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ABSTRACT

An understanding of past technological advancements can help educators understand the influence of new technologies in education. Inventions such as the abacus, logarithms, the slide rule, the calculating machine, computers, and electronic calculators have all found their place in mathematics education. While new technologies can be very useful, it is important to keep in mind that no machine can replace instructors in getting students to understand mathematical concepts and that students need to develop the necessary critical-thinking skills to analyze problems and develop solutions beyond the use of technological aids. A distinction should also be made between the teaching of applied mathematics, in which aids can be very useful, and pure mathematics, in which they are less relevant. It is also important to modify educational materials, including examinations, when new technologies are incorporated into the curriculum. When appropriately used, graphing calculators, like the TI-92, and software packages, like DERIVE, can be very valuable conceptual aids and effective tools for both the learning-teaching and the testing processes. To make the transition to incorporate such technologies, instructors should know what the machines can do and how to use them to avoid diverting class time to learn by experimentation. Contains 13 references. Sample calculator graphs are appended. (BCY)

NEW TECHNOLOGIES IN MATHEMATICS

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Issues of Education at Community Colleges: Essays by Fellows in the Mid-Career Fellowship Program at Princeton University

NEW TECHNOLOGIES IN MATHEMATICS

J. Sarmiento, 1997

"*Those who scorn computer history are those who really don't grasp what is happening today and will never really shape tomorrow.*" (Don Congdon, [1])

To understand the influence of new technologies in education, specially in the field of mathematics, we have to look back in the History of Information. By knowing the past we can have a better understanding of the present, and perhaps predict the future. Some instruments and Nobel technologies had an immediate impact on education; this was the case of book printing, the Abacus, the logarithms, or the Slide Rule. Others, like the Calculating Machine, the radio, the T.V., the computer, or the electronic calculator, needed more time to get proper recognition as educational tools. As a matter of fact the use of computers and graphing calculators in the classroom is a current, sometimes controversial, issue, subject to daily debate. The resistance to use these tools in education can be attributed to two factors, one of technological and logistic character, which includes difficulties with their use, cost, accessibility, and implementation; and the other one related to the human nature of potential users and their fear to the unknown, fear to be displaced by technology, lack of knowledge, and unwillingness to learn. In the end though, the History shows that new technologies always find their place in education; in fact, the radical changes in this process always coincide with the introduction of new instruments. The following table shows, in chronological order of appearance, some of the most relevant computational aids and mechanisms (other than oral) used by humankind to transmit information throughout the ages.

600 A.C.: Book printing begins in China.

1400 : First calculating machine. The Abacus.

1614 : Logarithms and Napier Bones. John Napier.

1642 : Pascal's Calculating Machine. The Pascaline.

1650 : The Slide Rule.

1823-1843 : Babbage's first calculating machines. Ada's first "computer program."

1896 : Marconi invents the radiotelegraph.

1925 : First television transmission.

1944 : Aiken builds the first automatic computer. The Mark I.

1946 : ENIAC (Electronic Integrator and Computer)

1950 : Cable TV.

1951 : The IBM 701.

1952 : The UNIVAC (Universal Automatic Computer).

1956 : Texas Instruments patents the integrated circuit.

1971 : First use of the semiconductor chip. The pocket calculator.

1976 : Apple II introduces the first microcomputer.

1981 : The IBM PC.

1990's : The Information Age. Networking and the Internet.

The development of mathematics is directly or indirectly associated with these selected landmarks and we can analyze it from different perspectives. Focusing on physical devices, we can look at two major groups, the mechanical and the electric. Instruments from both groups played an important role in mathematics. The Abacus, The Slide Rule and The Calculating Machines (ancient and modern) for instance, are considered milestones in this History of Calculating. Next I include a brief, but informative description of some of these instruments.

The Abacus. The name Abacus derives from the Greek word ABAX, meaning table or board covered with dust. Its origin is unknown. What we know is that in its 'modern' form it appeared in China in the 13th century AD. The Chinese Abacus has 13 columns with two beads on top (heaven) and five beads bellow (hearth). Around the 17th century AD the Japanese copied the Chinese Abacus and adapted it to their way of thinking. Their version has 21 columns with one bead on top and four beads below. The Abacus is still part of the regular school training in the Far East, and is commonly used in many places. In 1946 a contest between a Japanese Abacist (Kiyoshu Matzukai) and an electronic computer lasted two days resulting in an unmistakable victory of the Abacist. A third modern form of the Abacus is Russian with 10 arched rows.

Logarithms. John Napier, 1550-1617. Napier played a key role in the History of Computing. Besides being a clergyman and philosopher he was a gifted mathematician. In 1614 he published his work of Logarithms in a book called "Rabdologia." His remarkable invention enabled the transformation of multiplications and divisions into simple additions and subtractions. His logarithmic tables soon became wide spread and universally used. Another invention of his, nicknamed "Napier Bones," was a small instrument constructed of 10 rods with the multiplication table engraved on it. This device enabled to multiply faster, provided one of the factors was one digit only.

