

Coping with Multiple Calculator Models in College Algebra

Mark Farris

Midwestern State University

http://www.mwsu.edu/~math/math_faculty/Mark%20Farris/farris_page.htm

farris@nexus.mwsu.edu

Abstract

New models of graphing calculators arrive on a regular basis. Texas Instruments alone introduced 8 models in a 10 year period. At many schools it is impractical or impossible to have every student use the same model and often different brands as well as different models are used in the same classroom. This situation brings about both advantages and disadvantages for a College Algebra instructor.

Calculators differ in how they handle order of operation and in the number of pixels in the graphical display. When the instructor is aware of these differences, they can be used to provide instruction on concepts such as appropriate use of parentheses, aspect ratios, and vertical asymptotes. Specific examples will be given.

Scatterplots and regression analysis are now common in College Algebra textbooks. Producing these on a calculator is a relatively complicated procedure compared to the usual types of calculations students are expected to do. Teaching this to students can be handled by using a general procedure given at a level that works on any model accompanied by more specific details on a case by case basis. Breaking the details up into pieces makes the regression analysis easier for the students to grasp.

Introduction

At Midwestern State University, College Algebra courses typically have an enrollment of approximately 40 students. The students are not restricted to any particular model calculator. The instructors usually use a TI-86 viewscreen calculator in class, but viewscreen versions of the TI-82, TI-92, and TI-89 are available. Although the mix changes with time, currently the models used by my students are distributed as follows.

| Model | TI-85,86 | TI-82,83 | TI-89,92 | Other |
|------------|----------|----------|----------|-------|
| Percentage | 50 | 35 | 12 | 3 |

About 30% of the TI users use older model calculators: 82, 85, and 92, but the students in the "Other" category almost always have an outdated model of whatever brand they are using.

Although these calculators all operate similarly, there are differences. The differences can be put into three categories. First is a difference in precedence relations for the various operations. In particular, implied multiplication has higher order precedence on some models than on other models. For example, if the variable X has the value 4 a TI-82 interprets $1/2X$ as 0.125 while a TI-83 thinks $1/2X$ is 2. Second is a difference in the window size. The graphing window in a TI-86 is 127 pixels wide. On a TI-83 it is 95 pixels wide. A third difference is in what I'll refer to as the operating

system. Choosing a function key on the TI-83 results in a function symbol followed by an open parenthesis, but this doesn't happen on other models. Another issue is that the availability of lower case letters on some but not all models. The biggest difference in operating systems is the way in which data is entered and manipulated when doing regression analysis on the various models. The sections below indicate ways in which these differences can be handled and in fact taken advantage of in the classroom.

College Algebra is our lowest level course with a graphing calculator requirement. Many students enter the course with graphing calculator experience from high school, but this is not uniformly true. For students with no previous graphing calculator experience, the stress of enrolling in a college level mathematics course for the first time is compounded by the need to adapt to the technology. Recognizing this, I use the viewscreen calculator extensively during the first few class periods. Concepts such as window/range are introduced as definitions with the same formality that I would use for the definition of polynomial or the point-slope form of a line. On a less formal basis, I place emphasis on how any expression that is written using a horizontal bar, such as $\frac{x+3}{x-2}$ or $\sqrt{4-x}$, requires the use of at least one set of parentheses on the calculator.

Order of Operations

It is important to realize that the implied multiplication coming from juxtaposition has an equal order of precedence with explicit multiplication is some models but in other models it has a higher order or precedence. Consider the two screens below. In both cases the same keystroke sequence is used, but the results are different.

| | | | |
|---|----------------------------|-----------------------------------|------------|
| $4 \rightarrow x$ $1/2 \times$ \blacksquare | $\overset{-}{4}$ $.125$ | $4 \rightarrow x$ $1/2 \times$ | 4 2 |
|---|----------------------------|-----------------------------------|------------|

One of these screens is from a TI-85 and the other is from a TI-86. There are several morals to this example. First of all, teaching students to use a calculator on a keystroke by keystroke basis is not a good idea. Second, the instructor should avoid using this construction of a division followed by an implied multiplication. In fact, even though the instructor will typically be thoroughly familiar with the precedence relations it is not a good idea to take advantage of this knowledge in order to save a keystroke or two. A better idea is to always use constructions that will be interpreted the same way by any model. In this case you could use $1/(2x)$ or $(1/2)x$ depending on which expression you want. The third moral is that this problem will come up in your classroom. When it happens it can be used to advantage. Use this issue to emphasize appropriate use of parentheses.

An interesting aspect of this is the distinction between -2^2 and $(-2)^2$. This is one place where TI is consistent across models. In every case, exponentiation takes precedence over negation. As a result, for TI $-2^2 = -4$. This is an important fact to know when you are dealing with a beginning College Algebra student. This convention is useful because it makes the result that appears on the TI screen consistent with the way we write things by hand on paper or on the blackboard.

