USING THE TI-NSPIRE™ CAS SOFTWARE AS A CLASSROOM DEMONSTRATION TOOL

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Introduction

Since Texas Instruments no longer supports Derive, those of us who have relied on it in teaching calculus are faced with finding an alternative software product. In this paper we present detailed steps for creating several calculus classroom demonstrations using the TI-Nspire™ CAS Computer Software.

Graphing the Derivative Function

In this demonstration, we graph a function and measure the slope of its tangent line at various points. We then plot points of the form $x, slope$ to create a scatter plot of the graph of the derivative. Here are the steps we use to create this demonstration.

- On a Graphs & Geometry page, create a function, such as $f(x) = \dfrac{x^3}{4} - x^2 + 1$.
- Click the Points & Lines button ⟦ • ⟧ and select Tangent ⟦⟧. Then click at a point on the graph where the slope is relatively small, to draw the tangent line.
- From the Measure ⟦⟧ menu, select Slope ⟦⟧. Then click on the tangent line. Click in the white space, to fix the position of the slope measurement. Right-click on the slope measurement, select "Attributes," and change the precision to two decimal places. (Note: Even this simple construction gives you the ability to demonstrate the connection between the shape of the graph of f and the slope of the tangent line. By selecting the pointer tool, you can drag the point on the graph and watch how the slope of the tangent line changes.)
- Right-click on the slope value and select "Store." Change var to $slope$.
- Right-click on the point of tangency, and select "Coordinates and Equations."
- Right-click on the x-coordinate and select "Store," changing var to x.
- Hide the coordinates of the point, by right-clicking on the coordinates and selecting "Hide/Show."
- Drag the point over to the left side of the graph.
- Insert a new page, and add a Lists & Spreadsheet application to it.

- Right-click on the gray cell at the top of column A, and select "Data Capture ... Automatic." Right-click on *var*, select "Variables," and then choose *x*. Then press Enter. This column will collect the *x*-values of the point as you drag it around on the graph. Repeat this step for column B, except choose *slope* as the variable whose values will be collected in the column.
- In the heading for column A, type the name *xlist*. Similarly, give column B the name *ylist*. The data in these columns will provide the coordinates of the points that will be plotted, to show the graph of the derivative.
- Click the Graph Type menu ▦ on the Graphs page, and select Scatter Plot ▦. Choose *xlist* and *ylist* from the drop-down menus as the *x*- and *y*-coordinates. Hide the label $\langle xlist, ylist \rangle$, the equation of $f(x)$, and the equation entry line.
- Now save the document, and open it during class, for the demonstration.
- To use the demonstration, slowly drag the point on the graph, and watch as the graph of the derivative is created, point by point. Pause at strategic locations to discuss how the graph of the derivative relates to the graph of the original function.
- To repeat the demonstration, move the point to the desired starting location. Then go to the Lists & Spreadsheet window, right-click on the grey regions in columns A and B, and select "Clear Data" to reset the graph of $f'(x)$.
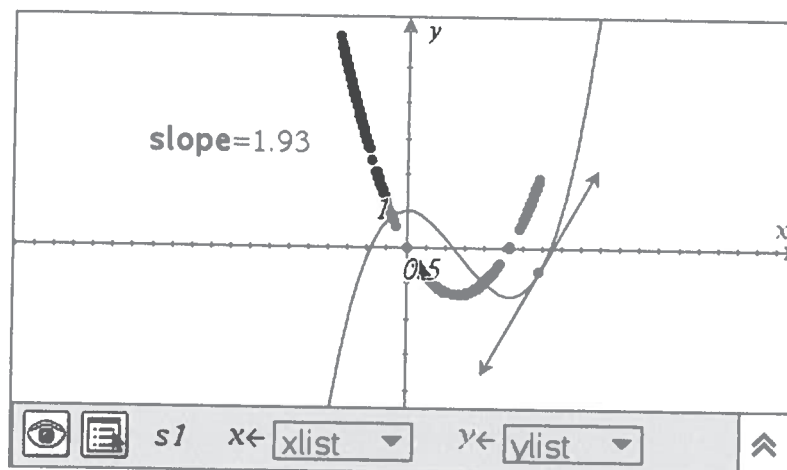

Figure 1: The Graph of the Derivative

Graphing the Definite Integral Function

In this demonstration, we sketch the graph of a function $f(t)$, collect values of definite integrals of that function, and then plot points on the graph of $F(x) = \int_a^x f(t)\, dt$.

- Open a new Graphs & Geometry page, and plot a function, like $f\ x\ =0.5x^2-x+1.5$.

- Click the Measurement button 🖊 and select Integral ◣.

- Click on the graph of $f\ x$, and a dotted vertical line appears. Move the line to the lower limit of integration, and click to place the line. Then move the cursor to the position for the upper limit of integration (marked by another dotted line), and click the cursor to place it. Once they have been placed, drag the line segment at the right side of the shaded region so the upper limit of integration is concurrent with the lower limit of integration.

- Right-click the numerical value of the integral, and select "Store." Name the variable *integral*.

- Select the point on the x-axis at the upper limit of integration. Right-click on it, and select "Coordinates and Equations." Right-click on the x-coordinate of the point, and select "Store." Name the variable x.

- Insert a new Lists & Spreadsheet page. Label column A as *xlist* and column B as *ylist*.

- Right-click on the grey region in column A, and select "Data Capture ... Automatic." Right-click on the highlighted variable, and choose "Variables." Select x from the list of variables. Press Enter, or click outside the grey region. Repeat this process to capture values of *integral* in column B.