The Slide Rule. The first Slide Rule appeared in 1650 and was the result of a joint effort of two Englishmen, Edmund Gunter and William Oughtred. This rule, based on Napier's logarithms, was to become the first analog computer (of modern ages) since it figured out multiplication and subtraction by physical distance. This invention was dormant until 1850 when a French Artillery officer, Amadee Mannheim, added the movable double sided cursor, which gave it today's appearance.

The Calculating Machine. Despite all marvelous mechanical computational devices mentioned before, the glory goes to the Frenchman Blaise Pascal. In 1642, at the age of 21, Pascal invented the Calculating Machine, also known as the Pascaline. Blaise Pascal who was a gifted lad from childhood wanted to spend more time with his father, a tax collector. Since Dad was always busy at home adding columns of numbers, Blaise decided to invent a machine that would free his father from this tedious task. This machine, measuring 20" x 4" x 3", was of metal with eight dials manipulated by stylus. Today there are 50 surviving Pascalines manufactured by Blaise Pascal most of them in the large science museums. He built these calculators for sale, but clerks and accountants refused to use them for fear it would do away with their jobs. As far as we know, there were two prior attempts to create a calculating machine. The first one was by Leonardo da Vinci. His notes, found in the National Museum of Spain, include a description of a machine bearing a certain resemblance to Pascal's machine. The second one was by Wilhelm Schickard who invented a mechanical calculator in 1623. He built two prototypes, but their location is unknown. In 1820 the Frenchman Thomas de Colmar invented the 'Arithmometer' using a 'stepped drum' mechanism. This was the first calculating machine produced in large numbers. It was active until the late 1920's. The next generation of calculating machines came from the Swedish inventor Willgodt T. Odhner. His machine incorporated a 'pin wheel' mechanism. Based on mechanical principles, hundreds of manufacturers produced an amazing variety of calculating machines up to the late 1960's. Then they surrender to the appearance of the electric calculator and the computer.

The Computer. The First Generation Machines began with the ENIAC. Its designers were J. W. Mauchly and J. P. Eckert Jr. from the University of Pennsylvania. They completed the project in three years, from 1942 to 1945. This machine weighed 30 tons, contained 18,000 vacuum tubes and had dimensions 100' x 10' x 3'. On average, a tube failed every 15 minutes. Programming required six thousand switches to be set, and it took 200 microseconds to add and 3 milliseconds to multiply by three. In 1951 the US Census Bureau received the first UNIVAC, and with it the Computer Age began. IBM started building and marketing the IBM 701, followed by the IBM 650. The Second Generation of Computers (1958-1964) includes the IBM 7090, 7070 and 1410. These machines used transistors instead of vacuum tubes, reducing the size and improving the performance. The Third Generation (1964-1970) includes the first true minicomputers. The use of integrated circuits, improved the reliability, size, cost and power. One of the most popular was the IBM 360. The Fourth Generation (1970-) marks the beginning of machines based on microprocessors. Early microcomputers include Altair, EMCII, Tandy TRS-80, Atari, and Commodore. The industry, however, changed forever when S. Jobs and S. Wozniak built the first Apple computer. They did it in a garage, but by 1983, the company they founded, Apple, made the fortune 500 list. IBM announced its PC in 1981. Today, microcomputers like the IBM PC and the Apple Macintosh, are evolving with workstations into yet another generation of computer systems. The major innovation consists on sharing massive amounts of equipment and information resources throughout networks. This generation is bringing major changes in the way we work, teach and learn.

The Electronic Calculator: The first electronic calculators, like the IBM Selective Sequence EC (48K) with three levels of memory, electronic, relay and paper tape, were constructed in the 1940's. In 1964 a Japanese firm introduced the first hand-transistor desktop calculator; it weighed 55 pounds and cost $2,500. However, the program that resulted in the development of the hand-held calculator was written in 1965. The authors were three Texas Instruments engineers, J. S. Kilby, who ha invented the integrated circuit in the late 1950's, J. D. Merryman and J. H. Van Tassel. They envisioned a calculator, based on integrated circuits and battery powered, that could add, subtract, multiply and divide, and fit in the palm of your hand. After two years of development Kilby, Merryman and Van Tessel completed their calculator at the Dallas headquarters of Texas Instruments. It could handle up to six-digit numbers, perform the four basic operations, and print results on a thermal printer. The calculator had an aluminum case, measured 4.25" x 6.125" x 1.75" and weighed 45 ounces. In 1975 the prototype device became part of the permanent collection of the Smithsonian Museum. Since then electronic calculators had evolved continuously at a dramatic pace. The latest generations include programable, scientific and graphing calculators.

