

## **Choosing Technology: Doing, Teaching and Presenting Mathematics**

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When teaching mathematics, a major issue to address is the choice of technology to incorporate into the classroom. The intention of this article is to describe and evaluate the technological options for students in light of current technologies – calculators, pda's, and computer options – and to briefly address “inevitable” future options. While not exhaustive, the article includes evaluation of software/platform combinations for value and practicality and an analysis of the particular mathematical functionality of each option. The appendix to the article includes charts addressing mathematical functionality organized with respect to commonly taught first and second year college level mathematics courses.

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### **1. Introduction**

When teaching mathematics a major issue to address is the choice of technology to incorporate into the classroom. The intention of this article is to describe and evaluate the technological options for students in light of current technologies – calculators, pda's, and computer options – and to briefly address predictable future options. While not exhaustive, the article includes evaluation of software/platform combinations for value and practicality and an analysis of the particular mathematical functionality of each option. The appendix to the article includes charts addressing mathematical functionality organized with respect to commonly taught first and second year college level mathematics courses and evaluated by topic.

The impetus for this article is the fact that the immediacy of a new consideration of choices will soon be upon us as mathematics faculty. New innovation in calculators has not occurred in years; there are indications that some old familiar calculator configurations will soon be discontinued. On the other hand, pda technology has evolved quickly in the last five years and software has been developed for this technology. Finally, the tablet PC and the tablet hybrid PC are gaining ground with the related pen-on-screen technology, even though compatibility issues, especially with respect to non-Microsoft programs, have not been resolved. The basis for inevitable change has been established. Inevitably, the pda and the tablet PC will evolve toward each other, eliminating the notebook PC altogether. The change in hardware and software options will shortly – within the next 3 years – force a change in technology

upon us. So it is time to look at where we are now, consider the features we most value, and prepare for making changes in the future before we invest additional resources in technologies which will soon be no longer viable.

### ***Platform vs. software***

One of the most difficult aspects of choosing the technology to use for the teaching of mathematics involves the fact that the software/mathematical functionality is so often connected to the hardware platform. This article will not address the issues of the best manufacturer, the best customer service, or other similar issues; *Consumer Report* regularly publishes articles reporting on these issues with respect to desktop and laptop/notebook computers and others that deal with personal digital assistants (pda's) and calculators. The issues of manufacturing and corporate branding are best left to that venue. The focus for this article is the mathematical functionality and the practicality of the various choices for classroom use. The choices to be considered in this article, as representative of a class of similar technology configurations are the following:

- ☞ TI-73
- ☞ TI-83+
- ☞ TI-89
- ☞ PDA (Palm) with PowerOne Graph
- ☞ Laptop with Scientific Notebook
- ☞ Computer with Scientific Notebook

The selection of "classes" of technology and the ratings of value, price and mathematical functionality are experientially based and therefore to some extent subjective. The evaluations are based on information as complete and as current as possible.

## **2. Why use technology**

There are as many or more reasons to include the use of technology in the teaching of mathematics as there are types of technology. If you ask different faculty to elaborate on why they use technology for teaching mathematics, you will get different variations on the reasons along with a clear expression of a love/hate relationship. Most mathematicians will refer to pragmatic, content-related reasons; a few will add some motivational reasons. A very small number may add some comments regarding the effect of the use of technology on cognition. You will also get some added comments regarding the potential for the use of technology to interfere with the learning of good, basic mathematical skills. Just for the record, we will review some of the reasons to use technology in the teaching of mathematics.

