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The professional development of graduate mathematics teaching assistants

Gary Harris[a]*, Jason Froman[b] and James Surles[a]

[a]*Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX, USA;* [b]*Department of Mahematics, Lemesa High School, Lemesa, TX, US*

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There is significant interest around the world in all issues involving the recruitment and retention of students in mathematics and sciences at all levels. Because of this there is great need for programmes that focus on providing well-prepared and effective teachers of mathematics and science at all levels. In this article, we present sample programmes in the US that focus on the professional preparation of mathematics graduate student teaching assistants. We give a detailed description of one such programme along with an assessment of its effects on the graduate students' teaching practice and philosophy.

Keywords: graduate teaching assistants; professional development; mathematics

1. Introduction

In response to the increasing need for a technically literate workforce, the US has commissioned several studies addressing the pressing need to recruit and retain larger numbers of students in science, technology, engineering and mathematics (STEM) related fields [1–3]. These studies have concluded that to have students who have the interest and the necessary educational backgrounds to pursue STEM areas, we must 'insure that students are taught by well-prepared and highly effective teachers' [2, p. 20]. Following the recommendations of these studies, the US has initiated several major programmes to recruit and retain primary and secondary teachers in STEM areas, primarily science and mathematics. One such initiative is the Math Science Partnership (MSP) programme initiated in 2002 and funded through the National Science Foundation (NSF). Projects in the current MSP portfolio (2002–2007) are expected to impact more than 141,500 science and mathematics teachers and 4.2 million students in more than 550 local school districts. Since its inception, MSP has funded 89 projects [4]. These projects are devoted primarily to the professional development of pre-service and in-service primary and secondary school teachers in mathematics and science. In 2006 alone, the US Department of Education (DOE) and NSF spent over $480m on STEM education projects [3].

With all the efforts to get more students into the STEM pipeline at the primary and secondary levels, it makes sense to do everything possible to guide them to a successful conclusion in the STEM areas at the tertiary level. However, compared to the primary and secondary levels, relatively little attention has been paid to the relationship between teacher qualities and student learning and interest at the tertiary level. The basic

*Corresponding author. Email: gary.harris@ttu.edu

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assumption seems to have been that if the instructor has sufficient content knowledge then he/she can teach that content to students [5]. Only within the last few decades have significant studies been directed at the professional development of teachers at the tertiary level [6–8]. The primary focus in the US has been on providing professional development opportunities for new and future faculty members. Notable examples are the Mathematical Association of America (MAA) Project NExT programme with focus on new faculty members and the Preparing Future Faculty (PFF) programme with focus on graduate teaching assistants (GTAs) [9,10]. The selected reading *Preparing the Professoriate of Tomorrow to Teach* (*PPTT*) provides an excellent historical perspective on the origins of GTA professional training programmes at universities in the US [6].

Of course, the US is not alone in this regard. Perhaps with less focus on the STEM areas and with somewhat different motivations, countries around the world began to pay more attention to teaching and learning at the tertiary level. A comprehensive discussion of such efforts is reported in a study of the International Commission on Mathematical Instruction (ICMI) [7]. Two particular programmes showcased in the ICMI study are relevant here. One is the Centres d'Initiation a l'Enseignement Superieur (CIES) for the training of *moniteurs* [11]. The nearest counterpart in the US would be the advanced GTAs. The challenges encountered in developing and promoting the moniteurs professional training programme in France are not dissimilar to those encountered with such training programmes for GTAs in the US and many of the PFF initiatives have similar goals to CIES. The Institute for Learning and Teaching (ILT) in the UK is another programme of note [12]. The ILT is a nation-wide programme designed to support the professional development of the existing professorate. Possibly the nearest counterpart in the US would be the MAA Project NExT programme. Both the CIES and ILT programmes are not discipline specific, but do have components directed at mathematics and sciences.