In contrast with earlier technologies, pocket calculators did not have a very warm reception in mathematics education. It took about ten years, since their arrival to the markets in the early 1970's, to partially recognize them as teaching tools in the mathematics classrooms. Different reasons, some academic, some administrative, and others perhaps more personal as it happened with the Pascaline, contributed to this delay. They finally became common teaching tools in the early 1980's when their cost dropped considerably and the Academic Institutions agreed to revise the curriculum to allow their use. Nevertheless the controversy about the use of calculators in the classroom did not stop there and it continues today as new generations of machines become available. With the introduction of more sophisticated and powerful graphing calculators, the old issue about their efficiency in the education process is resuscitated. While some Institutions ban or restrict their use, others strongly recommend or require them. A similar situation occurs with individual instructors when the Institution is indifferent to this matter. In all instances though, there is an increasing tendency toward the use of new technologies at all levels, mainly in applied fields. According to the NCTM's (National Council of Teachers of Mathematics) Curriculum and Evaluation Standards for School Mathematics, calculators should be available always to all students. Lynn Arthur Steen, executive director of the Mathematical Sciences Education Board, says that the MSEB and the NCTM share a general vision for technology in math education. Although Steen discounts the importance of using computers at the K-12 level, he acknowledges the role technology has had in shaping the new math curriculum when he says: "The curriculum is a mix of what we teach and how we teach it. Some topics used to be very important to teach. Now, because of computers and calculators, other topics are suddenly important." Others, like Judah Schwartz, professor of mathematics and physics at Harvard and MIT, passionately disagree. "That is a narrow view" he says, "I think computers are necessary tools for all math curriculum starting at age zero." James Landherr, mathematics coordinator for the East Hartford (Conn.) Public Schools, strongly believes that students need access to computers. Without them, he says, "they are deprived. Those who use programs like Geometric Supposer are more empowered to become better problem solvers. Students need to be exposed to technology because they need to be exposed to change to be flexible problem solvers with reasoning skills. In this day and age, you are handicapping those who don't get to use technology." Some like Jim Kaput, professor of mathematics at University of Massachusetts, go even farther when they claim that "you cannot really achieve what the Standards suggest without technology." (The Standards include: Number Sense, Algebra, Data Analysis, Geometry, Measurement, and Computation. Important advances made in mathematics in the last twenty years, which include fractals, tessellations, and graph theory, are also accessible to K-12).

The truth is that the revolution in technology is affecting routine mathematical and scientific work, just as the industrial revolution affected manual labor. Graphing calculators, like the family of TI, HP, SHARP or CASIO, are already having a significant impact in the teaching of mathematics at secondary and college levels. They bring changes, not only to the way we teach, but also to the subject content. Furthermore, they have certain advantages over microcomputers, like portability, low cost and friendly-use. The symbolic capabilities of the calculators, however, are restricted due to their small memory and slow processing speed. Consequently, sometimes, it is convenient to supplement them with microcomputer software packages such as DERIVE, MAPLE, MATLAB or MATHEMATICA. Nonetheless, graphing calculators are very powerful computational and instructional tools. With these calculators the students can do multiple symbolic manipulations, numerical, and graphical analysis, avoiding the tedious pencil-and-paper process. This however, does not mean that we have to delete those topics from the curriculum. It would be a mistake to think that with new technologies there is no need to teach basic computations, theory of equations, curve sketching, differentiation or integration. If we look back, the adoption of the Slide Rule for instance, did not replace the teaching of arithmetical, algebraic or trigonometric operations. On the contrary, instructors had to teach more (and consequently students had to learn more) although with different emphasis. A similar situation occurs with the use of graphing calculators. Their incorporation to the teaching process implies the concurrent development of two interdependent tasks, learning the mathematical theories, and the functions of the calculator. How to combine these tasks is a challenge instructors and students face, and, to certain extent, it is the core of the controversy about the use of graphing calculators. Personally I favor the use of new technologies, including graphing calculators, in the classroom. However, based on my experience with calculators and computers over the past ten years, I must say that:

1. No machine can replace the instructor to carry out the must difficult part of teaching mathematics, which is getting the students to understand the concepts. A conceptual approach is crucial to understand the subject matter and its applications. For example, something as basic and important as estimations requires proper knowledge and understanding of the concepts involved in the procedures. Graphing calculators and computers however, can help students to understand certain concepts like oscillatory or harmonic motions, through the graphical analysis of motion pictures (see Appendix A.)

2. The students need to develop the necessary critical-thinking skills to analyze problems, develop solving strategies, interpret and judge the reasonableness of the results. At this point, computers and calculators must remain one step behind the academic process. Their <u>main</u> role, along with the graphical analysis, will be, as it was in Pascal's mind, to speed processes and not to replace fundamental knowledge. This role is by itself crucial because it replaces not only the tedious and time consuming computational process, but it also gives students and instructors more time to explore new concepts. How could we keep up with the astonishing progress of human knowledge without shortening the learning process? At least, in applied fields of mathematics, computers and calculators must be part of the answer.

