The Calculus&*Mathematica* Project

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The Calculus&*Mathematica* project began at the University of Illinois in 1988 when Horacio Porta and Jerry Uhl first saw *Mathematica* and decided that the living textbook envisioned by Jacob Schwartz could be realized. From the beginning, the project has been primarily concerned with the teaching of calculus. All content and design decisions are based on the fundamental question: "What does this have to do with a student's learning of calculus?"

William Davis entered the project by encouraging Porta and Uhl to define calculus, and hence, to both limit and expand the scope of the project. Here is that definition:

Calculus coalesced as a coherent body of knowledge when Isaac Newton announced the fundamental theorem of calculus. C.H. Edwards, in his book *The Historical Development of Calculus*, states:

The contribution of Newton and Leibniz for which they are properly credited as the discoverers of the calculus was not merely the fact that they recognized the "fundamental theorem of calculus" as a mathematical fact, but that they employed it to distill from the rich amalgam of earlier infinitesimal techniques a powerful algorithmic instrument for systematic calculation.

Thus, while arithmetic is the introduction to the science of counting, calculus is the introduction to the science of measurements—both exact and approximate. This is why with Calculus&*Mathematica* students are asked to think of calculus as a toolbox of measurement devices. Calculus&*Mathematica* consists of learning what the tools are and how to use them.

Calculus&*Mathematica*—A Lab Course

Calculus&*Mathematica* is a lab course. We do not lecture. We treat Calculus&*Mathematica* as a shared challenge for both faculty and students. Students are given lessons and assignments, and they spend their time in a lab working on the lessons, asking questions, and sharing insights with their peers. We see students working during their assigned class time and for another hour or two each day. The center of the course is the "Give It A Try" problems. Everything is there: the experiences introducing ideas and topics, the challenges to intellect and patience, the excitement of beating the course, and solving a very difficult problem.

The course is presented to the students as *Mathematica* Notebooks. Each Notebook is broken into three principal sections: "Basics," "Tutorials," and "Give It A Try." The Basics and Tutorials contain the first worked examples that lead the students to the content of the Notebook. Since these are *Mathematica* Notebooks, students are free and encouraged to modify the

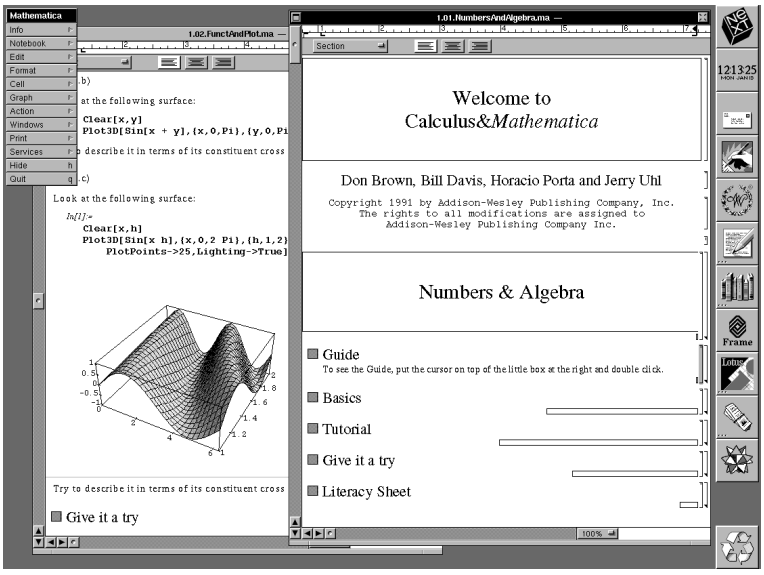

Figure 1 *Calculus&Mathematica is a one-year course taught in a laboratory setting. Lessons are in 60 Mathematica Notebooks that students complete at a rate of two per week.*

examples presented there in order to attempt to discover the principles involved. The Give It A Try problems lead the students through experiments that ask them to discover and apply basic principles of calculus. They play, conjecture, test conjecture, play more, and almost always come to the correct conclusion.

One of the basic design principles of the course is that it must run with off-the-shelf *Mathematica*. As a result, there are no added gimmicks or toys that employ other software or operating system features. Furthermore, we strongly believe that mathematics is anything but a spectator sport. No one learns mathematics by simply watching it. Therefore, we do not provide the students with an array of animated secant lines, or rolling wheels, or orbiting planets.

The project is supported at both the Ohio State University and the University of Illinois by the National Science Foundation. This year, Calculus&*Mathematica* runs at more than 20 institutions. Of those, half use NeXT computers.

Advantages of NeXT Technology for Mathematics Instruction

We chose NeXT computers for our new lab for several reasons. Primary was the value-per-dollar of the machine. All of the features in common use in a lab situation come with NeXT. The critical software—*Mathematica*—is bundled along with T_EX, and NeXTmail. Built-in, easy-to-use-and-maintain networking is also essential for a learning lab. NeXT includes the physical Ethernet connections as well as NetInfo, NFS, and TCP/IP for file and traffic management.

Our experiences on other platforms has led us to using computers with a friendly user interface, easy networking, true multitasking, and virtual memory. We are quite pleased with the fact that the NeXT machines are so fast.

Furthermore, in Calculus&*Mathematica*, students frequently compute complicated graphic images of surfaces. We know that such images must be computed and recomputed before one is happy with the results. This process is exaggerated with students. NeXT machines saves students enormous time in completing their homework.

We are also happy that students are no longer required to carry floppy disks. We are finally able to tell students that all their work will be preserved on our network. Other platforms provide irritating features in which students must carry their own work with them on floppy disks. Inevitably, the floppy disks fail, students forget to save their work to their disks as they leave the lab, they forget to bring their disks to class, and so forth. Students now receive their lessons from the lab's server, and turn in homework via NeXTmail. Now, faculty can sit at remote machines with the lab's server mounted to grade. That was not possible in the previous labs.

For more information about the Calculus&*Mathematica* project, please contact:

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William J. Davis is Professor of Mathematics at The Ohio State University. He received his B.S., M.S., and Ph.D. degrees in Mathematics at Case Institute of Technology, his Ph.D. in 1965. He has been on the faculty at Ohio State since 1964, except for sabbatical leaves in Jerusalem, Israel, Cambridge, England, and France. His research interests have centered around geometry of Banach spaces, with particular recent interest in vector valued probability and harmonic analysis. His teaching interests have ranged throughout the mathematics curriculum, and he has been deeply involved in the honors curriculum, experiments in teaching calculus with hand held, programmable calculators, Socratic methods in Real and Functional Analysis, and so forth. For the past two-and-a-half years, his passion has been the teaching of calculus with the aid of Mathematica.