At the same time as these initiatives are going on, the cost of education at public universities in the US is increasing significantly with tuition and fees alone increasing at an annual rate 4.4%, after being adjusted for inflation, for the last decade [13]. Thus public universities in the US are under great pressure to cut costs, and a primary way to cut cost is to have more classes taught by adjunct (part-time) instructors and by GTAs [14,15]. There is, however, evidence that a student whose first class in a particular content area is taught by an adjunct instructor or by a GTA is less likely to pursue more classes or choose to major in that content area than is a student whose first class is taught by a full-time faculty member. This is especially true in the hard sciences [14]. Unfortunately at most public universities in the US, most of the first classes in the content areas are taught by adjuncts or GTAs [14,15]. In fact, a significant percentage of all lower division (first- and second-year) courses, at doctoral-degree-granting universities in the US are taught by GTAs [16]. Moreover, there are indications that such reliance on GTAs will only increase in the US for the foreseeable future [17].

There is great need around the world for professional development programmes that focus on providing well-prepared and effective teachers of mathematics and science at the tertiary level. In the US, such programmes are particularly important for part-time instructors and for GTAs. To refer to the education system in the U.S as decentralized would be an understatement. Thus, effective professional development programmes for faculty members (including part-time and GTAs) in the US are likely to vary greatly from one university to another, even within university systems. This is evidenced by the variety of sample programmes described in *PPTT* [6, pp. 111–219].

In this article, brief descriptions of a sampling of the GTA training programmes described in *PPTT* are presented with particular attention paid to professional

development of mathematics GTAs. Next follows a detailed description of a graduate-level professional development course for mathematics GTAs at a large, public, doctoral degree granting university in the southwestern part of the US. Finally, an assessment of the effect of the course on the mathematics GTAs' attitudes and practice is provided.

2. Sample GTA training programmes

2.1. *University of Washington*

The GTA training programme at University of Washington (UW) originally placed significant emphasis on institutional culture (values and assumptions) with primary responsibility for GTA training placed within individual departments [18]. The Math Department's current training programme includes a great deal of material that is specifically oriented towards teaching math courses at UW. It is a 1-week programme conducted prior to the start of Fall classes and is required for everyone who will be employed as a GTA in the Math Department. In addition to providing practice in basic teaching techniques, it introduces essential information about the content and structure of calculus and pre-calculus courses at UW and also involves discussion groups and observation of video tapes. Most training sessions are organized in 'mentor groups' of new GTAs all assigned to the same course and led by an experienced GTA mentor (counterpart of the French *moniteur*). The mentor meets and talks with, and observes the new GTAs throughout their first quarter in the classroom. All GTAs who are teaching their own sections of courses they have not previously taught must register for a one-credit 'teaching internship' that pairs the GTAs with experienced faculty advisors, usually teaching the same course at the same time [19].

2.2. *Ohio State University*

The initial GTA development programme at Ohio State University (OSU) focussed on the question of whether to organize a centralized, university-wide workshop, or work within and through individual departments. The result was the creation of a campus-wide 2-day workshop during the week prior to the beginning of Fall classes. Departments are given three options involving varying levels of GTA participation [20]. The Math department currently offers two summer 3 credit-hour courses, one titled 'Seminar in Teaching College Mathematics for International Graduate Students' and the other 'Seminar in Teaching College Mathematics for Domestic Graduate Students.' The implication is that one of these is required of all new GTAs; however, this is not explicitly spelled out on the departmental website, nor are any course details provided [21]. However, a 1999 departmental committee report concluded that modifications were needed in the GTA training programme. In particular, the report recommended changing lower division course content and structure to emphasize more active student participation, hence requiring modification in the GTA training to provide them the necessary capabilities to teach these courses. In particular the committee recommended more active participation by experienced GTAs as an aid in training their peers [22].

2.3. *University of Michigan*

For the University of Michigan (UM) GTA training programme developers envisioned an year-long programme of workshops, seminars, speakers, individualized consultation and

classroom observation, and, at its core, a one-credit (18 contact hours) course required for all new GTAs in the College of Literature, Science and the Arts. The course took the form of 6 weekly, 3 h seminar sessions. Each weekly seminar was devoted to a particular topic: week 1 to university culture and GTA/Faculty relations, week 2 to instructional methods, week 3 to microteaching, week 4 to diversity and multicultural issues, week 5 to active learning issues and week 6 to testing and grading [23]. The Department of Mathematics currently offers a Seminar on Teaching Mathematics that appears to meet four or five times each Fall and Winter term; however, there is no indication that GTAs are required to participate. The department offers a course called GSI Training (Graduate Student Instructor Training) but there is no course description provided and no indication that GTAs are required to take it. Indeed, the department website offers no information about departmentally initiated GTA training requirements [24].

