity vector to be adjusted for various angles and magnitudes. A graph of the projectile is traced on the screen. The affects of the change in angle or magnitude is observed from the graph (a trace of the projectile's path). This type of use of technology allows the student to "explore" physics.

The physics lab is making use of the computer and other technology. Experiments have been rewritten to use sensors to make the various measurements. The motion sensor will measure the position of an object as a function of time and store the data in the computer. Graphs of postion vs time, velocity vs time, acceleration vs time are possible from the motion sensor. The force probe produces a force vs time graph and the temperature probe produces the temperature vs time graph. Graphs are also produced from the electricity and magnetism areas.

These graphs are analyzed using the concepts of calculus for the slope (derivative) and area under the curve (integration). The results are discussed in terms of the meaning and other applications. The data can be stored in a spread sheet and analyized. The technology is used for the majority of the lab report - listing data, graphs, many of the calculations, and the word processor to print a readable report. Sketches of the equipment setup are usually drawn using a pencil.

Results of Using Technology in the Classroom

The inclusion of technology in the classroom has changed the "atmosphere" of the classroom. The instructor must have a broader view of the subject matter and be open to other approaches. The problems can be an order of magnitude more difficult due to the "ugly" numbers and real life situations that can be included. The students are questioned and work on the concepts and approaches to the problem, instead of a final answer from a memorized sequence of steps or formal proofs. They start forming ways to think through a problem, to model the problem, and finally to solve the problem.

I give the calculus students a real life problem or data from a physics lab experiment, for them to analyze, about every other week. It does not always match what they are doing in class during that week. They may have to look a few days ahead for a clue on how the handle part of the problem or regress several weeks to find methods or combinations of methods to solve the problem. They looked forward to these applied problems.

I no longer work a calculus or physics problem before I include it as part of a test. The tests are of the take home variety, where they may use anything that is not living (no friends or other people who may be knowledgeable in mathematics or physics) to do the test. The students usually have at least 48 hours to do the test. They are to provide solutions or valid explanations why they could not do a problem. They also know that a second chance at one of the problems will be facing them once the test is corrected. The second chance is usually on a problem they struggled with, but just couldn't get by some point. This encourages them to get as close to the solution as possible, because I give some clues, based on their effort, in the correcting process. The random guess doesn't provide many hints from me.

The technology can help in the courses on the different types of problems from handling "difficult" numbers or graphs to the experimenting and discovering things about different functions. It can also require the instructor to be more creative in their questions. For example, the old question of sketching a graph of a given function, is a give-away when everyone has graphing calculators. The question may be revised so the graph will have a small bend that would not show up on the calculator display or the student is ask to provide other information about the graph, such as location of maximums and minimums. Another version that will take the graphing calculator out of the question, except to check the answer, is to give the graph or data points and ask the student to write the function to match the graph.

The use of technology in the classroom can be an asset, if used in a productive manner to enhance the students understanding of the course material. It is not a substitute for the instructor. It expands the capabilities of the student and instructor to better understand the concepts and helps prepare the student for the technology competitive job world.

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Maple® is a registered trademark of Waterloo Maple Software.

Interactive Physics® is a registered trademark of Knowledge Revolution, San Mateo, CA.

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