Chapter 4
Dynamical Mathematical Software:
Tools for Learning and for Research

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ABSTRACT
Understanding mathematical concepts is many-folded. Traditional mathematics mostly emphasizes the algebraic/analytical aspect of a problem with minimal reference to its graphical aspect and/or numerical one. In a modern learning environment, however, multiple representations of concepts are proving to be essential for the teaching of mathematics. The availability of user-friendly dynamical software programs has paved the way for a radical yet smooth way for changing the way mathematical concepts are perceived. This chapter presents some of the author’s attempts for employing innovative methods in teaching topics in calculus, in differential and difference equations. The focus is on the use of dynamical programs that boost the visual component of the topics being investigated, hence contributing to a more complete understanding of these topics.

INTRODUCTION
In the year 2000, the Standards of the National Council of Teachers of Mathematics (NCTM, 2000) acknowledged that multiple representations help students solve problems, support their understanding of concepts, and better communicate mathematical ideas. Consequently, mathematical visualization has become a core
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element for learning mathematical concepts. The advancement of technology has largely reshaped the teaching and learning of mathematics. It is now widely accepted that the strength of technology is mainly in its capability for providing greater and easier access to multiple representations of concepts (Kaput, 1992; Porzio, 1999), in particular visualizing mathematical concepts and ideas, and even sometimes abstract theorems (Pool, 1992). This chapter is intended on one hand to present some ways to exploit the dynamical feature of few mathematical programs so as to introduce and clarify concepts in calculus and in an introductory differential equations course. On the other hand, dynamical programs can also be used to conjecture and write proofs and thus may also be useful for research purposes. The chapter ends with an example showing how a dynamical software program created for a specific purpose can help conjecture new results for linear iterative systems.

BACKGROUND

Emphasizing the importance of mathematical visualization can be traced back to the early 1990s. The Mathematical Association of America published a note in 1991 on visualization in mathematics (Zimmermann, 1991). In this publication, Zimmermann, the Note editor, wrote: “Conceptually, the role of visual thinking is so fundamental to the understanding of calculus that it is difficult to imagine a successful calculus course which does not emphasize the visual elements of the subject” (p. 136). Even though Zimmermann targeted only calculus, research and practice have shown that visualization can be critical not only to add a new dimension to many topics in various fields of mathematics, but is also a mean for conjecturing and for writing proofs. The emphasis on visualization began at a time when technology was becoming more widely used in education; however, the technology employed was still more or less static except for few attempts. Reformers were using Maple, Mathematica but others were thinking ahead trying to explore the full power of technology. One cannot but refer to a pioneering dynamical software program called MacMath (see the reference to this software in other chapters of this book) developed at Cornell University by John Hubbard and Beverly West (authors of two other chapters in this book). With dynamic mathematical software programs, the benefits of a visual representation are doubled to say the least. According to Noss and Hoyles (1996, p. 245), when the algebraic representation is complemented with a dynamic environment, it “comes alive”. Such an environment therefore constitutes “a rich experimental arena: Students receive the feedback as a direct consequence of their actions and not as a judgmental statement from their teachers” (Arcavi, A. 2008). In addition, one should not undermine the role of the instructor in properly
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