Teaching Mathematics (TM) Course – Teaching Experience for Undergraduate Students

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The Practice: Introduction

The project "Teaching Mathematics" (TM) was designed at McMaster University in an effort to improve the quality of teaching delivered by teaching assistants. This course is related to the first-year introductory science calculus course ("Calculus I" 1900-2000 enrollment,883; 2000-2001 enrollment,

Instruction in Calculus I consists of lectures (3 hours per week), tutorials (one hour per week) and computer labs (five per term). Teaching assistants are in charge of in-class tutorials. Traditional use of graduate students as teaching assistants has been a source of frustration for several reasons. Since the Mathematics and Statistics Department does not have a sufficient number of graduate students, teaching assistants for first-year math courses have been "borrowed" from other departments.

Generally, the "borrowed" graduate students tried to minimize the time spent doing tutorials and other teaching-related duties, in order to devote maximum time to their studies and/or other paid employment. They would often come to tutorials unprepared, their performance resulting in numerous serious calculus errors. Their inability to handle conceptual questions was alarming.

Communication between a lecturer and teaching assistants was reduced to e-mail, leaving few opportunities to monitoring teaching assistants' performance. Additionally, more than half of the graduate teaching assistants in successive terms had significant problems communicating in English, even in the context of a fairly limited vocabulary of mathematics.

"Teaching Mathematics" Course Project

Preparing for the 1999/2000 school year, the instructor decided not to use "borrowed" graduate students as teaching assistants. Instead, we interviewed undergraduate students until we had 22 students who met the following criteria: currently enrolled in 2 4^{th} year of undergraduate science program; had achieved a course grade of A- or better in Calculus I and Calculus II; had satisfactory performance in their other course work as determined by their cumulative average; and, most importantly, were deemed to have an interest and aptitude for teaching. We will refer to these students as "undergraduate TAs" or just as "TAs."

To provide a context that would allow us to integrate the TA's into the Calculus I easily and efficiently, the instructor organized a new course called "Teaching Mathematics" (TM). The students who were selected as TAs had to enroll in the TM course.

The TM course had two components: practical ("hands-on") and theoretical. The TM semester started with a session where principles of good teaching practice were outlined and discussed (preparation, attitude, personal aspects of teaching, communication issues, blackboard technique, time management, etc.). This introductory session was followed by intense training sessions during the first week of classes where TAs would take turns presenting a Calculus problem and discuss how best to approach teaching the problem. The help and advice from experienced ("older") TAs proved to be very valuable. The final session of the first week, before the TAs were sent to do their first in-class tutorial, provided the instructor with an opportunity to address logistics, to summarize most important issues related to teaching and to provide support and encouragement.

Weekly group discussions in the TM course provided a constructive atmosphere for discussing, analyzing and monitoring TAs' work - thereby modeling the principles of good instruction for the TAs to emulate with their own students. TAs were asked to write a self-evaluation (three times during the term); each time they were asked to identify their strengths and weaknesses and construct plans for improvement. Next, in small groups, they discussed the issues that they raised in their evaluations, and then revisited their individual evaluations. Finally, the instructor conducted personal interviews with every TA, to get a better feel of their performance in class and also to give encouragement and suggestions for improvement.

The heaviest emphasis in terms of elements that constitute a good teaching practice in (not only) mathematics was placed on preparation of mathematics material and communication skills. In TM sessions, we would take a problem and break it down into “smallest pieces”: we analyzed every aspect of it, anticipated every possible question students might have, considered and discussed alternate approaches, explanations and solutions. Very specific issues were dealt with, such as: how to explain a definition; how to discuss a theorem or a formula; how to explain the difference between evidence and proof; how to approach a conceptual question; how to construct examples and counterexamples, etc. That way, TAs got a really good feeling about how to prepare well for their tutorials. They soon realized that benefits were far reaching - they were discovering a way to properly study mathematics!

A significant part of the TM course was devoted to the improvement of communication of mathematical content. Each TA was required to chose a topic in mathematics and present it orally in the TM class. A presentation was followed by a question period, that would usually force a presenter to reformulate or clarify something they said. TAs were asked to write about mathematics, their essays covering a wide range of topics. Several TAs kept diaries of their mathematical activities during the term. In-class discussions on communication focused on our attempts at learning what our students really learn when we teach them calculus. We tried to understand how the learning process functions. TAs were warned against committing the most common error in teaching - immediately producing “the correct answer” to a question from their audience. Instead, they were encouraged to act as discussion facilitators, strengthening the view that education is not a product of one mind, but a product of a communication of minds.

