

**Excerpts from A Computer for all Students - Revisited
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Introduction

Ten years ago graphing calculators started a revolution in the teaching and learning of mathematics. This was only the tip of the iceberg! In early 1992 we published an article in the *Mathematics Teacher* about how inexpensive graphing calculators were really computers with built-in graphing software. These calculators could be viewed as *computers available to all students* because of their low cost, ease of use, and portability [Demana and Waits, 1992]. Our point was that only a few elite would benefit if teachers had to rely exclusively on expensive computer laboratories to deliver computer enhanced visualization in mathematics teaching and learning.

We followed the first article with another *Mathematics Teacher* article making a case *against* student use of computer symbolic algebraic manipulation (CAS) in school mathematics *at that time* [Waits and Demana, 1992]. Our reasons then were simple. Material deleted... .

[However]..at the end of the "A Case Against..." article we wrote, "We are convinced that CAS [computer algebra systems] methods are the way to go in the future... ."

The Future is Here!

Texas Instruments recently introduced a relatively inexpensive hand-held computer with built-in computer algebra system. It is the first of a new generation of super graphing calculators because other calculator manufacturers will surely follow with similar products. Material deleted....

Implementing The Standards

A major concern to us today is that the following underlying assumptions about computer technology of the *Curriculum and Evaluation Standards for School mathematics* (NCTM, 1989) are still nearly *impossible* to implement in typical high schools. Material deleted....

Many teachers have simply opted to avoid using computer symbolic algebra and computer interactive geometry in their high school mathematics classes because it was simply not practical or possible to do so. Now it is both possible and practical! For example, a set of TI-92's is an inexpensive and portable computer laboratory. Implementing the important computer technology strands of the NCTM grades 9-12 *Standards for all students* is finally feasible.

The Twilight of Traditional Paper and Pencil Algebraic Skills

In the past, teaching of traditional (paper and pencil) algebra symbolic skills in school mathematics *was* necessary because they were the *only* procedures available for algebraic manipulation necessary to "solve" problems. Today this simply is not the case. CAS algorithms now do algebraic manipulations (much) faster and with far better accuracy than possible with the "traditional" skills. Material deleted...

A New Challenge

Mathematics teachers now have a new challenge. Our community can *no longer ignore* how student use of computer symbolic algebra and computer interactive geometry impacts the mathematics curriculum. This new generation of hand-held student computer tools will soon be as popular as graphing calculators are today. We *must* deal with the fact that computer symbolic algebra and computer interactive geometry are better - far better - tools than paper and pencil for doing many of the "manipulations" associated with mathematics. Material deleted...

Here are two examples. Consider every one's favorite algebra topic of factoring algebraic expressions. Factoring *is still* very important. After all, the *Fundamental Theorem of Algebra* is a *factoring* theorem. This theorem is central to good mathematical understanding, as are the very important connections among factors, x-intercepts of the graph of functions, zeros of ... Material deleted...

Another example from calculus is "partial fractions" as an integration technique. Figure 2 shows the result of applying the "Expand(" CAS command to a simple rational function $g(x)$. Notice it is now very easy to integrate $g(x)$ (find an antiderivative) mentally [using basic concepts of calculus] hMaterial deleted...

We believe teachers should definitely continue to teach the concepts of factoring and partial fraction decomposition and what they mean (and why they are useful). However, the *tools* we will use "to factor" and "to find partial fraction decompositions" will move from paper and pencil (history) to student use of CAS. Material deleted...

A Mathematics Image Problem

See article for this section

Summary

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The NCTM *Standards* (NCTM, 1989) speak well to the content topics and methods that are needed in a modern mathematics curriculum for all students. Today there is a new tool that makes possible and practical the vision of the rich computer technology enhanced mathematics curriculum for *all* students represented by the NCTM *Standards*. By facilitating the reduction of time spent on paper and pencil methods, this tool will provide the additional classroom time for the new mathematical activities recommended in the *Standards*.

We now need to be more specific and explicit about a controversial issue. We can no longer spend mathematics classroom time doing everything we did in the past paper and pencil era *and* adding on the many topics and methods our students need for the technological intensive future they face. Let's all get busy today and agree on what paper and pencil computation and manipulation algorithms can better be done by computers - our students are waiting for us!

Note: to obtain a complete copy of this article, contact Bert Waits at waitsb@math.ohio-state.edu