Teaching High School Mathematics over a Network with *Mathematica*

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Abstract

Many reports studying the use of *Mathematica* in the teaching of high school mathematics have been published. The majority of these reports focuses on the benefits of using *Mathematica* in the classroom. For example, the use of *Mathematica* enables students to perform complicated calculations, make assumptions and predictions based on the results derived from these computations, and then verify their findings. This represents a rather experimental method in mathematics instruction. Before the advent of *Mathematica*, students who were not proficient in calculations spent a majority of their time performing the computations, and very little time analyzing and processing the results. However, with the aid of *Mathematica*'s computational power, students can now focus on and enjoy the thinking and analytical part of the process– something which is completely independent of their ability to calculate. In this respect, *Mathematica* is a powerful tool for studying mathematics, especially useful for those students whose strength lies not in their computational capabilities. In this article, we will introduce the networked *Mathematica* system and how , in its development, we focused on its ease of use in classroom instruction.

Math Education in Japan and the Role of Mathematica

Before computer programs such as *Mathematica* were available in Japanese high school classrooms, students were trained to manually calculate the given expressions as fast as possible. Students were forced to group math problems into known categories and then apply formulated methods to solve the equation in a given period of time. While this method is not conducive to developing analytical thinking in math education, it is widely used by Japanese teachers in an effort to prepare their students for university entrance examinations.

With the advent of *Mathematica* in the classroom, we are hoping to change this method of thinking and mathematical instruction. High school education relies heavily on "trial and error" reasoning, and with the use of *Mathematica*, we can continue along that line of thinking. *Mathematica* allows students to take a large amount of data and then critique and analyze the results. While we believe that the use of *Mathematica* in the classroom is nothing short of revolutionary, some concerns have been expressed. Some educators argue that the use of *Mathematica* and other computer programs will lead to a decline in the students' ability to manually perform basic mathematical functions. This is certainly a valid concern if a student who has not yet grasped the understanding of basic principles of calculus and laws of computation is relying solely on the use of *Mathematica* for his mathematical needs. However, for students who have mastered calculus and have considerable computing skills, *Mathematica* becomes an ideal aid in further enhancing these abilities and then mastering the technique of analyzing the results.

Problems with Using Mathematica in the Classroom

In *Mathematica* version 3.0 and later, we can use palettes. The most common request from students when applying Mathematica in a classroom to avoid typing at all cost. Even though a palette such as BasicInput is available, most novice computer users have difficulty using it. This is a key in introducing Mathematica to a classroom since there is a wide range of computer experience among students. Although the palettes facilitate the students' ability to input expressions, they also lack flexibility. No matter how carefully a teacher prepares the lesson plan for the day, activities rarely go as planned. Teachers frequently need to rearrange their lesson plans and materials so as to accommodate how well the students are learning the material, any questions they may have, and the possibility of repeating examples. Similarly, while we can carefully set up the *Mathematica* program like courseware, it is impossible to prepare a complete set of palettes that would cover all bases and completely prepare us for any diversion from the programmed plan. Moreover, in addition to the palettes, the program also requires a mechanism which enables active interaction in the classroom.

Network based Mathematica

One of the methods used to reduce the students' key typing is to distribute a prepared Notebook. For example, students can download the notebook from a website. Students are expected to do "trial and error" by changing the parameters of the function as described in the Notebook. However, this is no better than from using courseware. The problem is that this doesn't allow for interactivity. The teachers cannot design and present Mathematica functions in real time. To help correct this problem, we developed a networked-based *Mathematica* system. This system facilitates the communication during *Mathematica* sessions by letting each participant work with his own copy of *Mathematica*. Participants can also exchange *Mathematica* expressions over the network. The teacher can broadcast instructions to the students, which in turn the students will read and respond to, and then both teacher and students can join together in a live discussion on a topic of choice from within their *Mathematica* session.

The System configuration

The following experiment was done in an actual math classroom over a local area network (Fig. 1). The usage of this system is easy. Simply install Serializer to both clients and the server.