The TM course also provided an insight into other (e.g. theoretical) aspects in teaching and learning mathematics. Topics discussed in class and covered in written essays ranged from mathematics curriculum reform issues and “classical” vs. “reform” calculus battles, to introduction of the concept of math anxiety and exploration of history of instruction in mathematics. Also, a guest lecturer led a discussion on “deep” vs. “surface” learning in mathematics.

Calculus I students’ responses were surveyed on an in-class paper survey to ascertain their responses to the TM teaching assistants (response rate of 72% or n= 639/883). The students’ overall rating of the tutorials was positive (mean = 5.8, median = 6) on a seven-point Likert-type scale (all scales: 7 = excellent, 1= poor). Ratings on TA communication and approachability were 6.2 (median =7) and 6.4 (median = 7) respectively while ratings of TA explanations of basic math and Calculus concepts both had means of 5.7 (median = 6). High students’ overall tutorial rating was statistically significantly associated with a higher Calculus course grade ($p = 0.01$, CI 0.012 to 0.50). Also teaching assistants’ TM course grades were associated with a higher student evaluation of course elements such as communication, preparation, explanation of basic and calculus mathematics concepts ($p<0.01$ for all listed domains). Therefore it would appear that improved teaching assistants’ performance had a positive impact on the students’ experience of the tutorials and contributed to improved student Calculus grades.

Epilogue

Undergraduate TAs established a productive and mutually beneficial communication with their students that has not been witnessed when graduate teaching assistants were involved. Calculus students felt less intimidated with undergraduate TAs, and were not afraid to approach them: a communication started during a tutorial sometimes continued elsewhere on campus. Each TA was asked to write about her/his personal perspective on learning mathematics; their responses were posted on the web page for the

course, for all calculus students to read and reflect.

After successful completion of the TM course, several TAs who expressed interest were used as teaching assistants for other math courses were used as teaching assistants for other math courses. Moreover, they are allowed to repeat as teaching assistants for Calculus I. The TM course gave them a breadth of experience in teaching and learning mathematics (history, communication, delivery styles, group work, etc.). For some, it strengthened their decision to pursue mathematics as a career. Skills that they acquired (communication, organization, time management) are certainly valuable in contexts outside mathematics. The TM course project continues … the course is running again in the fall 2000, for a new batch of undergraduate students.

References

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4. Wood, T. (1999). Creating a Context for Argument in Mathematics Class. *Journal for Research in Mathematics Education,* Vol. 30, No. 2, 171-191.

Guiding Principles Behind the Practice

The common teaching-assistant/student interaction model of "question from the student - answer from the teaching assistant" gives the teaching assistant a distorted view of what constitutes teaching and does not sufficiently enhance the student's learning of mathematics. Learning mathematics can be facilitated through ongoing discussion which encourages self-reflection, opportunities for self-correction, peer support and synthesis of concepts. Encouraging teaching assistants to move out of the didactic teaching mode, so that they can be oriented toward being discussion facilitators is the intent of the "Teaching Mathematics" course described in this paper.

- First-hand experience in teaching motivates teaching assistants to learn more about mechanisms of learning, various teaching techniques, etc.

- Two most important principles of good teaching practice (in mathematics, and elsewhere) are preparation (i.e., knowing the material well) and communication (i.e., ensuring the message is clearly delivered and understood).

Sources of Inspiration or Influence for the Practice

Studies in mathematics education emphasize that students need to learn mathematics the same way mathematics researchers do - by proceeding in a non-linear fashion: asking questions, exploring concepts and ideas through discussions with others, by connecting concepts coming from different areas, etc. [Ref. 1-4]

Frequently Asked Questions About the Practice and Responses

1. How were the students marked in the TM course?

   Course evaluation was done using a learning contract that each teaching assistant (TA) designed themselves by assigning weights to the following elements: written review of a journal/newspaper

article, written book review, oral presentation on a math topic, keeping a journal of TA activities, attendance and participation in class, and in-class performance as a TA.

2. Do undergraduate TAs know enough mathematics to be able to teach well?

   Yes - first of all, they are required to review material in depth (attending lectures is optional). In each TM session teaching assistants are given a list of sections they will be discussing in their tutorial, brief overview of the material and hints/suggestions on important issues. To further deepen understanding, a problem is chosen and analyzed in depth (both from mathematical and pedagogical viewpoints). Moreover, TAs know that they are not required to produce a correct answer immediately, but rather to act as discussion facilitators. In that sense, they can count on help coming from their audience if needed.

3. How did the Calculus I students respond to the TM teaching assistants?

   It would appear that improved teaching assistants' performance had a positive impact on the students' experience of the tutorials and contributed to improved student Calculus grades. Calculus I students were surveyed with very positive responses as discussed below.

For More Information (References and Links)

Math 2U3: Teaching Mathematics provides additional information on the TM course project. It also contains handouts and students' critiques of journal/newspaper articles and book reviews.