2.4. *Carnegie Mellon University*

The developers of the GTA training programmes at Carnegie Mellon University (CMU) envisioned creating programmes tailor-made to address the needs of individual departments, with the underlying assumption that 'incorporating a teaching component into the curriculum should not delay progress towards the degree beyond the normal time limits'. This meant that programmes would have to be class-intensive and require little outside-of-class preparation on the part of the GTAs. The model originally developed by the Department of Mathematics involved the requirement that GTAs attend two mini-courses, one titled 'Teaching Mathematics' and the other 'Mathematics Course Design'. These were to meet weekly for the first 7 weeks of semester 1 and semester 2, respectively [25]. The current website lists two seminars with the same titles. The first is offered each Fall and has the following description:

> This seminar is required of first-time teaching assistants. Topics discussed are: getting started the first day, how to help students learn, lecturing, and grading. Each new teaching assistant is videotaped, and her or his performance is reviewed.

The second is offered each Spring and is described thus:

> This seminar treats syllabus writing, lecturing, test design and homework assignments. The seminar is a prerequisite for students interested in teaching their own course [26].

2.5. *Summary of Programmes*

The programmes described above are only 4 of 14 GTA training programmes included in Section 3 of *PPTT*, which also contains five other sections devoted to various issues involving GTA professional development [6]. A few traits seem common among most GTA professional development activities. One is the emphasis on the local culture within the universities and within departments within universities. A common feature of the cultures of all the universities presented above is the emphasis on disciplinary research and preparing PhD students to participate in disciplinary research. Another common trait of the GTA professional development activities is the peer interaction, with video-recorded mini-lectures critiqued by peers being prevalent in most programmes. A third, and perhaps most important, commonality is that the professional development activities are designed to have minimal impact on the GTAs' timely completion of their disciplinary programmes.

3. GTA professional development course description

3.1. *Local context*

The context for our GTA professional development course is a large (~30,000 students) state-supported university. The Department of Mathematics and Statistics consists of 45 tenured or tenure-track faculty, 8–10 lecturers, and 80 or so mathematics GTAs. The department offers bachelor through PhD degrees, but the bulk of the department's teaching load is service courses at the undergraduate level (e.g. maths for business students, for engineers, for pre-service primary and secondary school teachers, etc).

During the Fall semester of 2000 just over 8000 students were enrolled in our undergraduate mathematics classes, while in Fall 2005 our enrolment was over 9000. Always crucial, the role of GTAs in meeting the department's undergraduate teaching responsibilities has become all the more critical since the number of full-time faculty positions has remained static during this period of enrolment increases.

Prior to Fall 2000, the only preparation provided for mathematics GTAs was a 2-h orientation session just before the start of each term. A typical assignment for GTAs with at least 18 graduate mathematics credit hours is to teach, as instructor of record (with sole authority to mark student articles and assign final course grades), two sections of one of the multi-section courses such as college algebra, taught in 25–30 sections of 40–50 students each. A full-time faculty member is assigned to teach one section and is designated as the course coordinator. The course coordinator meets with the GTAs for 1–2 h at least once in each month for the purpose of coordinating the conduct of the course and dealing with issues that arise. GTAs with fewer than 18 h of graduate mathematics credit cannot be assigned as instructor of record for a class, so there is pressure for all new GTAs to obtain 18 credit hours as quickly as possible.

In Fall 1999, our chair came to the conclusion that our GTA professional development programme was inadequate. Moreover, as indicated above, it is in the department's best interest for new GTAs to obtain as many credit hours as possible during their first semester. He asked the Director of Undergraduate Programmes (DUP), first author of this article, to develop a 3 credit-hour, graduate-level course devoted to the professional development of our GTAs. The DUP was given explicit instructions that the course should not place such a burden on the GTAs as to hinder progress in their 'real math classes'. The resulting course, referred to as The Course, is the result of this effort.