### ***2.1 Cognition***

Although not the first reason that you will generally hear from a mathematician, there are some very good cognitive reasons for using technology in the teaching of mathematics. Some of these have to do with recent brain research and others relate to learning styles or motivational issues. A sampling of reasons includes the following:

- ☞ Preferred learning styles include kinesthetic, active mode and or a visual mode of learning. [Eppel], [Finster], and [Gardner] For these students, the lecture mode is more auditory and passive. The use of technology appeals to students who prefer more activity and visual aspects to learning.
- ☞ Use of technology allows one to analyze real data and make problem solving decisions which relate to "real world" situations. This process advances one further on the Perry Scheme of Intellectual Development [Perry] and improves a student's ability to make critical decisions and next-step analyses[Sternberg]. It also adds to the student's lifelong ability to analyze and process information.
- ☞ Students can be moved toward more task-oriented approach (vs. ego-oriented) [Ward] with the use of technology to improve focus learning

on the students' ability to make conclusions and justify their thinking. Calculators assist in this process by taking the emphasis off the details of calculations and placing it back on the global process.

⇒ Brain research indicates that there is evidence to suggest that the learner “chunks’ knowledge for processing [Ashcroft] and that there is a limit to the amount of working memory that we can successfully employ at any given time [Baddeley]. The calculator can relieve the need to perform detailed calculations while we are in the process of focusing on the global issue of the steps in the problem and collecting information we need to work the problem.

There are many other theories of brain research and learning which support the use of calculators for enhancing the learning of mathematics and should be seriously considered when we plan our activities in our classes.

## ***2.2 Theory vs. calculation***

At some point in their teaching career, most mathematicians argue about whether it is better to learn from clear principles to realistic example or to use examples to motivate general principles. Generally, the first direction is conceptually less cluttered while the second is more historically accurate regarding the development of the topic and therefore the rationale for the topic. While both approaches are valid under particular circumstances, almost every mathematician will agree that it is appropriate and critical to relate theory to application and to use realistic data for examples periodically. Furthermore, technology allows the calculation of a more meaningful number of problems in order to help the student practice the post-calculation analysis of the outcome of the calculation. In other words, you can assign realistic exercises and have the time to do more of them for practice in “connecting the dots in the big picture”.

## ***2.3 Learning theories uniquely associated with technology***

While the cognitive issues addressed above relate different aspects of learning with the use of technology, there are two relatively recent theories that directly connect the use of technology to the teaching of mathematics. When doing mathematics, there is a constant tension between the understanding of the mathematics and the doing of the mathematical calculations. When teaching with technology, that can potentially throw a third activity/process into the classroom. There are some conflicting issues with which to deal in this context.

Recent studies indicate that the use of technology can actually aid students who are somewhat deficient in basic mathematical skills. In particular, students who are less proficient in arithmetic calculations can use the calculator for assistance and continue to move forward in algebra and other coursework. This allows students to continue to progress through the curriculum with more mathematically mature analysis of problems and concepts without being held back by the need to improve their ability with the multiplication tables, for example. In other words, the technology acts like a patch over a hole in the student's learning.

A relatively recent learning theory involves the concept of working memory. This theory promotes the idea that a person can only do a certain amount of intense processing at a time. [Ashcroft] If one cannot add easily, then one will never be able to perform readily any mathematical processes which require addition as a basic step; the brain cannot concentrate intensely on both the larger process and the problem of adding. At first glance, and to some extent a true statement, this would seem to imply additional support for the use of technology in the classroom. The use of technology allows the use of the brain's capacity of working memory on the process being learned instead of on the arithmetic. On the other hand, this is a double-edged sword: The learning of technology can be a third activity requiring working memory, adding on to the process of basic calculations and the new process actually being taught. For this reason, it is critical that one follows some basic rules when considering the choice and use of technology for a class:

⇒ Choose the technology that is reasonably priced and of good value, **and** which has the least steep (quickest) learning curve. A quick

learning curve always uses less working memory, even after the technology is familiar.

- ☞ Choose the technology that most closely mirrors the calculations being taught and which has the easiest access to the mathematical functionality.
- ☞ Never teach spend the whole class teaching how to use the technology. Our goal is to teach mathematics, not the technological tools.
- ☞ Choose technology for greater functionality and longer usability – but not at the expense of students’ ease of learning.
- ☞ Plan your class so that the students are rarely if ever processing three ways at once. Two is more than enough. With appropriate planning, pre-learning can help a lot with teaching the technology.

