MY STUDENT KNOWS THE MATHEMATICS, BUT HAS NEVER USED THE GRAPHING CALCULATOR

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Montgomery College is a community college in Maryland with about 14,000 students at the Rockville campus. We teach as many as 40 sections of intermediate algebra with up to 28 students each. Typically we have over a thousand students in the fall semester. This is where we introduce the graphing calculator. Our lives would be simpler if all of our upper level students went through our program. Unfortunately we have students entering at all levels. However on all three campuses, over 500 students taking Precalculus or first semester Calculus have not taken the proceeding course at Montgomery College. This means that many of the students who know the mathematics for, say, Calculus II, may have never used a graphing calculator. Some of the students went to the Montgomery County public school system and learned the calculator there. But about 35% of the students at the Rockville campus of Montgomery College are not US citizens, representing (for the whole college) 165 countries.

It is not practical for a teacher to start out teaching the calculator from scratch in every course. The first day a calculator is introduced, some students bring calculators they have been using for the past 4 years and some bring calculators new in the hard plastic wrap. (Hint: never spend class time opening the box. Bring scissors and let the students do it themselves.)

We solve this problem through the use of our well-run Math/Science Center. Not only can students get individual help there, but we run special workshops to learn the calculators, which are announced by the classroom teachers. I teach these workshops.

We start out at the end of the first week and the beginning of the second week. with four sessions, averaging about 10 students each. Each of these sessions is identical, but a couple of students come a second time to finish the material. These sessions are for students who are taking precalculus, any of our calculus classes, or anything with calculus as a prerequisite. My goal is not to teach the use of the calculator for the course they are taking, but to teach what they should know entering the class. I teach no statistics or matrices, which are covered in some of our classes, because these classes are not prerequisites for anything. If the student wants to know how to find the standard deviation or to multiply matrices, he must do so with the help of the teacher of his current class or with a tutor.

One of the difficulties that I have with students is that students do not know what they need to know about the calculator. The problems students have with the calculator fall roughly into two categories: 1. Those things the students do not know and are aware they do not know and 2. Those things the students do not know and they think they know. Category 1 is fairly easy to deal with. If you ask a student how to find the x-intercept of an equation where the intercept is visible in the window they are viewing, the student usually can find it or knows he can't. He might use TRACE and get approximations, when you wish more precise answers. This can be taught relatively easily. But suppose the student thinks he knows how to find x-intercepts. But he may have no clue how to do it if the x-intercept occurs outside the window. It gets worse with order of operations. I have had many questions about the graphing calculator, but I have never had a student say to me that he knows that when the numerator of an expression is a binomial he should put in parentheses, and his problem is that he doesn't. If they know it is a problem they know the solution. If they don't know it is a problem, they don't know enough to ask.

My method of teaching these workshops is to seat people together who have the same calculator and give them a worksheet. In an ideal group, people work at their own pace, helping each other while I walk around giving occasional help. Sessions are seldom ideal, but with up to 12 students they work quite well. We have anywhere from three to 25 people at each session. This allows us not to require reservations. Perry Peebles, who works in the Math/Science Center helps me when the sections are too large.

I have given you a slight variation of what I use.

Worksheet.
Note: the actual worksheet contains graphs of the answers so students can check. There is not enough space in this paper for them.

The worksheet starts having the students enter the following five equations.

$Y_1 = 10 + 3x$

$Y_2 = 4$

$Y_3 = -3x + 10$

$Y_4 = -0.84x - 4.84$

$Y_5 = \frac{21}{25}x - \frac{121}{25}$

If they are done correctly in the standard window they show a star. There are several features of this that students do not recognize as useful: they are given an opportunity to learn the difference between subtraction and negation, they learn where the division sign is, they learn they can enter more than one equation at a time, and TI-82 and TI-85 users learn the fact that their calculators treat 21/25X as 21/(25X).

Each of the next several questions point to a specific problem. I give graphs of the answers on the worksheet to make them self-correction

2. $Y_1 = -x - 2$ $\quad$ $Y_2 = 2x$

This can be the same graph if the second "–" is the same as the first.

3. $Y_1 = x - \frac{1}{x}$ $\quad$ $Y_2 = \frac{x-1}{x}$

4. $Y_1 = \frac{5}{x} + 7$ $\quad$ $Y_2 = \frac{5}{x+7}$

3 and 4 show the need for putting in parentheses in rational expressions.

5. $Y_1 = 3 - x$ $\quad$ $Y_2 = \sqrt{9 - x}$

6. $Y_1 = 3 - x$ $\quad$ $Y_2 = \sqrt{4 - x} + 1$

5 and 6 show the need for parentheses when using radicals.

7. $Y_1 = \frac{9}{5x}$ $\quad$ $Y_2 = 1.8x$ (TI-83 and TI 86 users) $\quad$ $Y_2 = \frac{9}{5}x$ (TI-85 or TI 82 users)

7 shows the need to put parentheses around the denominator for the newer calculators or around the fraction for the older ones.

8. $Y_1 = |x - 5| + 2$ $\quad$ $Y_2 = |x| - 3$

Although part of the reason for 8 is to have them put in parentheses, it also teaches them where the absolute value is found.