3.2. *The course*

The Course consists of 3 contact-hours per week for the 16-week fall semester. The course meets for 1 hour and 20 min, twice per week in a traditional classroom setting. A significant portion of the first day is devoted to introductions. The GTAs are asked to talk about their backgrounds, as well as motivations and aspirations for graduate school and their professional careers. This information is recorded by the instructor and used to assign the GTAs to groups of three or four which will function for the entire semester. The idea is to develop and foster a culture of collegiality and peer support among the new GTAs. Group assignments are made on Day 2 with the first exercise for each group being to construct a list of initial concerns, fears, apprehensions, questions, issues, etc., they would like to see discussed in the course. These lists are compiled, and perhaps supplemented, by the instructor and used to guide the remainder of the course. The typical routine for subsequent classes is as follows: class begins with an invitation for the GTAs to ask any questions and/or express any concerns they might have. These are addressed via

whole-class discussions as needed. Next follows a 15–20 min presentation by one of the GTAs. Third follows a combination of group and whole-class discussions centred on a case study and/or a pre-assigned reading.

3.3. *GTA presentations*

Each GTA must present two 15–20 min video-taped lectures, one in the first half of the semester and one in the second half of the semester, on topics he/she expects to be teaching in a college maths class. This allows the GTAs to present a mini lecture after they have more experience watching their peers and reflecting on their first lectures. After each presentation the GTA is evaluated by the other GTAs using the Mini Lecture Critique form [27, p. 60]. The video recording and GTA critiques are given directly to the presenter and not seen by the instructor; however, each GTA is asked to provide a written reflection on his/her presentation and subsequent criticisms. No other analyses occur. No particular help is given to the GTAs in preparation for their presentations; however, issues involving preparing and presenting maths lectures are covered in several of the readings and case studies. The primary purpose of the presentations is to introduce the GTAs to self-reflection and constructive criticism as mechanisms for improving classroom practice.

3.4. *Case studies*

The case studies are specifically designed to focus on issues that arise in the teaching of mathematics at the college level and are drawn from the Friedberg case studies [28]. Here we provide one example, 'Seeking Points', that has the following scenario, which we paraphrase:

> A student, Ted, who by all previous indications on homework and quizzes appears to be one of the best students in the class, appears at Joe's (his GTA) office to question his grade on the first hour exam. Ted received only 5 out of 20 possible points on problem 3, thus getting 85 out of the possible 100 points on the exam. Problem 3 was the following:
>
> 3. Use the definition of derivative to find the slope of the tangent line to the graph of $y = x^3 + 1$ at the point where $x = 1$.
>
> Ted's solution was the following: $y' = 3x^2$ so the slope of the tangent line is 3.
>
> Ted wants to know why he lost so many points when he got the correct answer. Joe explains that Ted did not do the problem as told, i.e. use the definition of the derivative. Ted is not happy with this answer, especially when Joe informs him that during the previous night's optional review session Joe reminded the students that they needed to know the limit definition of the derivative. Ted didn't come to the review session because he had to work. A lengthy (the actual case study is over 3 pages long) discussion follows between Ted and Joe in which many issues are raised.

The GTA groups are given roles to play. Some are assigned the role of the student arguing why he should be given a better grade. Others are assigned the roll of the TA trying to justify why the student received the grade he got. After 20 min, or so, the groups provide their arguments to the class and a whole-class discussion ensues. Some of the issues/questions that come up are the following:

- Why teach the limit definition in the first place?
- Does working through the algorithm for finding this limit show understanding?

- Just what was the problem trying to test, limit definition of derivative or derivative as slope of the tangent line?
- How do you handle a disgruntled student?
- What is the appropriate information to give out during an optional review session?

