

The Design and Use of eActivities for Learning Mathematics

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Abstract: The recent development by Casio of the hand-held *ClassPad 300* device raises a number of important questions for the design of mathematical learning experiences for students. This paper provides a brief description of the *ClassPad 300* and its mathematical capabilities, followed by a description of the idea of an eActivity, well provided for in the operating system of the device. As their name suggests, eActivities are electronic learning activities, designed to be used by a student with a personal hand-held *ClassPad 300*. Designing suitable eActivities requires decisions to be made about the suitability of various pedagogical approaches that might be accommodated. These approaches include exposition or authoritative presentation, controlled practice of skills, open exploration and discovery. The *ClassPad 300* offers ways of connecting mathematical ideas together within an eActivity that can be taken advantage of with these various approaches. Examples of recent eActivities are presented and briefly analysed. Practical design issues are provided and illustrated through examples. The paper concludes with an assessment of the prospects of the idea of an eActivity for student learning of mathematics.

1. Introduction

The *ClassPad 300* is a new hand-held device produced by Casio. About the same size and weight as a graphics calculator, the *ClassPad 300* offers a rich variety of opportunities for students to explore mathematical ideas.

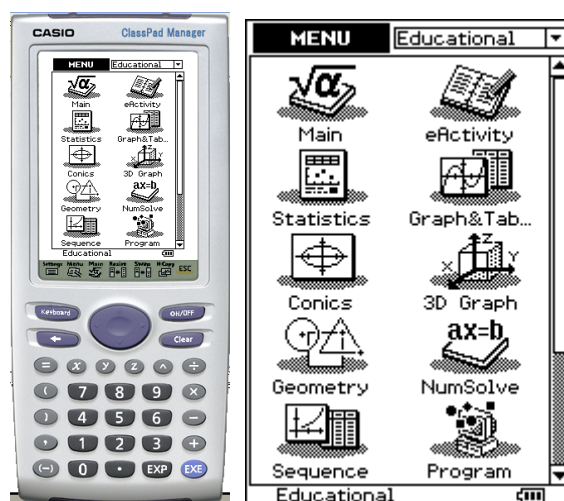


Figure 1.1 Casio *ClassPad 300* and icon menu screen

As Figure 1.1 indicates, the *ClassPad 300* provides several different modes of operation, selected from an icon menu screen. The screen is touch-sensitive, so that selections and other actions are made by the user with a stylus. The mathematical capabilities of the device are impressive, and incorporate most elements of mathematical activity relevant to secondary school,

including significant improvements on capabilities generally available on a graphics calculator. Figure 1.1 shows what some of these are; greater details are available from the manufacturers [1].

The *ClassPad 300* is highly interactive, allowing for various kinds of operations linking different modes. As evident from the image in Figure 1.1, the *ClassPad 300* has remarkably few keys for such a sophisticated device, so that most interactions take place using the stylus. To facilitate more complex communications, consistent with the mathematical sophistication involved, drop down menus (much like a computer menu), iconic toolbars and various soft keyboards are used. The *ClassPad 300* has apparently been designed to provide all the necessary technological support for secondary school mathematics (except telecommunications) within a single hand-held device. The additions of CAS, geometry, three-dimensional graphing and a spreadsheet over the conventional capabilities of graphics calculators are significant, as are the interactions possible between different applications on *ClassPad 300*. The substantial capabilities for storage of information and upgrading of capabilities through the use of flash memory are also impressive. Again, readers are referred to the manufacturer's site [1] for details of the device.

Taken together, these features suggest that *ClassPad 300* represents the single most significant improvement on the graphics calculator for secondary school mathematics since the beginning of the ATCM conferences. While it is clearly incorrect to regard the *ClassPad 300* as a species of graphics calculator, one way of thinking of it is as a device that is capable of providing for students whatever a graphics calculator can provide (outlined in [2]), as well as many other opportunities for learning.

In this paper, the focus is on the use of the device to provide students with eActivities, which are best regarded as small electronic activities stored in the *ClassPad 300* that utilize the device's capabilities for various learning purposes. Attention now turns to this idea.

2. The concept of an eActivity

In essence, an eActivity comprises a pre-programmed use of the *ClassPad 300*, generally consisting of instructions to the user as well as various window settings and *ClassPad 300* operations appropriate to the mathematical task involved. An eActivity is self-contained in the device, and does not rely on separate printed instructions for the user. Although other purposes might be involved (eg to streamline practical use of the *ClassPad 300* or even to learn how to use the device itself) the main idea of an eActivity is to support student learning in some way, and so this paper is restricted to consideration of eActivities for learning some aspects of mathematics.