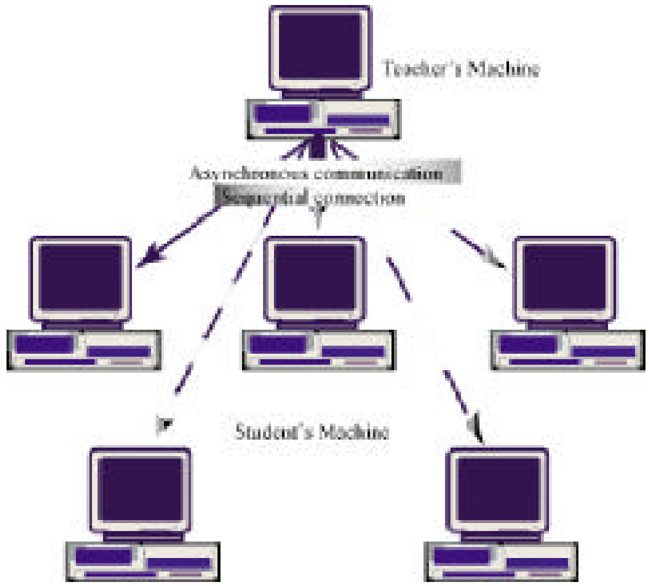

Fig. 1 System configuration

Serializer is a MathLink program we developed that is designed to enable *Mathematica* to *Mathematica* asynchronous communication. If the package is successfully read, two Notebooks are automatically opened (Fig 2) in Mathematica. On each client system, the Blackboard notebook and the Discussion notebook are opened. For students, a button appears that lets them post (broadcast) messages to the Discussion notebook. For the instructor, the same notebooks appear, but with an additional button to post messages to the Blackboard notebook. The Broadcast notebook will receive broadcast from the server machine which is accessed by the teacher. The discussion notebook is where students and teachers will write their respective opinions during the *Mathematica* session. The messages written on the local notebook will reflect the opinions shared during the classroom attendances. Expressions broadcast and/or submitted automatically appear at the bottom of the destination notebook. Because these expressions are broadcast in *Mathematica* format, students can copy and paste them, and evaluate cells directly on the their systems.