This is one example from the Friedberg case studies. Issues raised in other studies involve such things as student cheating, fair and consistent grading, classroom management, instructor–student relationships, professional relationships, departmental responsibilities, cultural issues, academic issues, appropriate use of technology, etc. Generally there are no black or white answers; usually there are good points to be made on either side of an issue that is raised. The main objective of the case studies is to create awareness and get the GTAs to start thinking about the issues. The instructor is always listening to, and sometimes even participating in, the group discussions, and facilitates the whole-class discussions. The instructor can always ask leading questions; however, it is very important to note that the instructor is not the driver. Only once do we recall having to step in and say 'NO, that is not the way it is'. We have learned that the best rule of thumb is, in the words of David Smith, 'to keep our brilliance to ourselves' [29].

3.5. *Reading assignments*

The GTAs read selected materials which are then covered in group and/or whole-class discussions. We add or change reading materials each year, but two dealing primarily with ethics and professionalism have remained key readings over the years [29,30]. The readings focus primarily on ethical, philosophical, practical, and theoretical issues related to teaching mathematics at the college level. The objective is to give the GTAs a broader understanding of the profession and help them begin the life-long process of developing their own teaching philosophies.

3.6. *Course expectations*

The expectation is that the GTAs, working together with their peers, develop their own teaching practice and philosophy. While the instructor provides examples and participates in the discussions, it is not his/her role to teach either methodology or philosophy. Grades are not an issue since the GTAs are guaranteed an 'A' if they attend and participate.

4. Assessment of the course

In Spring 2005, we decided to see what effect, if any, The Course was having on the GTAs taking it. The primary sources of data available to us were the university's teaching evaluation and course grade data from all courses taught by GTAs, and the GTAs themselves. Each GTA has complete autonomy in the assigning of course grades, thus we decided the lack of a uniform grading system made the grade data not useful.

4.1. *Student evaluations*

The end-of-term student course evaluations, Student Evaluation of Course and Instructor (SECI), used by the university has 16 statements, the first 10 with the subheading

'Instructor's Performance' and the last six with subheading 'Course Evaluation'. The students are asked to respond to each statement by choosing one of the following: strongly agree (5), agree (4), neutral (3), disagree (2) or strongly disagree (1). We considered only those responses to the 10 statements in the 'Instructor's Performance' category:

(1) Overall the instructor was effective.
(2) The instructor was available for consultation during office hours or by appointment.
(3) The instructor stimulated student learning.
(4) The instructor treated all students fairly.
(5) The instructor treated all students with respect.
(6) The instructor welcomed and encouraged questions and comments.
(7) The instructor presented the information clearly.
(8) The instructor emphasized the major points and concepts.
(9) The instructor went beyond presenting the information in the text.
(10) The instructor demonstrated knowledge of the subject.

We analysed the SECI results from all Fall 2004 classes taught by the 48 GTAs on staff in Spring 2005. This included responses from 1377 students taught by 28 GTAs who had taken The Course (GTA-C) and 906 students taught by 20 GTAs who had not taken it (GTA-nC). For each statement we compared the scores for GTA-C to the scores for GTA-nC. Here we choose to present the data for statements 5 and 6, Tables 1 and 2, because statement 5 is an example of a statement that yielded no significant difference and statement 6 is the one that yielded the most significant one. In all Tables, a p-value marked with '***' is interpreted as highly significant ($p < 0.01$), with '**' as significant ($0.01 \le p < 0.05$) and with '*' as marginally significant ($0.05 \le p < 0.10$). To maintain a 95% overall confidence level, we applied a Bonferroni adjustment using $\alpha = 0.05/10$ with $|z| > 2.807$ for each comparison [31]. There was significant difference in favour of GTA-C for all statements except numbers 4, 5 and 10 [27, pp. 21–30].

However, of the 28 GTA-C, 5 were international, while 14 of the 20 GTA-nC were international. This led to the question of whether the scores were the result of an international IGTA *versus* national NGTA issue. So we compared all groups with the same significance test. Results for statements 5 and 6 are given in the Tables 3 and 4.

Table 1. Statement 5 analyses: treated students with respect.

Course	Avg.	n	SD	z-value	p-value
GTA-C	4.510654	1361	0.696681		
GTA-nC	4.487859	906	0.707002		
Sig.				0.7563	1.0000

Table 2. Statement 6 analyses: encouraged questions.