There are many reasons – from elegance to tradition, cost, or political correctness – for finalizing the choice of technology; these are irrelevant if eventually the choice of technology gets in the way of the students learning.

## **2.4 It's there**

The final reasons for incorporating technology into the classroom involve the idea that basically you use technology “because it is there”. There is no denying to students that the technology exists and has an impact on calculations and the performance of mathematics. Denying them the reasonable use of technology marginalizes the credibility of the instructor. A second aspect to this argument, and possibly even more compelling, is that “it is there” for the students to use in their future employment. In the most liberal arts/general education sense (as opposed to vocational), learning how to use new technology is a long-term learning skill that students will arguably have to apply for the rest of their lives. Just as with critical thinking, problem solving, ethical decision-making, and the many other general education and liberal arts goals, the ability to acquire facility with new technologies is a necessary life-long learning skill.

## **3. Technological Options**

When choosing the technology for a course, you are always balancing cost against functionality and functionality against practicality. With the calculation and/or the production of mathematical text as an object, the classes of options fall basically into three platforms with (as appropriate) software: calculators, pda’s, and computers.

### **3.1 Calculators**

Calculators are targeted to efficiently perform mathematical and to some extent scientific calculations. Input is through a keypad; output is on a screen or perhaps transmitted through infrared or cable download to a PC. Extra functionality is menu-driven. Having said that, there is a keyboard attachment made for some calculators so that typed input is an option. This will also allow the particular calculator, with some coaxing, to perform as a calendar/organizer and as a very basic Word compatible document processor.

The most widely used calculator series is made by Texas Instrument. Using their line of calculators as a template, there are the TI-73, the TI-83+, and the TI-89/92. The TI-73 is aimed at the learning of middle school mathematics and early algebra; the TI- 83+ is for complete algebraic and pre-calculus manipulations. Finally, the TI-89/92 perform symbolic calculations for use in more advanced courses; the more sophisticated the mathematics, the more complex the calculator’s instruction and data-entry requirements.

It should be noted that Texas Instrument has announced that it is currently planning on eliminating and/or replacing at least one of these models. The calculators mentioned here along with competitive brands have been in use basically unchanged for close to fifteen years: with a change in model being forced through manufacturing discontinuations, it is a very good time to evaluate the future direction of technology in the mathematics classroom.

### **3.2 Personal digital assistant with PowerOne Graph**

Perhaps the newest platform included in the list of technologies within this article is the personal digital assistant. Basically a pocket-sized computer, the pda market is based upon two competitive operating systems: Palm OS and Pocket PC. The battle has not been won by either system

at this time; however, the PowerOne Graph program only comes in a Palm version. This is a software package that resides in the pda and provides all the functionality and more of the TI-83. While it does not have the symbolic manipulation capabilities of the TI-89/92, it has a color screen and easy data entry. Exporting the data is possible through a synchronization cradle to the PC. The color screen is a great advantage as is the other more versatile functionality of a standard pda. With the purchase of an unfolding keyboard, the pda provides very effective calculating capacity as well as greater memory, speed, color and versatility.

### ***3.3 Computer w/ Scientific Notebook***

The most powerful option available is based on having a computer for the hardware platform. This allows the most speed, memory, and computing power. It also allows more variety of output methods and has the keyboard (with one exception, as mentioned below) as the input method. The choice of software is much more varied also. There are several good new graphing packages available at this time. The one package that stands out for the computer is Scientific Notebook. This software combines the mathematical typesetting capability of LaTeX with the calculation capacity of Maple in a package that at most has a 30 minute learning curve. All of the output is exportable to Word products with little extra effort. In addition, this combination will take care of most computing needs for mathematics major throughout their undergraduate career.