Since eActivities comprise internal software files, they can be stored and retrieved in a *ClassPad 300*, and can be transmitted between two *ClassPad 300*'s, using an appropriate cable. They can also be moved via a USB cable to and from a computer loaded with suitable software and hence transmitted via the Internet to other computers. Once constructed, eActivities can be stored on websites for downloading, provided suitable software and cabling is available. Thus the concept of an eActivity allows for new forms of sharing of teaching materials. Most eActivities are small, lesson-sized objects, so that there is sufficient memory space in a *ClassPad 300* to store a substantial number of them. Storage, retrieval and manipulation of the files is fairly intuitive and does not require high level computing skills, so is accessible to typical users, both students and teachers. Extracts from various examples constructed by the author are shown in this paper.

In some respects, eActivities can be regarded as single-purpose applications similar in some ways to educational Java applets, intended to organize fruitful interactions between users and mathematics, as represented in the machine. An important difference is that eActivities are restricted to *ClassPad 300* operations, and thus are much less flexible and powerful than the Java environment. While this may at first seem a significant limitation, a significant advantage is that

construction of eActivities does not require sophisticated programming expertise (such as Java competence), and so is well within the reach of typical classroom teachers of mathematics familiar with the *ClassPad 300*. In most respects, a competent teacher user of a *ClassPad 300* can easily make eActivities for their students or to share with colleagues, which is rarely the case for sophisticated environments such as Java.

While standard *ClassPad 300* operations are all accessible in eActivities, there are a small number of operations that are *only* accessible in eActivities. One of these is a facility to make notes to inform the user of something (such as answers to questions or exercises) or to allow them to store information for themselves. These two are illustrated in Figure 2.1, where they have been employed to help users record and check predictions about the effects of transformations on standard deviations in an eActivity.

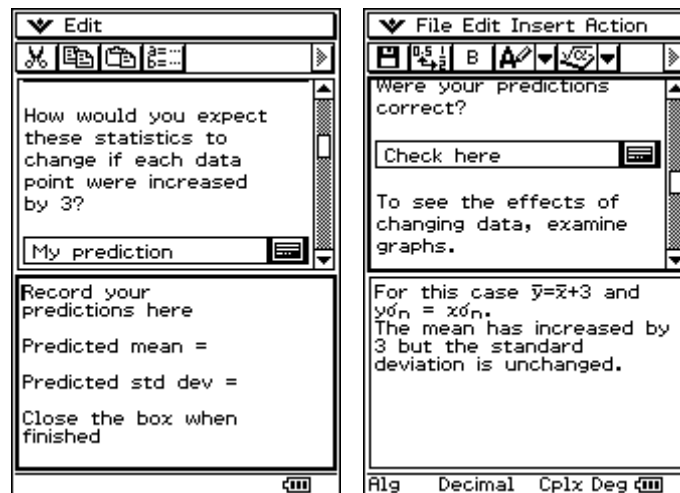


Figure 2.1 Using notes windows to make and check predictions in *StdDev* eActivity

A second capability only available within eActivities is a geometry link, a mechanism for providing a dynamic link between the main eActivity window and a geometry window.