- Return to the Graphs & Geometry window. Plot the points whose coordinates are $x, integral$ by clicking the Graph Type button 🔲 and selecting Scatter Plot 🔲. Select the variables *xlist* and *ylist* from the drop down lists to set the x- and y-coordinates of the points. Then click in the graph area. Until you adjust the limits of integration, you should see a single plotted point, with coordinates labeled $xlist, ylist$.

- In the Graphs & Geometry window, hide the entry line, the value of the integral, the coordinates of the point at the upper limit of integration, the coordinates of the point on the definite integral function, and the equation for $f\ x$. In each case, access the "Hide" command by right-clicking on the desired object.

- The page is now ready for classroom use. Drag the line segment indicating the upper limit of integration, and see plotted points for the function $F\ x\ =\int_a^x f\ t\ dt$. The number of plotted points depends on the rate of dragging. Drag slowly for more points.

- Change the lower limit of integration, and reset the page by moving the upper limit of integration to its original location and clearing the data from *xlist* and *ylist* by right-clicking on each of the grey regions in the Lists & Spreadsheet window, and selecting "Clear Data." Repeat the demonstration, and notice the effect that changing the value of a has on the graph of $F\ x\ =\int_a^x f\ t\ dt$.

- To change the definition of the function $f\ x$, reopen the entry line by clicking the View button 🔲 and selecting "Show Entry Line." If the entry line is in scatter plot mode, click on the graph of $f\ x$ to switch to function mode. If necessary, click the "up" button ⟨≫⟩ to see the definition of $f\ x$.

Plotting Points in Polar Coordinates

This demonstration allows the user to dynamically change the values of r and/or θ and observe the effect on the location of the point r,θ .

- Open a new Graphs & Geometry window.
- Insert a slider, by clicking the Actions button ⟨▶⟩ and selecting Insert Slider 🔲. Type r to rename the highlighted variable, and then click outside the slider area to set the slider. It may be helpful to drag the box containing the slider to a new position before inserting the next slider. Click the Actions button again, and insert a slider for θ . To get the symbol θ , click the icon for the Symbols palette 🔲 located along the top toolbar.
- Drag the right endpoint of each slider to lengthen the sliders. Also, right-click on each slider and select "Settings" to change the minimum values of r and θ to negative numbers. Change the maximum values of r and θ if desired. Choose initial values for r and θ that do not place r,θ on a coordinate axis.
- Insert a new Lists & Spreadsheet page. Label the first two columns x and y.
- In the first data cell in the x column, type the formula for the x-value of the point whose polar coordinates are r,θ : = 'r·cos('theta). Similarly, in the first data cell in the y column, type ='r·sin(theta). Leading with an equal sign indicates that these are formulas. Using an apostrophe before each variable name indicates that this value should change with the value of the variable.
- Return to the Graphs & Geometry window that contains the r and θ sliders.
- Plot the point whose polar coordinates are r,θ by clicking the Graph Type button 🔲 and selecting Scatter Plot 🔲. Select the variables x and y from the drop down lists to set the x- and y-coordinates of the point.
- Hide the label "(x,y)" displayed next to the point by right-clicking on it, and selecting "Hide/Show."
- Draw a segment from the point to the origin: Click the Points & Lines button ⟨•⟩ and choose Segment 🔲. Move the cursor to the plotted point until the phrase "point on" appears, and click to set one endpoint. Then move the cursor to the origin until the phrase "intersection point" appears, and click to set the other endpoint.

- Click the Actions button 🖱 and select Pointer 🖱. The demonstration is now ready for classroom use.
- Change the values of r and θ by dragging the indicators on the sliders, or set the values of the variables by clicking on their current values and typing the desired values, followed by "Enter." The point will move accordingly. Type "pi" for the value of π. A good starting point for a classroom demonstration is $1, 0$.

Graphing Taylor Polynomial Approximations to a Function

This demonstration shows Taylor polynomial approximations to a function, and shows students how the approximation improves with higher orders.

- On a Graphs & Geometry page, create the function that you would like to approximate by Taylor polynomials, such as $f(x) = e^{-x^2}$. (Remember to use the Symbols palette ∞β to get the symbol for e.)
- Use the Window menu 🖱 to zoom and/or specify window settings, as appropriate for the function.
- Insert a slider, as described in the polar coordinates demonstration. Name the variable n (for the order of the Taylor polynomial). An initial value of 1, with n ranging from 1 to 10, is often good. Leave the Step Size set to 1, because n should logically be a positive integer.
- Define $f_2(x)$ by clicking ∧ and typing "Taylor$(f_1(x), x, n, 0)$." The graph will then display the first order Taylor approximation to $f_1(x)$, expanded about 0.
- Use the slider to control the order of the Taylor polynomial. Rather than moving the slider with the mouse, click the slider button, and release the mouse without moving it. The cursor should look like a hand about to grab the slider. Use the left/right cursor keys to increase or decrease the order in integer increments.
- Optional: Insert a slider for another variable, a, to represent the expansion point. Then simply replace "0" in the definition of $f_2(x)$ by "a," to demonstrate how changing the expansion point affects the Taylor polynomial.

Conclusion

While the TI Nspire CAS can be used successfully as a demonstration tool, it has some drawbacks when compared to Derive. Because it models the handheld Nspire CAS calculator, using multiple colors in pages is not an option, and the screen has limited resolution. We cannot plot implicitly defined functions, or functions of two variables. Moreover, as of this writing, the Nspire CAS software is not readily available to students, so students cannot use the demonstrations described here for individual exploration. Nevertheless, the software appears to be adequate for a number of demonstrations that we like to use in our classes.