There are two notable decisions to make with respect to this configuration: “What size and type of computer?” And, “Why Scientific Notebook vs. Mathematica or Maple?” The first question takes longer to answer than the second. There are basically three “sizes” of PC available now: Desktop, notebook, or tablet. The desktop is the cheapest and marginally the fastest and most powerful. It is certainly the most repairable. The notebook is the next newest of the three, is very portable, and considerably more expensive than the desktop. Otherwise, it is comparable to the desktop. The tablet PC comes in two forms – with portable keyboard and without. The tablet PC is the newest version of PC and has the advantage that it accepts and works with handwriting. The disappointing news is that the converted handwriting so far works almost exclusively with Microsoft Office products and very little else. The bugs are not all eliminated yet and there is not quite the universality for true interaction between input and non-Microsoft products. This is a major disaster for the true keyless tablet PC – even though other programs will load, you cannot input without the non-portable keyboard. This platform is not quite robust enough yet for the classroom setting and non-Microsoft applications. The hybrid version (with keyboard) is slightly heavier and basically a notebook computer with a pen-on-screen writing ability. The lack of compatibility with other software is still an issue.

The answer to the second question – “Why Scientific Notebook instead of Mathematica or Maple?” lies partially with one of the previous comments about technology – keep the learning curve down. The learning curves of Maple and Mathematica are atrocious when compared to any extra value in computing and the total lack of value in the input and output flexibility. Unless you are performing seriously unique and complex calculations with differential equations or 3-D graphing, the value to the student over the cost of the increased use of time and working memory is not effective. A second seriously critical factor is the exportability of the product – be it typesetting or graphic; Scientific Notebook and its more powerful companion Scientific WorkPlace are strongly superior to Maple and Mathematica in this regard.

### ***3.4 And the verdict is....***

Without a doubt, the most cost effective, practical, and versatile combination for students at the college algebra level or higher is the pda configuration. This will be sufficient until the student simply must be able to typeset mathematics for teaching or upper level courses. When the mathematics major has a need for complicated work in differential equations or in three-dimensional drawing, then the student needs access to a desktop with Scientific Notebook.

For faculty, there are two scenarios: the pda for teaching purposes and a laptop for teaching preparation and presentations. The pda must be

available for demonstration purposes. Although the laptop is less repairable, more breakable, and more expensive than a desktop, the professional responsibilities of a faculty member today requires more mobile – from varying classrooms with incomplete software to conference presentations. The computer platform is necessary to use Scientific Notebook and to export to Microsoft programs (or the equivalent). If you teach in more than one classroom and give more than the very occasional presentation, then your need is for a laptop. If you are comfortable with the dual risk of theft and dropping, then the laptop is for you. Today, the expense for a laptop is no more than the expense for the desktop computer of three years ago; it also gives you the same wireless capacity as your students have with their computers and pda’s.

The tablet PC is the wave of the future, but it has not arrived yet. Within the next one to two years, the pda and the tablet PC will move to more similar structures and capabilities. At this time, the handwriting options and markup options (handwriting on Word or PowerPoint documents) of the tablet PC are simply not compatible enough with different software to make the data entry effective away from the home base.

The remainder of this article consists of a set of comparison tables which delineate the basis on which the previous recommendations were made. The first table compares basic pricing, learning curve, and other broad criteria. The last tables break down the specific mathematical functionality of the different technological configurations by course, with the courses selected being those which students traditionally encounter in their first two years of college-level mathematics. Some repetition is included in these tables in order to make them more useful “at-a-glance” for specific courses.

#### 4. Comparison of technological configurations – General

In the following tables, green indicates excellent; yellow represents acceptable performance; and, red is a warning of a less desirable comparison or missing option. Span of courses refers to the number of courses for which the calculator will be a usable technology. The first table will summarize the information relating to the previous discussions. The appendices include evaluations of mathematical functionality, separated for convenience by generally accepted course content requirements.