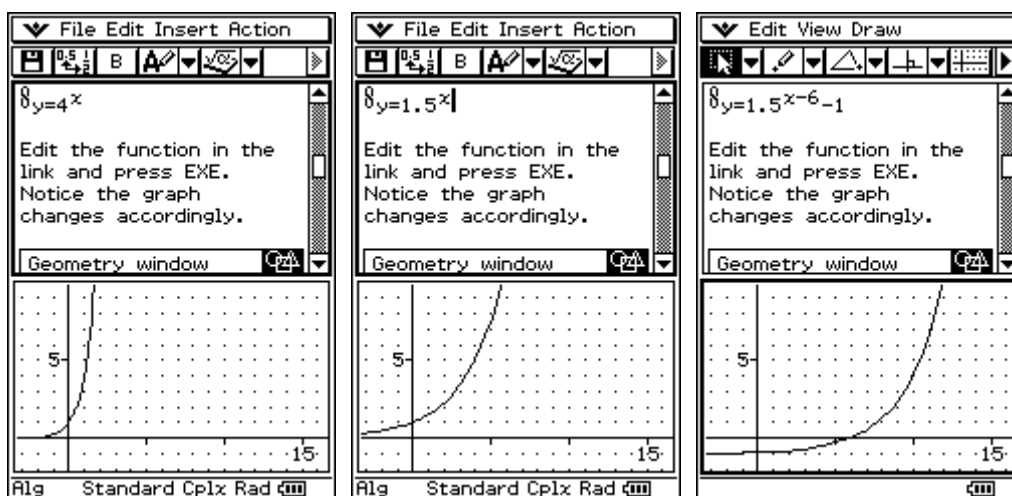


Figure 2.2 Using a geometry link in the eActivity *ExponentialFunc*

Figure 2.2 shows an example of this from an eActivity. In this case, changing the base of the exponential function in the eActivity window at the top of the screen immediately changes the graph in the geometry window at the bottom of the screen. Analogously, the third screen below shows that dragging the graph to a new position immediately changes the function accordingly, as the two windows are dynamically linked.

Clearly, these two capabilities highlight the fact that eActivities have an essentially *educational* role within the *ClassPad 300*.

3. Pedagogical styles for eActivities

There are a number of ways in which the *ClassPad 300* environment can be used to design eActivities for student learning of mathematics. Four of these are described and exemplified here:

Exposition or authoritative presentation

The essence of an exposition is that mathematical relationships and results have been carefully organized, sequenced and presented, in something akin to the style of a lecture. The *ClassPad 300* lends itself to the important idea of multiple representations, allowing students to see different manifestations of the same idea in different windows. Figure 3.1 shows two examples of this. In the first screen from eActivity *RadianMeasure*, the measure of angle A in radians is obtained directly by finding the ratio of arc BC to radius AC, while the measure in degrees is obtained directly in the measurement box, showing 28.72033° in this case. Similarly, the second screen, taken from the *InverseTrig* eActivity, verifies that the angle computed using the cosine rule matches the angle measured directly in the measurement box, within rounding error. Exposition of this kind allows students to interact with presented material in a way that normal textbook presentations do not.

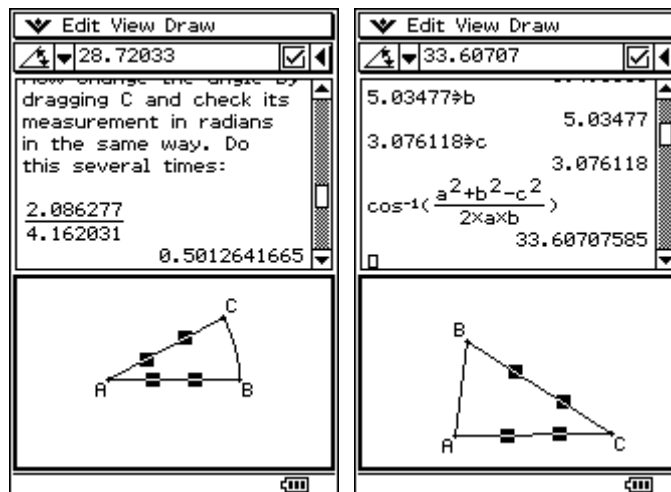


Figure 3.1 Different representations used in *RadianMeasure* and *InverseTrig* eActivities

In a similar way, Figure 3.2 shows some examples of discontinuous functions, which are presented in the *Continuity* eActivity. Rather than merely describing the phenomena and their representation, the eActivity allows users to manipulate the examples and study their origins.