3. A distinction has to be made when we teach applied mathematics to fields like engineering, and when we teach pure mathematics. While in applied fields computers and calculators could be used without practically any restriction, in pure mathematics their role would be, in general, less relevant.

4. The integration of new technologies to the teaching and testing process requires appropriate modification of all educational materials, including examinations. With the availability of computers and graphing calculators, the emphasis on computations, equation solving, or function graphing will no longer be same. The students will have to demonstrate the necessary skills to solve basic problems. Then they can take advantage of the new technologies to solve more, and more complex cases. They also can use them as instrumental aids to compare, interpret, and analyze the results.

As warren Esty points out on his article about "Graphics Calculators Concerns: An Answer," when algebra students with access to graphing calculators plot a graph, they should learn how to read it. This includes:

1. How the graph relates to the algebraic and numerical relationships it express,
2. How the graph relates to the equation we want to solve,
3. How the graph relates to the expression we want to maximize or minimize,
4. How the appearance of the graph depends upon the selected window, and
5. How to recognize interpret common types of expressions and equations.

As we will see next, the students can get most of this learning with the usual sorts of graphs that graphing calculators can draw. However, for a full comprehension of the subject matter we must supplement the automatic graphing and solving processes with some manual work. This could include simple problems with hand-drawn graphs that do not have an associated equation, and various questions about them, without particular numbers. The testing process should also combine both skills.

The following examples show some capabilities of the graphing calculator used here for illustrative purposes, the TI-92. This versatile calculator has a QWERTY keyboard and employs a friendly graphic user interface (GUI). A set of function keys provides access to pull down menus, similar to a PC. With optional GRAPH LINK and cable software, we can transfer data and programs between the calculator and the computer, store information on disk or print it. (See Appendix B.)

Example 1. Graphing a function.

1. Display the Y=Editor.
2. Enter the function or functions.
3. Select 6:ZoomStd (or any other appropriate window) and press ENTER.

Example 2. Finding y(x) at a Specified Point.

1. From the Graph screen, press F5 and select 1:Value.
2. Type the x value, which must be a real number or expression, between xmin and xmax.
3. Press ENTER. The cursor moves to that x value on the first function selected in the Y=Editor, and its coordinates are displayed.
4. Press the up or down arrow key to move the cursor between the functions for the entered x value. The corresponding y value is displayed.

Example 3. Finding a Zero, Minimum, or Maximum within an Interval.

1. From the Graph screen press F5 and select 2:Zero, 3:Minimum, or 4:Maximum.
2. As necessary, use the up or down arrow key to select the applicable function.
3. Set the lower bound for x. Either use the left or right arrow key to move the cursor to the lower bound or type its x value.
4. Press ENTER. An arrow head at the top of the screen marks the lower bound.
5. Set the upper bound, and press ENTER. The cursor moves to the solution, and its coordinates are displayed.

Example 4. Finding the Intersection of Two Functions within an Interval.

1. From the Graph screen, press F5 and select 5:Intersection.
2. Select the first function, using the up or down arrow key as necessary, and press ENTER. The cursor moves to the next graphed function.
3. Select the second function and press ENTER.
4. Set the lower bound for x. Either use the left or right arrow key to move the cursor to the lower bound or type its value.
5. Press ENTER. An arrow head at the top of the screen marks the lower bound.
6. Set the upper bound and press ENTER. The cursor moves to the intersection, and its coordinates are displayed.

Similarly we can find the derivative of a function at a point, definite integrals, inflection points, the distance between two points, the equations of a tangent line, the length of an arc, or use Math Tools to analyzed functions. Through the INTERNET, a supplementary library of functions and subroutines for the TI-92 is also available. The current edition of this library is down-loadable at http:/www.derive.com. It consists of an ASCII text version of the document

README.TXT, and three TI-GRAPH LINK(tm) group files, the UNIT.92G, the ELEM.92G, and the ADV.92G.

UNIT.92G implements units algebra and automatic conversions. ELEM.92G includes pre-calculus mathematics capabilities such as simultaneous nonlinear equations, regression, contour plots and plots of implicit functions. ADV.92G contains more advanced capabilities such as:

1. ImpDifN(equation, independent Var, dependent Var, n), which returns the nth derivative of the implicit function defined by "equation."

2. LapTran(expression, timeVar). If the global variable s has no stored value, returns a symbolic expression for the Laplace transform of thr expression in terms of s. If s has a particular numerical value, returns the Laplace transform for that particular value.

3. FourierCf(expression, var, lowerLimit, upperLimit, n). Returns the truncated Fourier series of "expression" for "var" from "lowerLimit" to "upperLimit," through the nth harmonic. With the split-screen feature we can get a simultaneous graphical representation.

