THE NEXT GENERATION OF HANDHELDS – FROM GRAPHING CALCULATOR TO MICROWORLD MAKER

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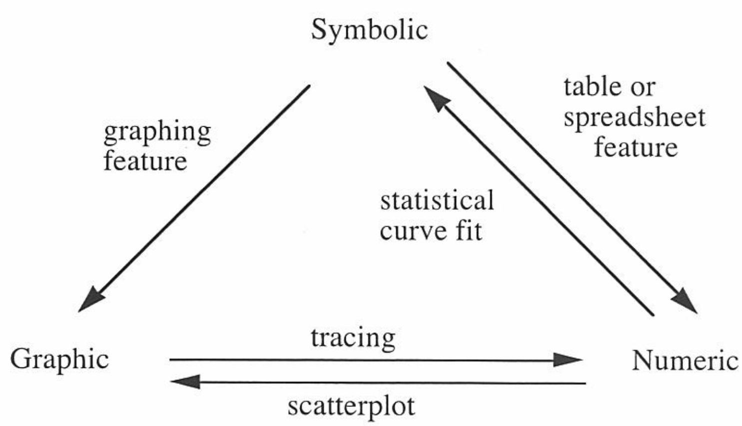
Since their introduction over 20 years ago, handheld graphing calculators have gone through an evolution punctuated by incremental changes in the form of added features or improvements in user interfaces. We make the case that the most recently developed generation of handhelds such as the TI-Nspire marks a real leap in ways that won't be immediately realized by many users.

Where does TI-Nspire fit?

I have found the following categorization scheme to be helpful in thinking about types of technology and their uses.

- Computational/representational toolkits (graphing calculators, CAS, spreadsheets)
- Dynamic geometry (Geometer's Sketchpad, Cabri)
- Microworlds (constrained environments with mathematically defined "rules of engagement")
- Computer simulations (parameter driven virtual enactments of physical phenomena)
- Presentation/communications (powerpoint/internet)

The following diagram depicts how the various features of a computational/ representational toolkit allow to traverse the three nodes of the "Rule of Three."



There are arrows that could be added to the the diagram representing moves within representations: within Symbolic are algebraic manipulations made possible by a CAS, within Graphic are the dynamic zooming features, and within Numeric are spreadsheet transformation features that allow column and row transformations. (There is clearly one arrow missing in this diagram – the one that suggests a move from directly from Graphic to Symbolic via a manipulation of a graph that results in a change in the analytic formula.)

The latest generation of handhelds (such as the Classpad 300 or the TI-Nspire CAS) are certainly computational/representational toolkits, but they also sport a document structure that allows the user to create their own stand-alone environments. With that in mind, let us propose the following

Pedagogical Axiom: action/consequence/reflection principle

Students **learn mathematics** by:

1) taking mathematical actions on mathematical objects,
2) observing the mathematical consequences, and
3) <u>reflecting</u> on their meanings.

If there is a robust dynamic linking capability (such as that found on TI-Nspire CAS) then that allows us to exploit such technology by creating action/consequence scenarios: documents that emphasize direct manipulation of visual models with immediate and transparent results. Dynamic links connect two or more representations so that changes in one are immediately reflected in the others. Dynamic links provide

–settings for mathematical exploration
–immediate visual consequences
–opportunities for prediction

This dynamic linking allows a direct action on one mathematical object to result in a change in another related object, so that one essentially has the tools to build a "microworld." That is, the technology becomes a microworld authoring kit.

Example: What's my rule?
Scenario: A coordinate plane with two points labeled *z* and *w* with displayed coordinates. The "driver" object is point *z* which can be moved by the user (with the coordinates instantly updated). The "driven" object is point *w* whose position and coordinate display is dynamically updated according to a rule relating the point *z* to point *w*. These rules can be guessed at by the user in a variety of ways: by coordinate functions, by geometric descriptions, or by complex function formulae.
Example: If point *z* has coordinates (x,y), the point *w* might have coordinates $(-x, -y)$. Point *w* is thus the reflection of point *z* in the origin, or as complex numbers $w = -z$.

A variety of questions can be asked to scaffold the inquiry. Can point *z* and point *w* ever coincide? What happens if point *z* is in the third quadrant? Can the two points ever be in the same quadrant? If one desires point *w* to move in a horizontal line from left to right, how must point *z* be move? By asking good questions, the instructor can emphasize sense making on the part of the student.

Indeed, several two-way action-consequence scenarios are provided by the graphing environment of TI-Nspire. For example, if one graphs a linear function $y = mx + b$ in the usual Graphs & Geometry environment on TI-Nspire one has a two-way action-consequence environment: one can rotate the graph of the line (driver is the graph) and see a resulting change in the numerical value of the slope in the equation for the line. Similarly, one can translate the graph and see a resulting change in the y-intercept. This effectively supplies us with the missing arrow for our "Rule of Three" diagram. Conversely, one can edit the equation for the line (driver is the expression) and see an immediate change in the graph.

Some have proposed a "Rule of Five" by adding additional nodes for physical and verbal representations. Here's a picture of such a diagram with every possible arrow shown between representations. Perhaps not all of the arrows can be implemented, but we should not be hasty to jump to conclusions. For example, the arrow from Physical to Graphic is already available via real-time graphical displays of motion detecting CBR's. The opposite arrow from Graphic to Physical has been implement in real environments using computer driven robots and in virtual environments such as SimCalc. It is a brave new world with the new generation of handhelds.