TEN YEARS OF MATHEMATICS REFORM AT THE LEBANESE AMERICAN UNIVERSITY: THE EXPERIENCE AND ITS IMPACT ON STUDENT LEARNING

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Ten years ago, few faculty members at the Department of Mathematics of the Lebanese American University (LAU) began implementing some level of reform in the teaching of mathematics, particularly the teaching of calculus and of differential equations. The importance of visualizing mathematical concepts and the abundance of specialized dynamical software were the main driving force behind the reform attempts. Since the reform movement was initiated, I have conducted various studies focusing mainly on students' acceptance of a qualitative approach for the learning of differential equations and also some key concepts in calculus. This paper summarizes the findings that have been collected throughout the 10 years and proposes means for improving student learning outcomes based on the LAU experience.

INTRODUCTION

The undergraduate curriculum in mathematics in general, and calculus and differential equations in particular, has undergone some important changes in favour mainly of the visual aspects of the concepts taught. To some extent, the emphasis on visualization is due to technological developments. Whereas in the past, calculus consisted mostly of a series of algorithms that students were asked to memorize, dynamical software programs provide the learner and teacher alike with unprecedented means to explore topics such as the derivative visually. It is now widely believed and accepted that visual thinking is fundamental to the understanding of calculus and that is difficult to imagine a successful calculus course which does not emphasize the visual elements of the subject (Zimmermann, 1991). In differential equations, a traditional course usually emphasizes analytical methods for solving first order equations. Being a core part of the curriculum in disciplines such as physics, chemistry, and engineering, it is often not the case that modelling produces a differential equation with solutions that are expressible in closed form. Hubbard (1994, p.372) had pointed out this discrepancy and added that "the search for formulas often obscures the central question: How do solutions behave?" It is well established now that technology adds a visual dimension to the teaching and learning of differential equations, thus allowing the learner to "read important information from these graphs, such as long term behaviour of the solutions and the existence of an equilibrium state" (Habre, 2000). The added benefits of using technology in the teaching of calculus and differential equations were the main driving force behind adopting curricula in these two courses at the Lebanese American University that emphasize the visual aspect of concepts whenever possible.

REFORM IN DIFFERENTIAL EQUATIONS

To initiate the reform in the teaching of differential equations, it was critical that an appropriate textbook be chosen. *Differential Equations* by P. Blanchard, R. Devaney, and G. Hall (2002) seemed to serve the purpose of the reform because its authors stress the qualitative approach for solving odes and often demand that outcomes be analysed (in writing). Simultaneously, it was important that the appropriate software be used in and outside the classroom. Thus ODE Architect was used for demonstration purposes because of its huge visual capabilities, while Interactive Differential Equations was used for homework assignments because it is designed as a set of 93 labs built each to offer a complete understanding of a particular concept. This reform curriculum has been in use at LAU since the year 2000 and many lessons were learnt from this experience.

The topic of differential equations is not entirely new for a Lebanese student. Indeed, first order separable and linear ones are discussed at the school level. However, students are taught recipe-style methods for solving such equations. At the college level thus, one notices a resistance of the new approach particularly in the early days of the semester. However, time has always proven to be crucial for the students to adapt to the qualitative approach. This is not to say that the approach becomes the students' first choice, nor is this saying that the concepts taught are more comprehensible because of the new teaching methodology. In fact, the many research studies conducted at LAU reveal to the contrary that students still prefer the traditional approach as is detailed below.

In traditional books, a differential equation is defined as an equation containing the derivatives of one or more dependent variables with respect to one or more independent variables. In contrast, the reformed textbook adopted at LAU introduces the idea of a differential equation by modelling a population growth problem. Predicting the future status of the population becomes the authors' main concern. In the case studies investigated at LAU, it was thus clear in the teacher's mind that the issue of modelling is fundamental, yet when pupils were asked to give their own definition of a differential equation, results show that most of them view the differential equation more in the traditional sense and rarely do they refer to the idea of a rate of change.

Another issue of major importance in a differential equation class is learning how to solve an ode. In a reformed setting, solving can be analytical but can also be visual through the sketch of a direction field. Yet students investigated faced the following dilemma: They are required to solve but unlike what they are accustomed to, the solution need not have an explicit algebraic form. Solving in this setting means in most instances drawing graphs of solutions and analysing them by writing about their increase, decrease, their long term behaviour, concavity, and the like. Research results show however that students do not adapt easily to this solution approach. A great majority of students prefer the algebraic approach. It is interesting to note that even when students do not remember the solution procedure, many still reject the geometric approach because they believe in the power of symbolic representation of the function solution. Only few students appreciate being able to draw solutions since it allowed them to analyse the meaning of the solutions, specifically when it modelled a real life situation. But the accuracy of the drawings seems to be of concern to them. The fact that solutions were drawn based on a slope field and not as the sketch of a specific function caused the students to doubt the solution process.

Writing in a reformed differential equations class is natural since in many a case, a student is asked to discuss and analyse the solutions obtained graphically. It is interesting to note that even though a majority of students prefer the analytic over the geometric approach, yet most of them agreed that writing was essential in such a course. Some reasoned that writing complements the geometrical approach while others argued that it was necessary for enhancing the learning (Habre, 2002).

REFORM IN CALCULUS

Calculus at LAU is a sequence of three courses, two at the freshman level and one at the sophomore. Most students of Lebanon enrol at the sophomore level and thus they already have the calculus knowledge covered in Calculus 1 and 2. Students who enrol in Calculus 1 are usually the weaker ones or those coming from abroad. For a reform to be effective, it is necessary to implement it at an early stage, thus reform was introduced in Calculus 1. The reformed book by Ostebee and Zorn (1995) was used and the important topic of the derivative was investigated. Because of the nature of the course, students were exposed to the idea of derivative in two different contexts: the geometric and the algebraic; however more time was spent discussing it as a rate of change and as the slope of a curve at a given point. Consequently, assignments request matching graphs of functions to the graphs of their derivatives, others inquire about the properties of a function given the graph of its derivative. This experimental class was only conducted once as its results were almost disastrous. While 41 students were initially enrolled in the class, only 25 remained at the end of the semester out of which 5 failed the course. The approach thus was not popular and perhaps difficult for the average and the weak students. The results however were not all very negative. There were some instances of success and this was reflected in comments collected throughout the semester. One student wrote: I really enjoyed the style of the course...It is not a memorizing style; it really justifies why something is being done. Another student stated that he had “learned about the derivative in my previous school days. We never drew graphs as much as we did this year...This course really enriched my knowledge about the derivative” (Habre and Abboud, 2006).

CONCLUSIONS

The first attempt to introduce changes in the differential equations curriculum took place in 2000. Since then, the course has been taught in a non-traditional way focusing on the qualitative rather than the quantitative approach. The students' good performance on exams (except for the first one) has always prompted me to continuously adopt this approach. A careful look however at their views of the course reveals that they have not always been satisfied with its learning outcomes thinking that they have not learned much. Students appear not to appreciate this learning method and seem to be nostalgic to the math they are used to. For this reason, it was recently decided to switch to the textbook by W. Boyce & R. DiPirma (2009) because it offers a more balanced approach between the qualitative and quantitative approaches. It remains to see if the new book fulfils the purpose for which it was chosen. As for Calculus, the high dropout rate in the experimental class prompted us to go back to the traditional way of teaching. However, the spirit of reform has always been in the backdrop of our approaches, and this has proven to be more effective.

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