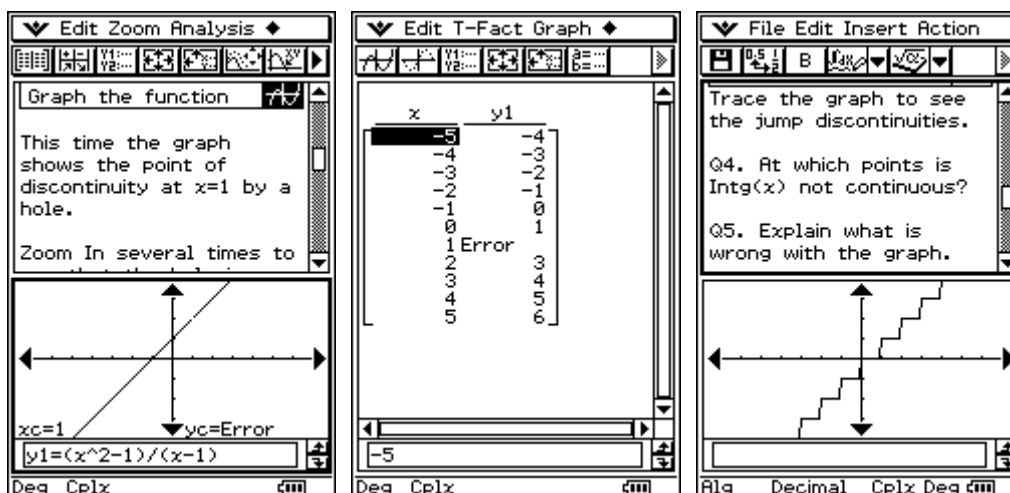


Figure 3.2 Representing and understanding discontinuities in the *Continuity* eActivity

Controlled practice of skills

This style of eActivity offers users an opportunity to practice particular mathematical skills, with a view to developing fluency. The *ClassPad 300* can be set up to describe the skill involved, support the user to check their results and provide them with a means of monitoring their progress. An example of doing these things is offered in Figure 3.3, concerned with expanding binomial expressions involving complex numbers.

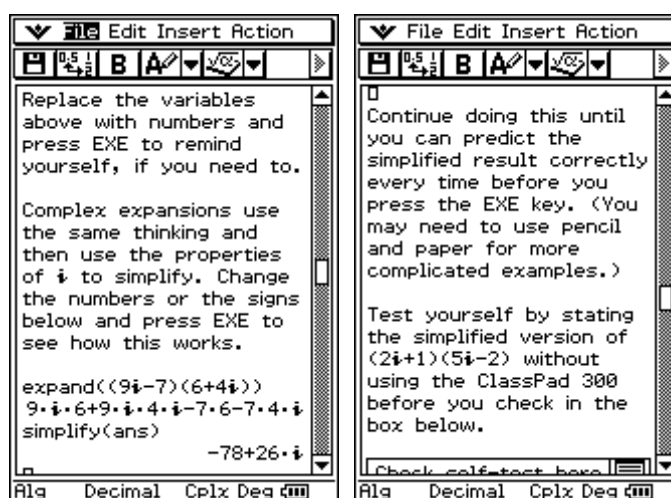


Figure 3.3 Practicing complex expansions in the *ComplexNos* eActivity

Open exploration

An eActivity in this style allows users to explore some aspects of a mathematical idea, or collection of ideas, in order to enrich their conceptual development. Figure 3.4 shows an example from an eActivity designed to help with explorations of the binomial probability distribution. The three graphs show the distributions associated with different probabilities of success ($p = 0.2, 0.5$ and 0.7 respectively). Within the eActivity, both numerical and graphical representations can be generated and explored to understand key similarities and differences.

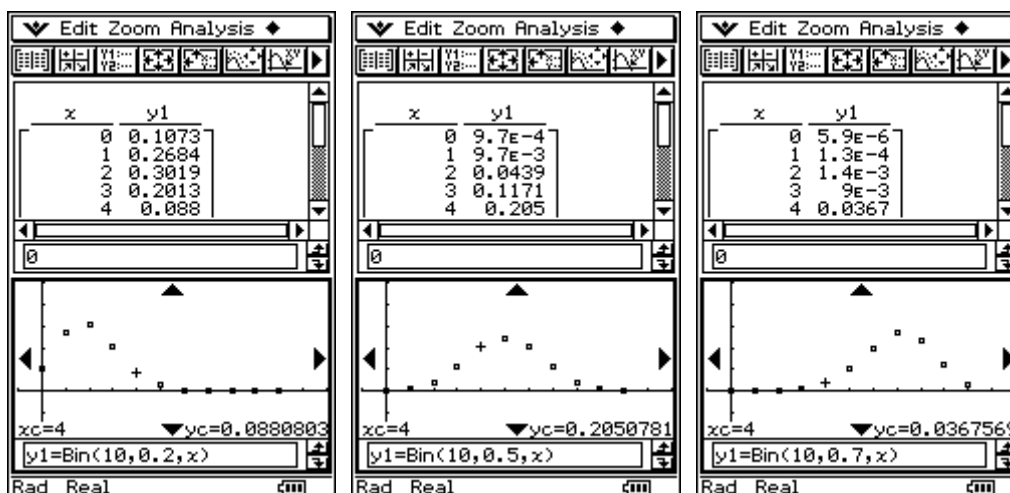


Figure 3.4 Exploring different distributions using the *Binomial* eActivity

Discovery

As its name suggests, the distinguishing feature of an eActivity in discovery style is that a user is helped to make a particular mathematical discovery for themselves, through some controlled interaction with the mathematical environment. While this might be regarded as a form of exploration, the distinguishing feature is that there is a specific mathematical endpoint envisaged as a result of the explorations. To illustrate this idea, Figure 3.5 shows sample screens from the *StdDev* eActivity, constructed to help students discover the effects of translations and scale changes on means and standard deviations of quantitative data.