The Graphing Window

The graph window on a calculator is divide up into a large but finite number of pixels. This leads to the concept of “magic windows” that have nice properties when using the TRACE key. Here’s a summary of resolutions.

| Model | TI-82,83 | TI-85,86 | TI-89 | TI-92 |
|--------------|----------|----------|-------|-------|
| Pixel width | 95 | 127 | 159 | 239 |
| Magic number | 47 | 63 | 79 | 119 |

You don’t need to remember all of these numbers. You can readily recover them by using the ZOOM DECIMAL feature of your calculator. The interesting feature to notice is that three of the magic numbers are prime numbers, but the magic number for the TI-85, 86 is not.

There are two teaching issues that need to be addressed. One is that in a typical window a graph of $y = \sqrt{64 - x^2}$ will not appear to touch the x -axis. The other is that the calculator will usually draw vertical asymptotes that we really don’t want to consider as part of the actual graph of a function. Of course, you can always isolate one particular x -coordinate by placing it in the exact center of the screen. For example, to see the sideways parabola mentioned above actually touch the x -axis you can use any window with $XMin = 4 - a$ and $XMax = 4 + a$ for an appropriate choice of a . By the way, this was a real shortcoming of the old TI-81, which used an even number of pixels.

The magic number for the TI-85, 86 is $63 = 7 \times 9$. When you use a window with $XMax - XMin$ equal to a multiple of 3 or 7 small integers like 2, 3, or 4 will appear as exact values of pixel coordinates. As a result, simple rational functions graphed in such a window will appear without the spurious vertical asymptotes.

The Operating System

The TI-83 has the distinctive feature that it automatically adds and open parenthesis after the user enters a function key. This feature makes life easier on the student who wants to graph $y = \sqrt{4 - x}$. The TI-83 user will normally not make the mistake of graphing $y = \sqrt{4} - x$ instead. On the other hand, if the desired calculation is $\sqrt{3}/2$ or $\frac{\ln 2}{3}$ the TI-83 user needs to be sure and close the parenthesis on time.

Curiously, this difference never seems to give students problems until we get to logarithms. It seems like some students get in the habit of ignoring the closing parenthesis. Since the calculator automatically assumes one when it doesn’t explicitly appears this usually doesn’t give a problem. As a result, when we get to logarithms and the TI-83 users see me type $\ln 2/3$ on my TI-86 they once again forget the close parenthesis. As a result, for this type of calculation I tend to be more explicit than usual. Rather than entering $\ln 2/3$ I attempt to be consistent about typing $\ln (2)/3$ or $(\ln 2)/3$.

The real place where the differences in calculator models gives a problem is when you want to do a linear regression. Here the similarities between the TI-85 and TI-86 and the TI-82 and TI-83 go away. On the other hand, the procedure that works on a TI-92

also works on a TI-89. Coping with this can be a problem, especially when regression analysis comes so early in the semester that the students new to the graphing calculator have not become comfortable in using them. This is one place where I give instructions particular to each model calculator. Even though these instructions are specific to each model, the instructions can be divided up into steps in a uniform way. There are three basic steps. One is entering the data. For regressions, the data consists of a collection of ordered pairs of numbers. These are stored in the calculator in two lists. List naming conventions vary from model to model, but each model has a pair of list names that are used by default. Restricting yourself to never doing more than one regression at a time allows you to consistently use the default lists. This is a minor restriction compared to the difficulty in teaching multiple file naming systems. A second step is viewing the data. Although the issue of choosing an appropriate window is handled the same way on all models, the technique for getting the data points to show up is different for each model. One shortcoming of the TI-85 in this respect is that this model only shows data points as single pixels. This can be overcome by writing a short program that draws a scatterplot using the data in the default lists. Such a program can easily emulate the hollow squares that are used on the other models. The third step is viewing/using the computed regression curves. The various models have capabilities of drawing in the regression curve directly from the STAT menus. Some also have “forecast” capabilities for evaluating the regression function at a point. Rather than take advantage of these features, which differ widely from model to model, it is better to have all students store their regression curve in a $y(x)=$ function slot. Storing the function is done differently on different models, but once the function is stored, the usual TRACE and VALUE features work for the analyses required by College Algebra texts. The instructions for each TI model are available on my website.

Conclusion

The same keystroke sequence can yield different results on different models of TI calculators. Said another way, doing a particular calculation correctly involves doing things differently on different model calculators. The awareness that there are differences can take you a long way on the road to coping with these differences. Difficulties can also be avoided by using parentheses in such a way that there is no question as to the order that any calculator will carry out the operations. For some tasks, such as regression analysis, the distinctions between the different models is unavoidable. In such cases, the tasks should be broken up into the smallest possible pieces.