Chapter 14

Teaching Basic Calculus Using SAGE

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ABSTRACT

This chapter presents an attempt to review basic calculus concepts to high school students with the help of a Computer Algebra System, namely SAGE. A review lesson on limits and derivatives as well as an introduction of the bisection method for finding roots of continuous functions is presented. The evaluation of the lesson by the students is analyzed. The aim of this chapter is to examine the power of SAGE in reviewing basic calculus concepts, presenting the advantages and disadvantages of SAGE compared to other Computer Algebra Systems, as well as the benefit from using a computer system in making concepts such as the squeeze theorem for computing limits of functions more clear.

INTRODUCTION

The use of Computer Algebra Systems (CAS) such as Mathematica (Mathematica Home Page), Maple (Maple Home Page), MATLAB (Matlab Home Page), DERIVE (Derive Home Page), MathCAD (MathCAD Home Page) and Magma (Magma Home Page) in teaching mathematics, has received a lot of attention during the last decades. These tools do not aid only in the learning process but have also been proven useful in finding new results in mathematics. However, the main problem with these tools is that they are commercial. This means that they are not accessible to all students and their source code cannot be examined in case of a new finding.

Recently, open source mathematical software named SAGE (from “Software for Arithmetic Geometry Experimentation”) (Joyner and Stein 2007; Erocal and Stein 2010; Stein 2011; Risse 2010; Finch 2011) has appeared as a free distribution over the Internet encompassing all the advantages of software developed by a wide range of programmers, available for inspection.
by anyone, and using almost all freely available mathematical packages.

Our aim in this paper is to examine the teaching process of basic calculus as well as the bisection method for finding roots of a function (Heath 2002) in a high school course using SAGE.

The rest of the paper is organized as follows: There is a section that performs a literature review on using Computer Algebra Systems for teaching mathematics. A section that describes, the selection of the specific mathematical material for the course, and justifies it, follows. Next, a section that describes the potential of SAGE and its advantages and limitations compared to commercial packages follows. The next section presents the course schedule that was followed in the conventional course as well as a detailed course schedule for the SAGE utilizing course, including a discussion of the process of the adoption of new mathematical concepts using this software. A section that concentrates on the evaluation of the course by the students participating in it is next. The final section provides some conclusions and future work.

LITERATURE REVIEW

The use of Computer Algebra Systems in Modern Education is commonplace nowadays. A lot of research has been devoted to examining the impact of these systems in the learning process of mathematics in the classroom.


Vlachos and Kehagias (2000) have evaluated the teaching of business calculus using MathCAD.

Kramarski and Hirsh (2003) have tested the process of solving equations in junior high school using traditional teaching an compared it to teaching using a computer algebra system.

Dana-Picard and Kidron (n.d.) describe a pedagogical process for examining the learning techniques assisted by a Computer Algebra System in the first year foundation courses of an Engineering College.

Brown (n.d.) provides us with an evaluation of teaching algebra in high school using a TI 92 mathematical computer.

Finally, Fuchs (2001) gives a restricted overview of the influence of Computer Algebra Systems in Mathematics Education.

SELECTION OF THE COURSE MATERIAL AND JUSTIFICATION

The course material selected included limits of functions, derivatives of functions and the bisection method, based on the Bolzano theorem (Apostol 1967).

The basic reason for selecting the specific material was that this material was already taught in a conventional course.

One basic reason for selecting limits and derivatives of functions for the course was the ability of SAGE to present illustrative plots of functions. Although a plot does not provide us with a proof that a mathematical function has a specific limit and/or a specific derivative, it can give us some intuition about this issue. The functions that were selected for illustration were functions that do not encompass smooth behavior and therefore plots of these functions may prove useful.

The reason the bisection method (Heath 2002) was selected for the course was the aim of introducing the students to algorithmic techniques in solving mathematical problems. Based on the repetitive application of the Bolzano theorem a basic algorithm for finding a root of a nonlinear function, introduced in almost all introductory Numerical Analysis books, was presented.
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