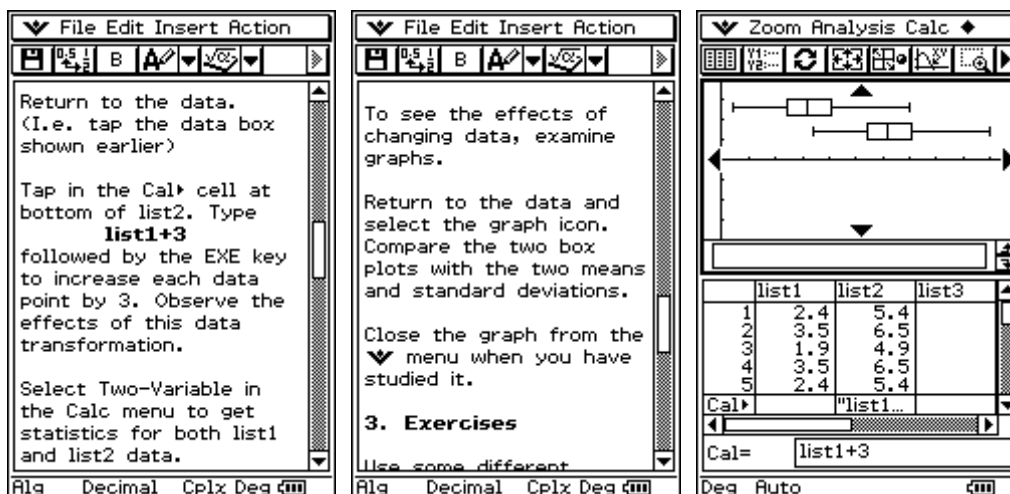


Figure 3.5 Discovering properties of data transformations in *StdDev* eActivity

No claim is made here that this paper provides an exhaustive list of pedagogical styles that can be incorporated into eActivities. Indeed, another possibility that is not illustrated here involves using the *ClassPad 300* for automatic data logging and subsequent analysis of physical data, with a view to understanding and representing various physical principles. However, it is suggested that the four styles briefly described here are different in character and together encompass most of the ways in which mathematical learning can be supported with this device.

4. An example of making connections

A powerful feature of the *ClassPad 300* is the capacity to make connections between different aspects of mathematics. This provides students with multiple perspectives on mathematical ideas, or sets of ideas, with potentially beneficial effects. To illustrate this, brief extracts from an eActivity, *Circles*, are provided in Figures 4.1 to 4.4. The eActivity is concerned with understanding connections between the equation of a circle and its graphical and numerical forms.

A particular equation, $x^2 + y^2 - 2x - 6 = 0$, is first chosen for student exploration, but users can explore others at a later stage. The opening part of the eActivity involves regarding this as an equation, which has two solutions for y for particular values of x . The equation can be solved numerically, using the NumSolve applet of the *ClassPad 300*, as suggested in Figure 4.1.