Course	Avg.	n	SD	z-value	p-value
GTA-C	4.532151	1353	0.703358		
GTA-nC	4.326923	884	0.840993		
Sig.				6.0109	0.0000***

Here we have made 60 comparisons, so to maintain an overall confidence level of 95% we apply the Bonferroni adjustment $\alpha = 0.05/60$ with $|z| > 3.34$. Again there appeared to be significance in all statements except 4, 5 and 10 [27].

This model, however, cannot account for all the dependence occurring due to possible variation between individual GTAs within each group. Thus we implemented a two-way factorial analysis of variance (ANOVA) [32]. Tables 5 and 6 show the results of

Table 3. Statement 5 analyses by IGTA or NGTA.

	Avg.	Total	SD	z-value	p-value	
IGTA-C		4.533040	227	0.705548		
IGTA-nC		4.511111	585	0.670026		
NGTA-nC		4.475083	301	0.763900		
NGTA-C		4.497832	1153	0.704798		
IGTA-C	IGTA-nC				0.4030	1.0000
IGTA-C	NGTA-nC				0.9017	1.0000
IGTA-C	NGTA-C				0.5477	1.0000
IGTA-nC	NGTA-nC				0.6926	1.0000
IGTA-nC	NGTA-C				0.3836	1.0000
NGTA-nC	NGTA-C				−0.4673	1.0000

Table 4. Statement 6 analyses by IGTA or NGTA.

	Avg.	Total	SD	z-value	p-value	
IGTA-C		4.576763	241	0.721197		
IGTA-nC		4.304274	585	0.769539		
NGTA-nC		4.371237	299	0.965500		
NGTA-C		4.511091	1127	0.716224		
IGTA-C	IGTA-nC				4.8394	0.0008***
IGTA-C	NGTA-nC				2.8296	0.2796
IGTA-C	NGTA-C				0.9041	1.0000
IGTA-nC	NGTA-nC				−1.0420	1.0000
IGTA-nC	NGTA-C				−5.3989	0.0000***
NGTA-nC	NGTA-C				−2.3397	1.0000

Table 5. Two-way ANOVA analyses: course effect.

Statements	F (df1, df2)	p-value
1. Overall instructor effective	2.58 (1, 46)	0.1153
2. Instructor available	5.09 (1, 49)	0.0287**
3. Stimulated learning	3.70 (1,46)	0.0608*
4. Treated students fairly	1.86 (1, 47)	0.1781
5. Treated students with respect	1.78 (1, 47)	0.1881
6. Encouraged questions	10.29 (1, 46)	0.0024***
7. Presented material clearly	3.55 (1, 46)	0.0658*
8. Emphasized major points	3.22 (1, 47)	0.0790*
9. Went beyond information in text	5.34 (1, 46)	0.0254**
10. Demonstrated knowledge	1.78 (1, 47)	0.1893

Table 6. Two-way ANOVA analyses: GTA-type effect.

Statements	F (df1, df2)	p-value
1. Overall instructor effective	0.11 (1, 46)	0.7418
2. Instructor available	0.40 (1, 49)	0.5322
3. Stimulated learning	0.11 (1, 46)	0.7437
4. Treated students fairly	0.74 (1, 47)	0.3930
5. Treated students with respect	1.97 (1, 47)	0.1674
6. Encouraged questions	1.33 (1, 46)	0.2546
7. Presented material clearly	1.05 (1, 46)	0.3107
8. Emphasized major points	0.24 (1, 47)	0.6269
9. Went beyond information in text	0.04 (1, 46)	0.8348
10. Demonstrated knowledge	0.18 (1, 47)	0.6765

the two-way ANOVA model on the course effect and the GTA-type effect for each statement.

4.2. *Interview data*

We interviewed 22 GTAs (13 males, 9 female) on staff in Spring 2005 who had taken The Course. We used a uniform interview instrument in which all GTAs were given the same instructions and asked the same questions, in the same order [27, p. 62]. The DUP (first author) was not present when the second author conducted the interviews, which were audio-recorded. We anticipated that the GTAs would assume the DUP would listen to the interviews. To mitigate this possibly intimidating factor, we chose interview questions that focussed attention on the content of The Course and solicited criticism. During each interview, the second author noted his observations on the interview instrument. After each interview, he reviewed the recording to insure that his noted observations were consistent with the interviewee's actual statements. Then the DUP listened to each interview and used the interview instrument to record his observations. Independently we made a subjective assessment of each GTA's overall reaction using the following descriptors: highly positive, positive, neutral and negative and highly negative. After our independent observations and assessments we met to compare conclusions. When there appeared to be inconsistencies, we listened to the appropriate portions of the recorded interviews together and arrived at a consensus. Extensive accounts of the interviews are available online [27].