9. $Y_1 = 0.2x^3$ $\quad$ $Y_2 = x^{\frac{3}{5}}$

Similarly 9 shows them exponentiation as well as the use of parentheses.

10. Graph the following. Find a window or range that displays the graph.

a. $y = \frac{(x-15)(x+20)}{10}$ $\quad$ b. $y = .001x$

c. $y = 9999x^2$ $\quad$ d. $f(x) = (x+20)(x+25)(x+30)$

These are designed to show how mathematics is needed to find the windows.

The worksheet has problems involving finding a local maximum and evaluating functions. Problem 13 and 14 are designed to show a use of the ans *button, as well as review fractional exponents and parentheses in fractions.*

13. Find $8^{2/3}$. You should get 4. Now find 3×4 using $3 \times \text{ans}$. This gives 12. If you hit **enter** again you will get 36. What is the calculator doing?

14. Evaluate $\frac{3-2^2}{7^2-6(3)}$. Your answer should be -.032258... Now raise 2 to that power..
Your answer should be 0.977889

15. Find the point of intersection of the two equations 5x + y = 10 and 3x + 7y = 12.
On TI-83/82 use 2nd TRACE (CALC) 5, intersect. Hit ENTER three times. On the TI-86 , when the graph is visible use MORE, F1 (MATH), MORE, F3 (ISECT) Hit ENTER three times.

(Answer: (1.81, .94))

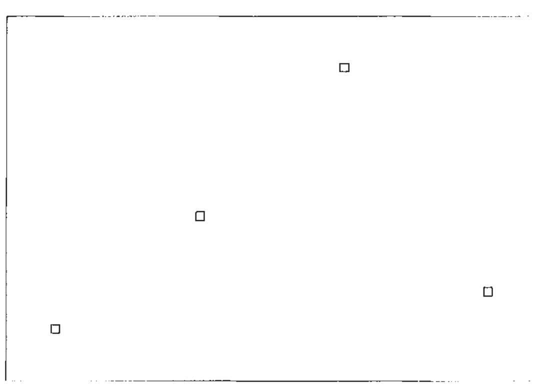
This is just for fun but it helps in graphing such equations as $(x-5)^2+(y-3)^2=8$

16. Describe in one word the graph of $y = |x| \pm \sqrt{1-x^2}$ **Hint:** Zdecimal.

The reasons for the remainder of the problems are fairly obvious.

17. **Plotting points on scattergrams**

For the TI-83 enter the following data in L_1 and L_2. (Use xStat and yStat for the TI-86) Both can be entered using STAT and EDIT. 1,2,3,4 in L_1 and 8,11,15,9 in L_2. Turn the plot on and zoom stat for the TI-83 (zdata for the TI-86)



The presence of the graph allows the students to check their answers.

18. Find all roots of the equation $5x^2 - x^3 = 2x + 2$ (Answers: 1, 4.449, and -.449)
Three methods are good. In two methods, put everything on one side of the equation.

Method 1: Set $Y_1 = x^3 - 5x^2 + 2x + 2$ Use ZERO or ROOT, which is in the CALC menu on the TI-82/83 and in MORE, F1 (MATH), ROOT on the TI 86. You will need to find the left and right bounds on the left and right of the root you wish to find. (The TI-82 calls these lower and upper bounds.) (The TI-85 uses MORE, F1 (MATH), ROOT, but does not use left and right bounds; it only requires a guess.)

Method 2: Set $Y_1 = 5x^2 - x^3$ and $Y_2 = 2x + 2$ and use intersect. (See problem 14.) You will have to guess three times to get the three answers. When the calculator asks for a GUESS, move the cursor near an answer before you hit enter. You are only interested in the x value of the answer. One intersection is barely outside the window if you have the standard window, but that is not a problem. (Often it is a problem because you cannot find it.)

Method 3: $Y_1 = x^3 - 5x^2 + 2x + 2$ and $Y_1 = 0$. Use INTERSECT for each of the three answers as in method 2.

19. Find an appropriate window to display the features of the following functions.

a. $y = -0.01x^2 - 5x + 8$
(Hint: This is a parabola; the window should contain its vertex.)

b. $f(x) = (x - 22)(x - 20)(x - 24)$
(Hint: Where are its roots?)

Possible answers to 18: a. xMin=-550, xMax = 10, yMin= -10, yMax = 640
b. xMin=19, xMax = 25, yMin= -15, yMax = 15

For students in Calculus II and up

1. Let $Y_1 = x^2$. Graph the derivative of Y_1 using Y_2 = nDeriv(Y_1,X,X). It should be the line y = 2x
2. Find $\frac{dy}{dx}$ evaluated at x = 3 using nDeriv(Y_1,X,3). (Answer: 6)
3. Evaluate $\int_{-1}^{4} x^2 dx$ by using fnInt(Y_1,X,-1,4). (Answer: 21.67)

These workshops do not solve all the calculator problems. I have not found the balance between a worksheet that explains everything and is not read and the worksheet that explains nothing and is not useful. The students obviously cannot become skilled users of a calculator with one hour of practice. Nevertheless, this appears to be a good start.