4. Ode1IV(expressionForDeriv, indepVar, depVar, initValIndepVar, initValDepVar). Returns a symbolic solution of the 1st-order differential equation. Otherwise returns false. Second-order Differential Equations, Surface Integrals, Centroids, Moments of Inertia, Characteristic Polynomials, Eigenvalues and Eigenvectors, Gradients and Divergencies, Curl, Gamma Function, Chevychev Polynomials, Normal Probabilities, Mean and Standard Deviations, are among other topics included in the library.

Along with the TI-92, a software package that I frequently use is DERIVE. This is a powerful system, yet affordable and easy to use for simplifying mathematical expressions, solving equations, and graphing functions. It runs on PCs based on the Intel 8086 or compatible microprocessors. DERIVE's Utility Files contain multiple instructional commands that we can use as pedagogical tools in courses like Calculus, Differential Equations, and Linear Algebra. They offer students and instructors an opportunity to reform the curricula by applying the subject matter to complex real data. We can also employ them to analyze algebraic and graphical solutions of equations that model physical phenomena. The next four examples will give us a concise overview of DERIVE's capability.

Example 5. Plotting the Direction Field of a first order differential equation y'=f(x,y). (Appendix C.)

1. Author the command DIRECTION-FIELD(f(x,y),x,x_0,x_m,y,y_0,y_n,n), where (x_0,x_m) and (y_0, y_n) are intervals on the x and y axes, and m and n are the corresponding step sizes.
2. Press ENTER, type approXimate, and press ENTER again. The result is a matrix of 2-component vectors which create the direction field through their graphical representation.
3. Type **P**lot twice from window 1 for a plot of the direction field.

Example 6. Solving an Exact equation of the form p(x,y)+q(x,y)y'=0.

1. Author the command EXACT_TEST(p,q,x,y) and Simplify. A result of 0 guarantees that the equation is exact.
2. Author the command EXACT(p,q,x,y,x_0,y_0) and Simplify.

Example 7. Using Euler's Numerical Method to obtain an approximation to the solution of the Initial Value problem y'=r(x,y), y(x_0)=y_0.

1. Author the command EULER(r,x,y,x_0,y_0,h,n), where h is the step size and n the number of steps.
2. Press ENTER, type approXimate, and press ENTER again. The result is a vector of n-coordinate pairs which are an approximation for the points in the solution curve.
3. Type Plot twice from window 1 for a plot of the approximate solution.

Example 8. Determining the n^{th} degree truncated Taylor series solution of a system of first order differential equations $y'=r_k(x,y_k)$, $k=1,2,\ldots,m$.

1. Author the command TAY_ODES(r,x,y,x_0,y_0,n), where $r=[r_1,\ldots,r_m]$, $y=[y_1,\ldots,y_m]$ and (x_0,y_0)=initial value.
2. Type Simplify. The result is a vector whose entries are n^{th} degree truncated Taylor series which approximate the entries of the solution vector y.
3. Type Plot twice to plot a particular entry, but make sure to first highlight only the entry.

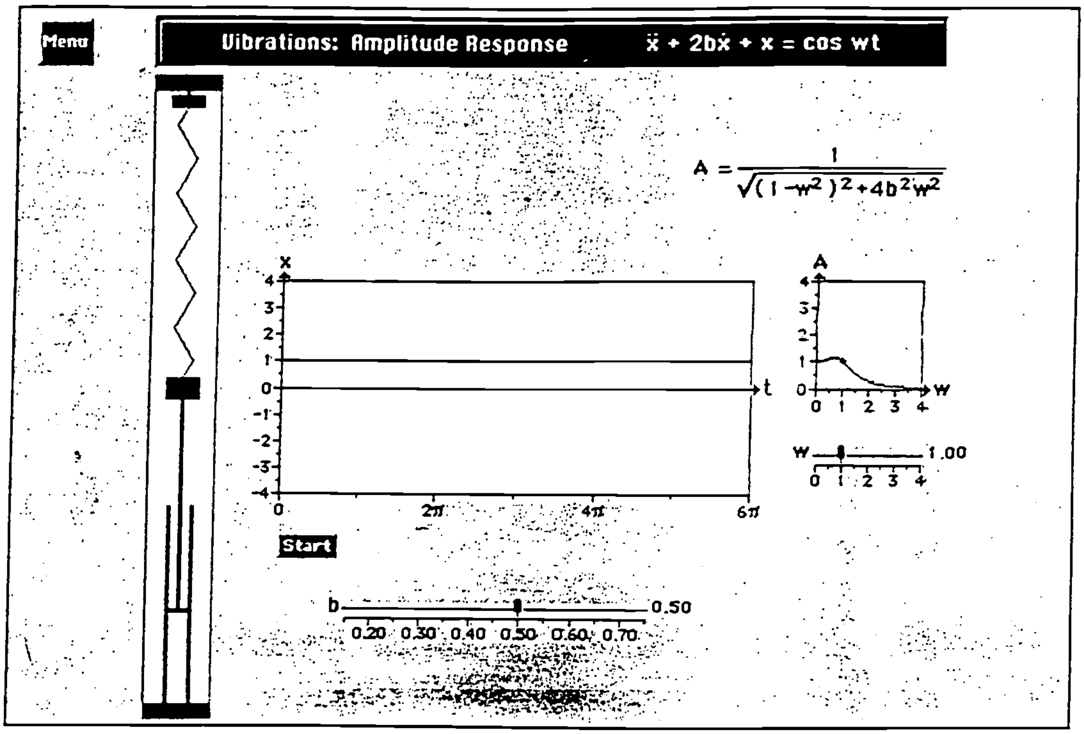
In a similar way we can solve linear, separable, and second order differential equations with initial conditions. We can also apply other numerical methods, like Runge-Kutta and Picard, to physical phenomena, like damped or undamped force vibrations, LRC circuits, and harmonic motions.