4.2.1. *Fall 2000 (Taught by DUP)*

Three GTAs (all male) were interviewed from the Fall 2000 course. One was rated as very negative and the other two as positive. The very negative GTA claimed to have gotten 'nothing out of the course', although later in the interview admitted to realizing that he learned that he 'needed to relax a little more'. He thought the video-recorded lecture was least beneficial, while the grading exercise from the case studies was the most beneficial thing from the course. Of the other two GTAs, one felt he gained more confidence while the other gained more humility and 'became more patient'. Both rated the video-recorded lecture as the most beneficial and one rated the grading exercise as the least beneficial: 'Everyone had their own way of grading, it didn't change them'. All three thought the course needed to have greater emphasis on practical issues: 'things we do every day'.

4.2.2. *Fall 2001 (Taught by our Chair)*

Three GTAs (all male) were interviewed from the Fall 2001 course. One was rated as negative, the other two as neutral. Two claimed no effect on either attitudes or teaching practise. One observed 'I'm old and set in my ways anyway'. The other confirmed a much held belief: 'How to teach a math course was based on my experience as an undergrad'. However, the third pointed to the grading exercise as affecting his practice, making him 'more lenient in my grading' and 'more patient with students'. One GTA thought that watching others teach was the most beneficial and the readings least beneficial. Two GTAs felt The Course was a good introduction to graduate school and the mathematics department. When asked what was lacking in the course two GTAs had very similar responses:

> *What they're doing now, having lessons on how students learn, dealing with students, video lessons, how to deal with complaints and false accusations, how to deal with parents and administration.*

One GTA added 'Since it is required it should count toward your degree'.

4.2.3. *Fall 2002 (Taught by DUP)*

Three GTAs (all female) were interviewed from the Fall 2002 course. One was rated as neutral and the other two as positive. Two noted a change in their attitudes towards teaching, while the third did not. However, the one claiming no change in attitude, claimed to have made significant changes in her practise, observing the need to 'try to incorporate different styles' and 'make students do examples in class. If they just watch me do it then they're not going to learn'. Video-taped presentations and the grading exercise case study were listed as most beneficial. An interesting response to the least beneficial aspect of the class was 'no closure to the discussions, all gray, not necessarily a right answer, maybe that's the point, there are gray areas'. When asked why she took the course one GTA responded: 'Required, well not required, but they say everyone takes it'. Two thought The Course was worthwhile, with one commenting 'Yes, recommend everyone to take it, even professors'. After hesitation, the third thought the course needed to include 'more mechanical aspects of teaching'.

4.2.4. *Fall 2003 (Taught by another colleague)*

Six GTAs (three males and three females) were interviewed from the Fall 2003 course. Three (two males and one female) were rated as highly positive, two (one male and one female) as positive, and the other female as neutral. One male GTA claimed no attitude change: 'I went in wanting to be a teacher, that goal was not changed'. The other GTAs said the course had contributed to changes in their attitudes, with one male observing 'It made me a little more calm. I was worried about teaching students of the same age or older'. The same GTA thought a main benefit of The Course was 'talking to fellow students (GTAs), knowing we're in the same boat'. One female GTA viewed the course as 'a therapy session'. Four GTAs felt The Course had affected their teaching practice with respect to improved classroom technique. Four GTAs viewed the case studies as being most beneficial and the other two thought the video-recordings and peer critiques were most beneficial. Two female GTAs mentioned the articles as being the least beneficial, with one admitting to not

reading a lot of them. One female GTA summarized the goal of The Course as follows:

> *Prepare you to teach, to make you more comfortable and let you know that you're not alone . . . course is a good example of how the department really cares about its TAs. I heard horror stories about how they hand you a book and say go teach.*

All six GTAs believed that the goals had been achieved with 'gaining confidence' and 'feeling more comfortable teaching college' being the two most often mentioned outcomes. The hours not counting towards degree plans were a concern.

