To: Phil Pratt, Dean Kindschi, Provost Niemeyer, President Lubbers, The Research & Development Center, and the Library
From: Edward Aboufadel, Associate Professor, Dept. of Mathematics & Statistics
Re: Report on Sabbatical (fall semester 2000)

Introduction

The title of my sabbatical project was "Textbook Writing: More *Discovering Wavelets*".

Wavelets are a mathematical tool that has become quite popular this decade. Here are some examples of the many uses of wavelets: the FBI processes fingerprint images with them; a Japanese company has designed speech recognition software that use wavelets; data from earthquake research is analyzed with wavelets; advances in radiology make use of this powerful instrument.

Over the past few years, I have been developing my expertise in this area, to the point that Steve Schlicker (another member of my unit) and I have written a book that has just been published on the subject. This book, *Discovering Wavelets*, makes topics in wavelet theory accessible to undergraduates (along with others who do not have a Ph.D. in mathematics). In fact, Steve and I tested ideas for the book here at GVSU, in MTH 227 and 327.

In the process of writing the book, I learned a lot about both wavelets and its cousin, Fourier analysis. In more advanced books, wavelet theory is developed using a significant collection of tools from Fourier analysis. Because we wanted to make the book quite accessible, we did nothing with Fourier analysis until briefly at its conclusion. The purpose of this sabbatical was to allow me to make better connections between Fourier analysis and wavelets in my professional development, my teaching, and in beginning the writing of another book or an addition to our book.

What I Accomplished

In my sabbatical proposal, I set a timetable of activities that would make up my sabbatical. Here, I reproduce this timetable, along with commentary written in Arial Narrow font.

Pre-Sabbatical
November 1999 – May 2000: write a 15-page article on wavelets (with S. Schlicker) for the *Encyclopedia of Physical Science and Technology*.

> This article was completed in May 2000, and accepted for publication in August 2000. It ended up being 45 pages, rather than 15, and in the course of writing this article, certain misconceptions that I had about wavelets and filters were cleared up. The article will appear this year on the web site http://www.apnet.com/physical/

Winter Semester 2000: Teach MTH 400, a course that focuses on Fourier analysis and partial differential equations. Develop course materials there.

> I did teach this course during Winter Semester 2000. It was very useful to bring to mind the difficulties that students have in learning Fourier analysis.

Summer 2000: I will participate in an NSF-sponsored "Research Experiences for Undergraduates" program at GVSU, with my student and I working on a research project in wavelets.

> Two students – Amy Vander Zee of GVSU and Amanda Cox of St. Olaf College – completed a research project with me on wavelets. The project was halfway done by the end of summer, and a significant amount of time during my sabbatical of Fall 2000 was spent working with these students on the rest of the project. We are seeking a place to publish an article about our work, and a preprint of our results is available online at: http://www.gvsu.edu/mathstat/wavelets/undergrad.htm

Sabbatical

September 2000: create outline for manuscript. Begin first part of manuscript introducing Fourier analysis. Included in this work is a day-long trip to the library at Michigan State.
October 2000: Finish draft of first part of manuscript. Begin second part of manuscript on connections between wavelets and Fourier analysis.
November 2000: Finish draft of second part of manuscript. Included in this work is a day-long trip to the library at Michigan State.

> Originally, I had expected the manuscript to be about 30 pages. However, by the end of November, I had written 50 pages, and the manuscript was only about 60% complete. I basically completed the first part – the introduction to Fourier analysis – and started the second part – the connections between wavelets and Fourier analysis. The first part is much longer than originally planned, because during my sabbatical I undertook at deep study of *quantum computing* and the *quantum Fourier transform*. I was first exposed to these topics in 1996, but it was only during my sabbatical that I reached a point where I really understood them.
>
> I traveled to Michigan State once during the fall to do research at the libraries there. Selected pages from my writings this fall are attached to this report.

December 2000: Write second draft of manuscript, after soliciting comments from members of my unit (e.g., S. Schlicker and M. Boelkins).

> During fall semester, S. Schlicker conducted an independent study course with four students on wavelets. During the final two weeks of the semester, they read about 20 pages of my manuscript, and worked through the problems in those pages. I received comments from S. Schlicker that I have incorporated into the writing. Clearly, more of this type of review will be necessary.

Sometime during the semester: attend a conference on wavelets.

At the end of October, I traveled to Yosemite Park, California for a 4-day conference on connections between wavelets, multiresolution methods, and partial differential equations. The conference consisted of a series of talks by well-known researchers in these areas. I received a grant from the FTLC to go to the conference (see account of financial remuneration below), and in my report for that grant, I wrote the following:

> My goal in attending the Symposium was to learn about new applications of wavelets and Fourier analysis to include in the new chapter. I also was seeking ideas for our NSF-sponsored Research Experience for Undergraduates program that we expect to run during summer 2001. Both goals were met, as I came home with several pages of notes and ideas for the book and the REU program, along with a 400-page book of collected lecture notes that were distributed on the first day of the Symposium.
>
> Some of the ideas that I brought back are:
> - Determining why Japanese bullet trains are too loud using partial differential equations.
> - Determining the electrical field on the surface of the heart by using skin electrode data with partial differential equations.
> - Cleaning up astronomers' radio images of stars and galaxies by using wavelet methods.
> - Analyzing EKG/ECG waves with wavelets or Fourier analysis.
> - A concrete understanding of the connections between filters, convolutions, and wavelets.
> - A new type of wavelets called "ridgelets" that would be a good topic for the REU.
>
> This state-of-the-art information will find its way into several GVSU courses over the next few years, including MTH 380 (a special topics course in wavelets), MTH 400 (our PDE/Fourier course that I have been assigned to teach winter 2002), MTH 227 & 327 (the Linear Algebra courses where *Discovering Wavelets* got started), and MTH 496 (our Senior Thesis course).

Post-Sabbatical

Continue working on improving the manuscript during 2001, with an expected completion date of August, 2001.

Fall 2001: Teach MTH 380 (Special Topics Course in Wavelets).

These items go together. I am scheduled to teach MTH 380 fall semester 2001, and I will have a completed manuscript done before that time. This course will be of interest to mathematics, engineering, physics, and computer science majors.

Account of financial remuneration

For my travel to California, I was reimbursed $650 from the Department of Mathematics & Statistics, and $700 from the Faculty Teaching and Learning Center. Of course, I also received full pay during my sabbatical.

Attached

Pages from “Enter, Fourier …”, which is the name of my manuscript.