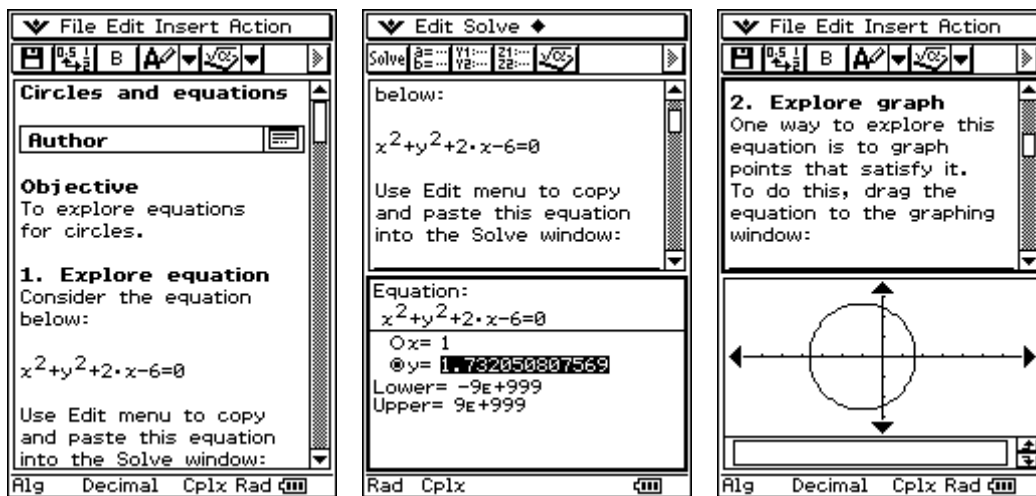


Figure 4.1 An equation and a graph in *Circles* eActivity

Connections between equations and graphs can be explored using a geometry link, shown in Figure 4.2. Through these explorations, users will be helped to see the relationships between the coefficients and the circle properties, including the (unexpected for novices) appearance of linear y terms as well as x terms.

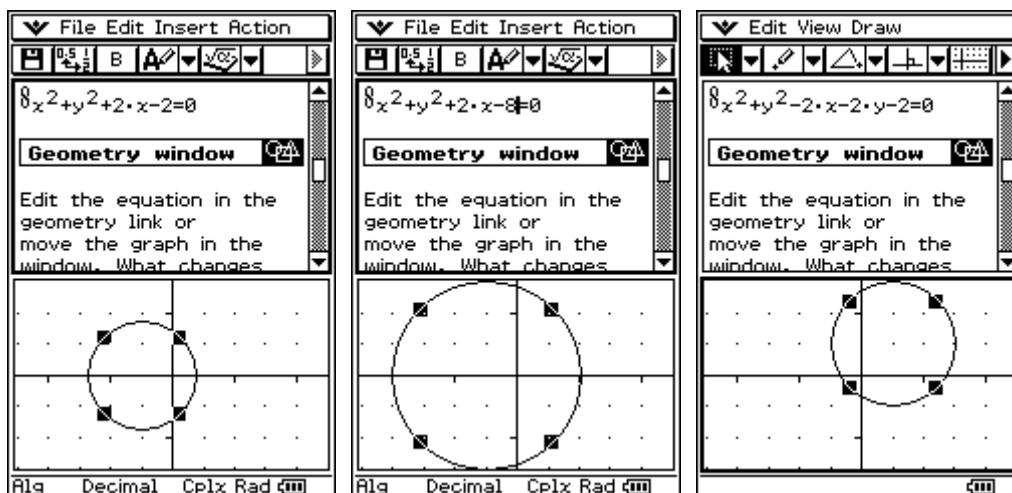


Figure 4.2 Using a geometry link in *Circles* eActivity

Geometric properties of the circle are accessible from the Conics applet, illustrated in Figure 4.3, which also shows how an equation can be represented in a more useful form to see the links between coefficients and the centre and radius of the circle.

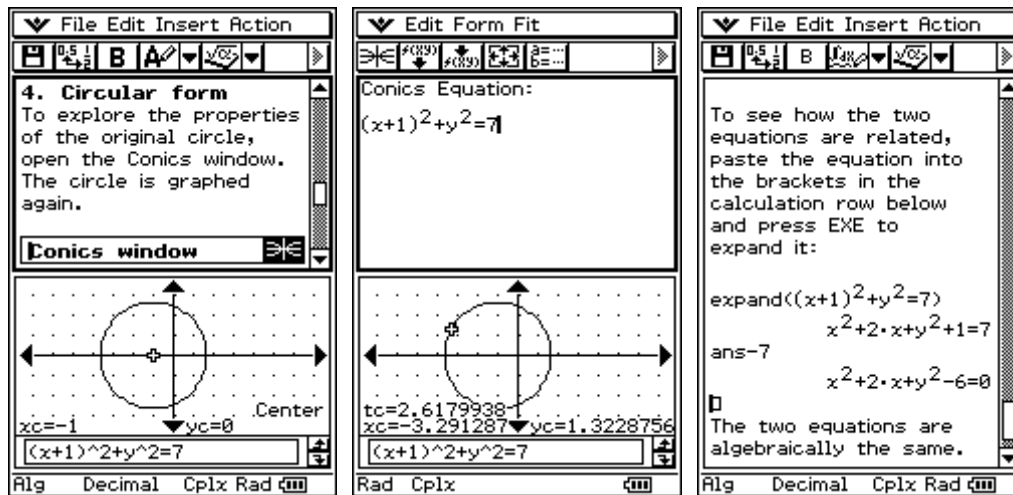


Figure 4.3 Exploring conics forms in *Circles* eActivity

The final screen of Figure 4.3 shows how the CAS capabilities in the eActivity screen can be used to highlight the algebraic manipulations involved in different representations of the equations of a circle.