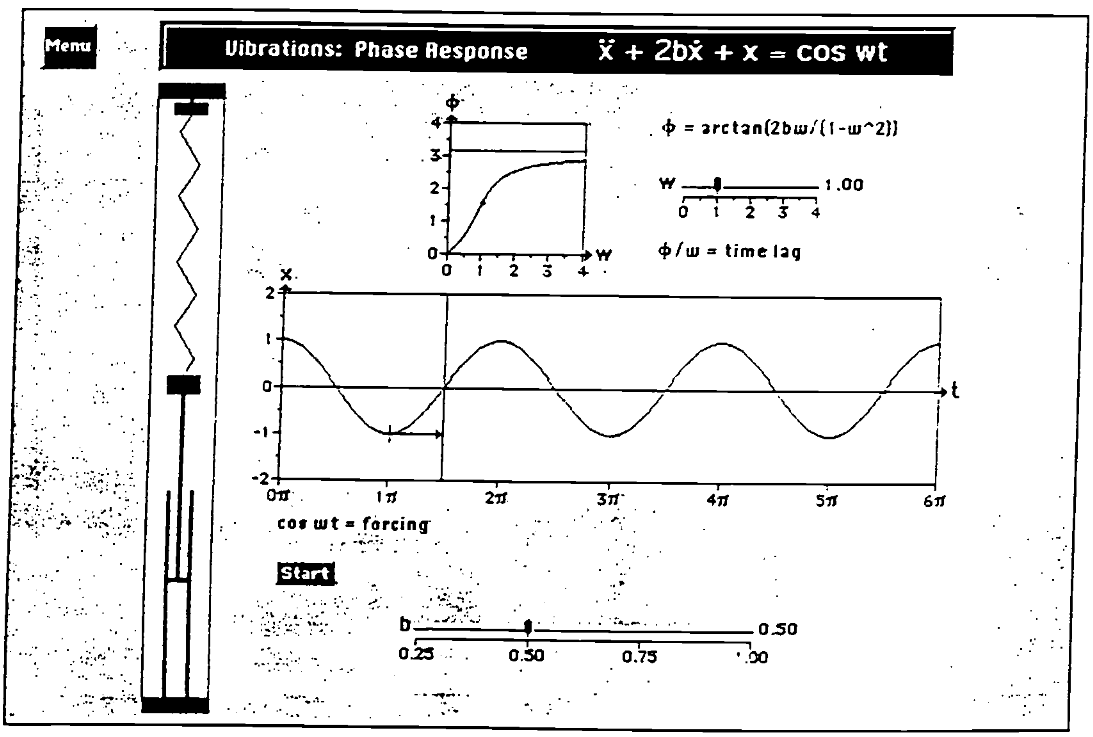
As we can see, graphing calculators, like the TI-92, and software packages, like DERIVE, are not just calculating machines. Appropriately used, they can be very valuable conceptual aids and effective tools in both, the learning-teaching and the testing process. Professional mathematics organizations, such as the National Council of Teachers of Mathematics (NCTM), the

Mathematical Association of America (MAA), and the Mathematical Education Board of the National Academy of Sciences (MSEB-NAS), have strongly endorsed their use in mathematics instruction and have emphasized that, consequently, they must be used in the testing process. So far all indicators point toward a complete integration of new technologies to the math curriculum. New computer systems, interactive technology, and graphing calculators, will mark the beginning of the 21st century in mathematics. To make the transition viable, math instructors should know what these machines can do and what topics will benefit the students most. They would also have to learn how to test the students and not the devices. Thus, all current mathematics teachers should get formal, and most importantly, frequent training in the use of computers systems and calculators. Rejecting the use of new technologies in the classroom is not a realistic approach, and improvisation or trial-and-error is not enough. On the other hand, diverting class time to learn how to use a calculator by experimentation is not a recommended practice. As a matter of fact, graphing calculators and computer systems should be a required component in all mathematics curricula, and the Mathematics Departments should have an ongoing mandatory training program in new technologies for all instructors.