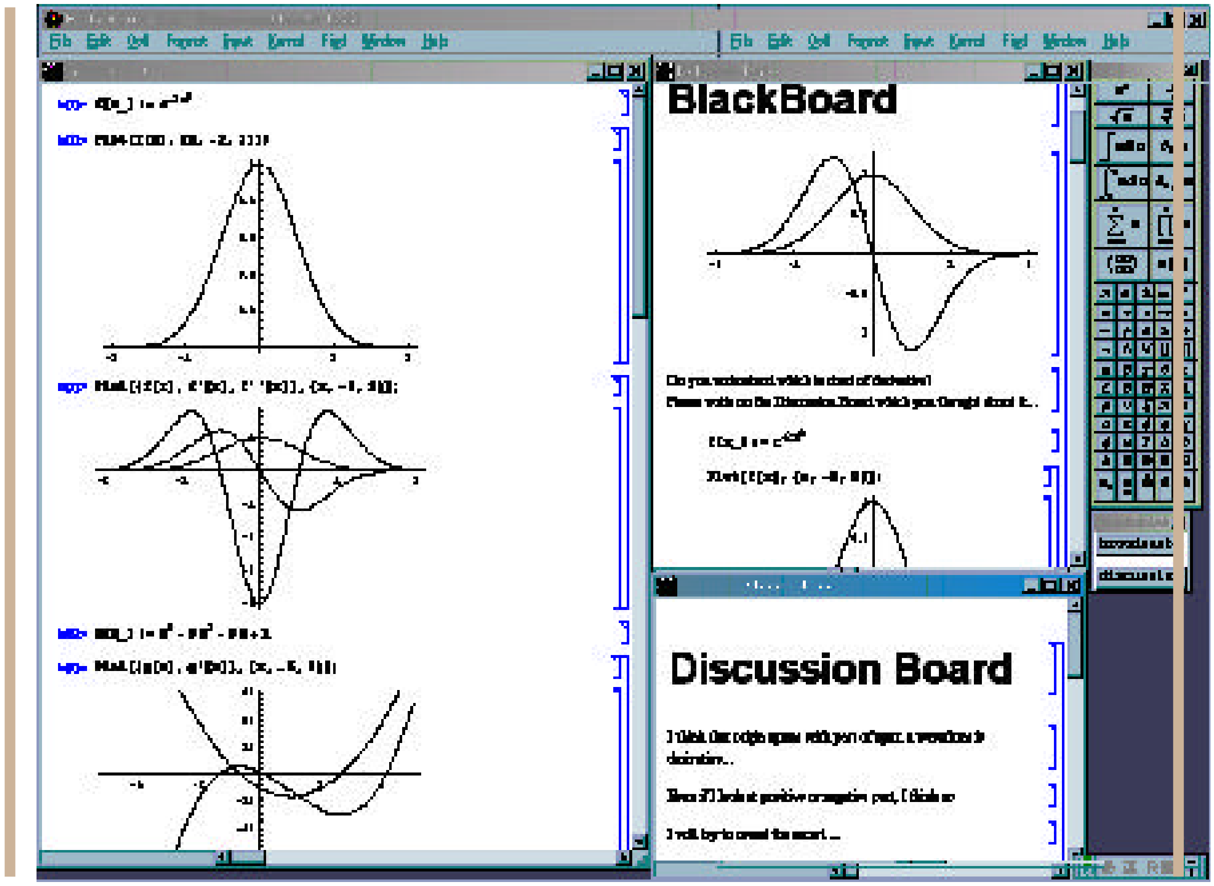

Fig. 2 Screen image

Experimentand

In this experiment, we prepared six machines (Pentium 400 MHZ, 64 MB RAM, 100Base Ethernet connection). One machine was for the teacher (server), and the other five were for the students (clients). All machines were connected via 100Base Tx. The experiment was performed in a junior-level calculus class.

The result

The students' impressions of this system were as follows:

1) The class was easy to understand

2) The system was easy to use

3) The system aids in critical thinking without disturbing the students ' pace of learning

Upon analyzing the students ' impressions, it appears that they do their job well with this system and that the simplicity of the program doesn't slow down or negatively affect the students' learning pace. Some of the comments received were, "the material was easy to understand," "the input takes less time,” and “I can take time digest the problem.” One reason for ease of understanding the material is that, using this system, students did not need to manually type in the expressions themselves and made differences in typing ability irrelevant. They were all able to follow the class equally. Based on this experiment, we believe this networked Mathematica system is an effective way for even novices to learn the operation or inputting functions.

Problems

However, during this experiment, the system’s weak points were obvious. These include the speed of message transfer and the system robustness. It took about 10 seconds to send the selected cell from the server to a client. Spreading the selected cell from the server to all clients to complete the broadcast took about 30 seconds. While this may not seem significant, it becomes more obvious when on a restricted schedule with limited time, such as an hour-long math class. Even in smaller classes with fewer clients, such as in this experiment, the transfer cannot keep up when heated discussions begin. Moreover, if the server-client link is lost, the system cannot resume unless rebooting both server and clients. These are problems that we are in the process of trying to fix.

New concept to math education

This system has the potential of being used for distance learning beyond classrooms. Mathematica based communications mainly involve exchange of functions over a general TCP/IP network (AppleTalk and file map protocol are also available). Therefore, the system can easily be extended to cover a WAN. The clients receive the functions and evaluate them on their machine. Functions take less space and therefore it enables smooth communications with distance learners (for example, consider sending GIF images of sin(x) and Plot[Sin[x], {x, 0, Pi}] over the Internet). Utilizing *Mathematica* as not only a symbolic computing system, but also as a computer terminal, it will create a whole new concept to math education.