This eActivity shows how the standard graphing applet, the geometry applet, the numerical solving applet, the conics applet and the CAS capabilities of *ClassPad 300* can all be employed in the same eActivity. The focus of this paper is on the design of eActivities, so available space precludes a fuller treatment of this particular eActivity or of the possibilities of connections of these kinds of interactions between users and the *ClassPad 300* more generally; a more thorough treatment of the latter point is available in [3].

With this array of possibilities, considerable care is needed to not make many connections within an eActivity merely because it is possible to do so, tempting as this might be. In support of this reservation, noted scholar and researcher Anna Sierpiska's recent remarks regarding visualization (but applicable more widely) are important:

[M]athematicians' external visualizations may be opaque to the novice; their understanding requires time and well-constructed tasks for the students; "a picture may be worth a thousand words", but the use of teacher-generated visualizations in teaching neither shortens the time of student's learning nor makes it easier. [4, pp192-3]

5. Practical design issues

Several practical issues emerge in designing eActivities for the *ClassPad 300*. These are described and exemplified briefly here.

Instructions

Assumptions need to be made regarding the familiarity of the user with the *ClassPad 300* and its operations and suitable instructions provided. This is relatively easy for a teacher designing eActivities for her own class, since the typical level of expertise is likely to be well known. However, when eActivities are designed for wider distribution, care needs to be exercised to not assume a user is familiar with all necessary operations.

Some examples of instructions for novice *ClassPad 300* users are shown in Figure 5.1, taken from three different eActivities. Shorter versions could be provided for users already familiar with the device, but this is a risky strategy for eActivities designed to be used by a wider group.

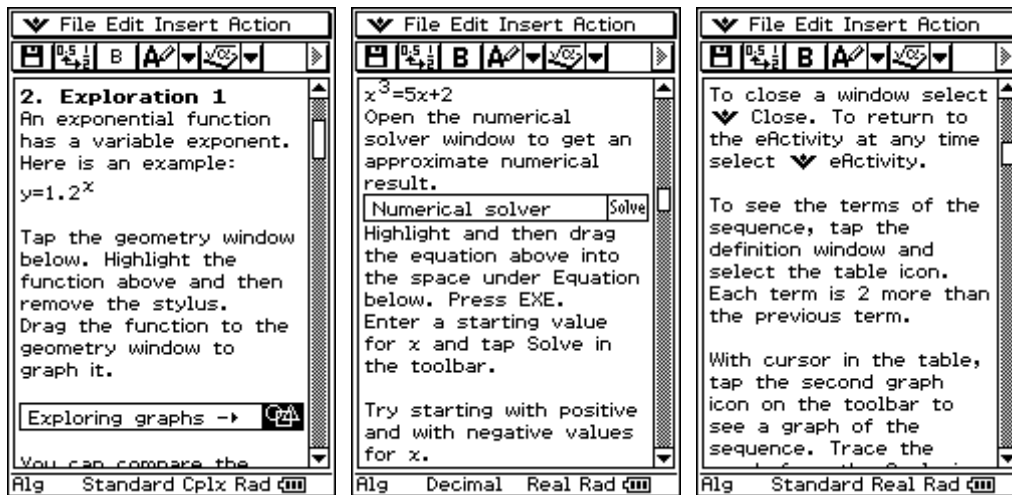


Figure 5.1 Instructions for novices in *ExponentialFunc*, *Polynomials* and *Recursion* eActivities

Scrolling text

While it is important that text messages in an eActivity are clear to the intended readers, which is rarely an easy matter when new ideas are being introduced, it is also important that the messages be fairly brief, since vertical scrolling takes time using a stylus and can get quite frustrating. In other words, text instructions should be as long as necessary, but no longer; it will usually be difficult to decide precisely how long this is, unfortunately, especially for a remote audience.

An additional issue with text use involves horizontal scrolling, since the *ClassPad 300* will allow designers to write lines longer than the screen width, as illustrated in Figure 5.2. The screen on the right shows a less careful choice of words and line breaks, which can be quite frustrating to a user, since the stylus must be used in each line in order to read the entire line satisfactorily. In the author’s opinion, it is better to take a few more lines than subject users to this particular frustration.