Appendix A

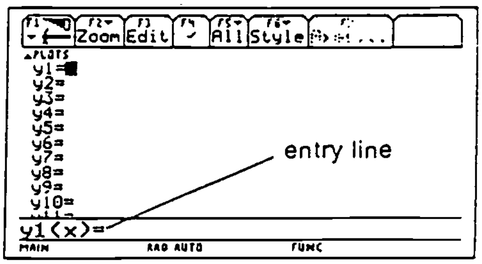
Vibrations: An example of Amplitude and Phase responses (IDE Addison-Wesley Interactive)

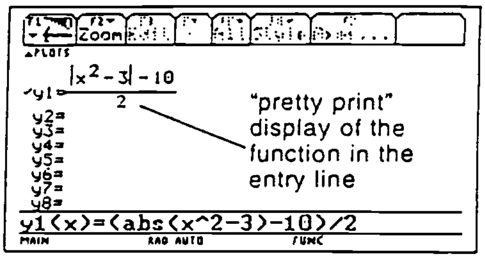


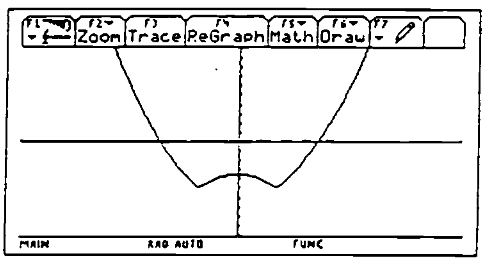


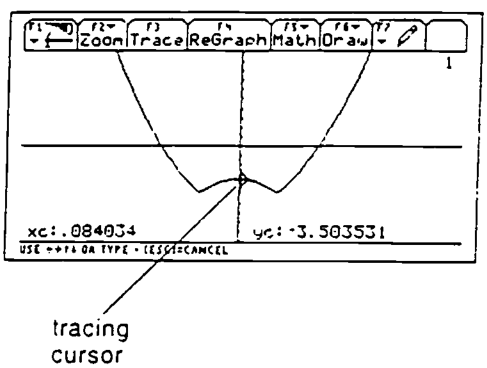
Appendix B

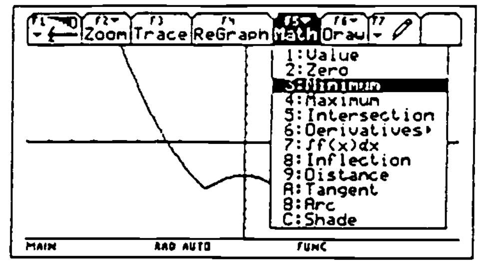
Exploration of graphing capabilities of the TI-92: Function graphing and relative extrema