**Table 1: Technology Comparison**

	TI-73	TI-83+	TI-89/92	PDA	Laptop	Desktop
Price						
Mathematical functionality						
Versatility						
Learning curve						
Input methods						
Practicality						
Durability						
Portability						
Repairability						
Breakability						
Battery life						
Screen visibility						
Screen clarity						
Transfer to other programs/ formats						
Color screen						
Span of courses						

It should be mentioned that portability is a “big deal” for teaching – having a calculator in hand during the class is critical to active learning and maximizing the effects of teaching with technology. This makes the desktop option less viable for student use, especially considering the expense, the lack of access at home, and the difficulty in seeing the instructor in most retro-fitted computer-configured classrooms.

### 5. Appendices: Comparison of mathematical features by course

In the following table, green is excellent, yellow is acceptable, and red is a warning of a less desirable comparison or missing option.

**Table 2: College Algebra**

	TI-73	TI-83+	TI-89/92	PDA	Laptop	Desktop
<b>Factoring</b>						
<b>Intersection of graphs</b>						
<b>Locating maxima and minima</b>						
<b>Locating roots</b>						
<b>Graphing piece-wise defined</b>						
<b>Common logarithms</b>						
<b>Natural logarithms</b>						
<b>Matrices – arithmetic operations</b>						
<b>Matrices – row operations</b>						
<b>Linear regression</b>						
<b>Additional regression</b>						
<b>Combinations and permutations</b>						

**Key**

Excellent	Acceptable	Unacceptable
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**Table 3: Precalculus**

	TI-73	TI-83+	TI-89/92	PDA	Laptop	Desktop
<b>Factoring</b>						
<b>Intersection of graphs</b>						
<b>Locating maxima and minima</b>						
<b>Locating roots</b>						
<b>Graphing piece-wise defined</b>						
<b>Common logarithms</b>						
<b>Natural logarithms</b>						
<b>Matrices – arithmetic operations</b>						
<b>Matrices – row operations</b>						
<b>Linear regression</b>						
<b>Additional regression</b>						
<b>Combinations and permutations</b>						
<b>Trigonometric functions</b>						
<b>Inverse trigonometric functions</b>						
<b>Hyperbolic functions</b>						
<b>Parametric graphing</b>						
<b>Polar graphing</b>						
<b>3-D dimensional graphing</b>						
<b>Solving equations</b>						

Table 4: Calculus

	TI-73	TI-83+	TI-89/92	PDA	Laptop	Desktop
<b>Factoring</b>						
<b>Intersection of graphs</b>						
<b>Locating maxima and minima</b>						
<b>Locating roots</b>						
<b>Graphing piece-wise defined</b>						
<b>Common logarithms</b>						
<b>Natural logarithms</b>						
<b>Matrices – arithmetic operations</b>						
<b>Matrices – row operations</b>						
<b>Linear regression</b>						
<b>Additional regression</b>						
<b>Combinations and permutations</b>						
<b>Trigonometric functions</b>						
<b>Inverse trigonometric functions</b>						
<b>Hyperbolic functions</b>						
<b>Parametric graphing</b>						
<b>Polar graphing</b>						
<b>3-D dimensional graphing</b>						
<b>Solving equations</b>						
<b>Numeric derivative</b>						
<b>Symbolic derivative</b>						
<b>Numeric integration</b>						
<b>Symbolic integration</b>						
<b>Sequences</b>						
<b>Series</b>						
<b>Partial derivative</b>						

Key

Excellent		Acceptable		Unacceptable	
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Table 5: Linear Algebra

	TI-73	TI-83+	TI-89/92	PDA	Laptop	Desktop
<b>Row operations</b>						
<b>Gaussian elimination</b>						
<b>Gaussian elimination – with symbols</b>						
<b>Gaussian elimination with more rows than columns</b>						
<b>Matrix arithmetic operations</b>						
<b>Eigenvalues</b>						
<b>Eigenvectors</b>						

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