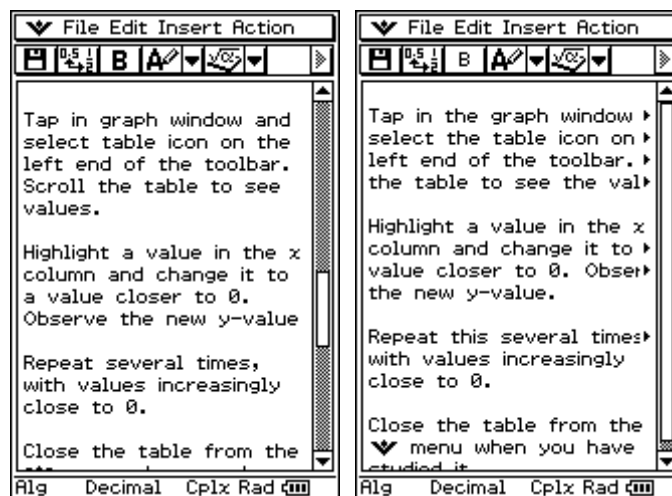


Figure 5.2 Avoiding the necessity of horizontal scrolling of text

Self-regulation

By their nature, eActivities are self-regulated, as the user is in control of the stylus. Attention is needed to help users monitor their progress with the mathematical ideas involved. One example of this is shown in Figure 5.3, illustrating explicit advice on self-regulation.

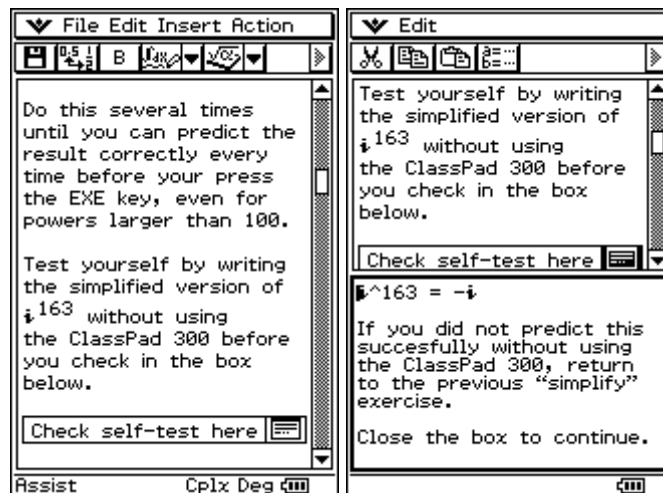


Figure 5.3 Monitoring progress in *ComplexNos* eActivity

Bells and whistles

The *ClassPad 300* is a quite remarkable device, with many rich connections possible. It seems almost inevitable that novice designers will be inclined to take advantage of the opportunities provided by the device to represent ideas in many different ways – essentially using as many as possible of the ‘bells and whistles’ provided by the manufacturers, in part because it is possible to do so. Great care must be exercised to resist this temptation, which is likely to focus too much attention on what is ‘possible’ with the device rather than on what students are learning, which ought to remain the major focus, as noted in the previous section. This sort of problem is not a new one, of course: it has appeared regularly in attempts to use technology for educational purposes.

6. Conclusion

The *ClassPad 300* offers new opportunities for learning mathematics, and it seems likely that eActivities will be a flexible and useful way of implementing it, provided care is exercised in designing suitable experiences for students. The paper offers some advice on some of the design issues involved, as well as some cautionary remarks, based on the author’s experience. Some of the design issues are particular to the *ClassPad 300* while others have a wider applicability.

References

- [1] Casio *ClassPad 300* specifications (http://www.casio.co.jp/edu_e/classpad/spec.html)
- [2] Kissane, B. (1995) The Importance Of Being Accessible: The Graphics Calculator In Mathematics Education. In Fong, H.K. (Ed.) *Proceedings of the First Asian Technology Conference on Mathematics*, Singapore, Association of Mathematics Educators: Singapore, 161-170.
- [3] Kissane, B. (in press) Interactive Mathematics on the *ClassPad 300*, In *MAV 2004 Annual Conference: Towards Excellence in Mathematics*, Melbourne: Mathematical Association of Victoria.
- [4] Sierpinska, A. (2003) Visualisation is in the Mind of the Beholder, *New Zealand Journal of Mathematics*, 32 (November supplementary issue), 173-194.