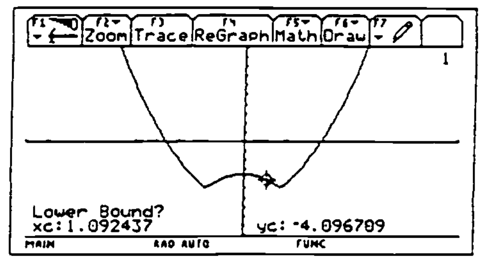


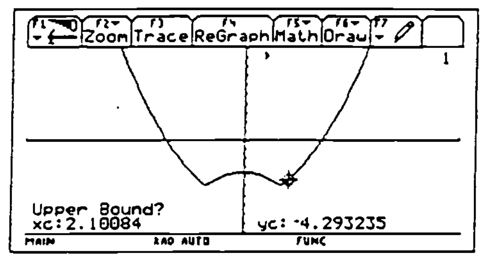


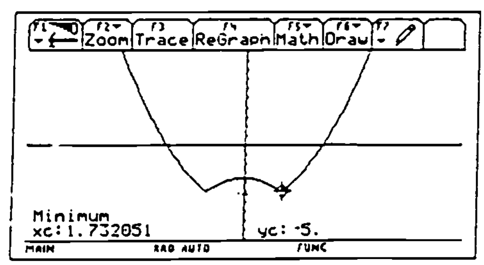


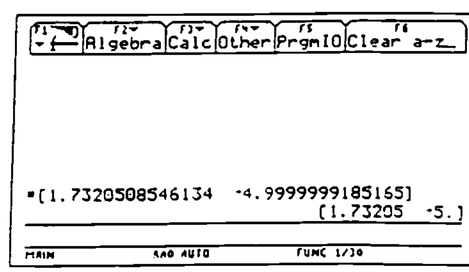








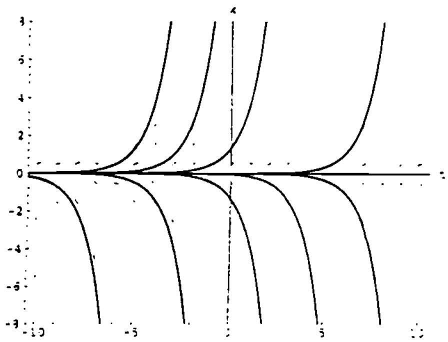




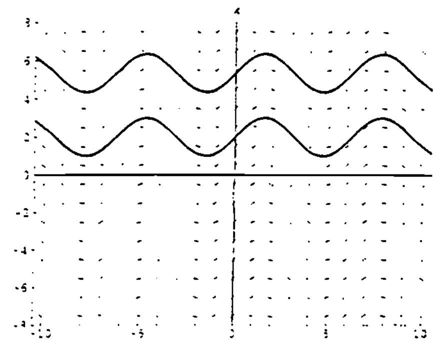
Appendix C

Six examples of direction or slope fields

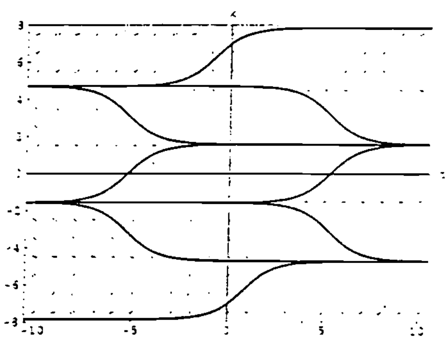
1) $\dot{x} = x$



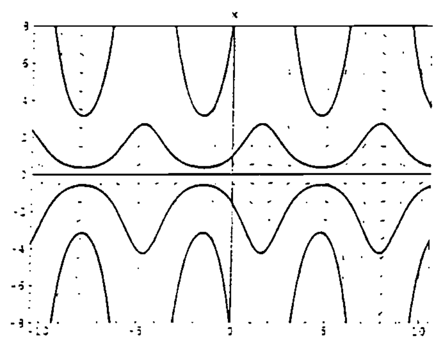
2) $\dot{x} = \cos t$



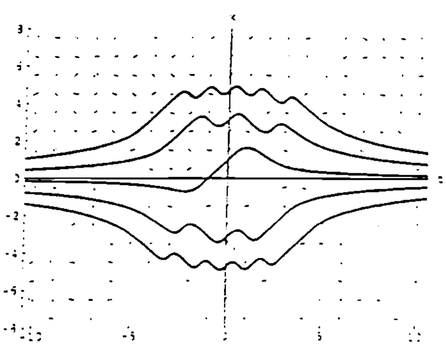
3) $\dot{x} = \cos x$



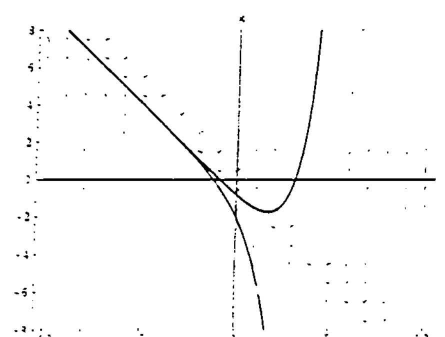
4) $\dot{x} = x \cos t$



5) $\dot{x} = \cos tx$



6) $\dot{x} = x + t$



Bibliography

1. Ancient Computer Machinery, http://www.ee.ryerson.ca:8080, 1996

2. Cheung, Y. L., Graphical Calculators in Math Education, Nanyang Tech. Univ., http://www.edu.cuhk/~fllee/mathfor/edumath/9512/yl.html, Oct. 24,1996

3. Derive, User's Manual, Addison-Wesley & Benjamin/Cummings Pub. Co. Inc, 1992

4. Eisenhower Nat. Clearing House for Math & Sci. Edu, Math Reform: No Technology, No Chance, http://www.enc.org/online/ENC2369/2369.html, Oct. 24, 1996

5. Esty, Warren, Graphic Calculator Concerns: An Answer, http://www.math.montana.edu, 1996

6. Hale, Handy, History of Computers, http://www2.ncsu.edu, 1996

7. Jefferson County Standards, Math Content Standards, 1995, http://jeffco.k12.co.us/edcenter

8. Selected Landmarks in the History of Books, Libraries, Information Agencies,Inf. Tech., http://www.albany.edu/~...3/isp601/landmarks.html, Oct. 24, 1996

9. Stoutemyer, D. R., Printable Doc. for the TI-92 Prog. Lib., Ver. 1.0, Soft Warehouse, 1996

10. TI Edit. Backgroud, Hand-Held Calculator Invention, http://www.ti.com/calc/news, 1996

11. Texas Instruments Inc., TI-92 Guidebook, 1995

12. The History of Calculating/Calculating Machimes, http://www.webcom/calc, Oct. 17, 1996

13. West, Strogatz, McDill, and Cantwell, Interactive Differential Equations, Addison Wesley Interactive, 1997.

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