4.2.5. *Fall 2004 (Taught by DUP)*

Seven GTAs (four males and three females) were interviewed from the Fall 2004 course. One male was rated as highly positive, two females and one male as positive, two males as neutral and one female as negative. The negative GTA claimed no change in her attitude, while all the other GTAs reported a change in attitude, with increase in comfort level being mentioned by several. One female GTA summarized her attitude change as follows:

> *I feel more privileged to teach students the same age . . . at first I hated it, still intimidated. I realize now it's not just giving out info, but communicating with people.*

Regarding teaching practice, one male and one female GTA referred to the video-taped lecture as pointing out things they will try to improve upon. Another female GTA observed 'I learned that I have the authority to gain control of class . . . became more comfortable using teaching skills'. Five GTAs mentioned the case studies as being the most beneficial, with the case studies involving grading, cheating, harassment and meeting students outside of class, all mentioned. One female and two male GTAs said everything was beneficial, while one female thought the articles were 'not helpful in general', and one male GTA observed 'A lot of days, just argued over opinions. Some would dominate and basically shut down discussions'. A summary of the course goals as perceived by these GTAs follows:

> *To prepare us to represent the department and university as educators and to set standards.*
> *To expose us to different styles of teaching, how to handle students, other TAs and faculty.*
> *Teach you how to teach.*
> *To get an overview of what to expect as a TA and to gain confidence in teaching. To get us ready to teach at the college level.*
> *To produce better teachers, not just teach, but implicate moral values and present material beyond the requirements.*

All GTAs thought The Course achieved its goals. When asked why they took The Course, four simply responded that it was required; one adding 'but I'm glad I took it, learned some stuff I didn't know I needed'. Six could not think of anything lacking in The Course, while one female GTA said 'Maybe some more role playing in groups'. Two male GTAs thought the course was not worthwhile because it did not count towards their degree and one female responded 'No, I don't feel I learned that much as far as how to teach. I think you learn to teach by teaching'.

5. Discussion

On average, 17 GTAs have enrolled in The Course each Fall and none have any prior college-level teaching experience. Other than having 18 hours of maths credit prior to coming to Tech and a greater number of international GTAs in the non-course group,

there was no demonstrable difference between the Course GTAs and the non-course GTAs. From the analyses of the SECI data we conclude that their students' perceptions, with respect to the specified attributes, were not measurably affected by the GTA type, international or national. This is perhaps not too surprising since all international GTAs are required to participate in an intensive university-wide training workshop before being allowed to teach any classes. The analyses of the SECI data show that GTAs who took The Course were viewed by their students as much more likely to welcome and encourage questions and comments, and as more likely to be available for out-of-class consultation and to present information beyond the text, than were the GTAs who had not taken The Course.

The literature contains numerous articles on the subject of student evaluations of faculty (SEF), many with conflicting claims. It appears that how SEF are used to evaluate faculty is a primary cause of controversy. Fich makes several suggestions on appropriate use of SEF [33]. One is particularly germane here: 'comparisons of results should only occur for faculty members teaching courses with similar characteristics' [33, p. 3]. All the GTAs in this study were teaching low-level mathematics courses populated by students who were taking them to fulfil requirements. Furthermore, we use the SECI data only to determine how students viewed the GTAs with respect to the specified attributes. We make no claims about teaching effectiveness. Nor do we have any reason to believe there is significant difference in motivation, teaching experience, and backgrounds of the two comparison groups, other than the GTA-C entered our programme with less mathematics background than did the GTA-nC.

Analyses of the interview data suggests the common attitude changes on the part of GTAs taking The Course involved gaining confidence and becoming more comfortable with their role as teachers. The case studies appear to be the primary impetus for change of attitudes and the video tapes for the changes in teaching practice. It appears The Course has become an accepted part of our GTA culture; however, there is lingering concern about hours not counting towards particular degree programmes and the need for more practical information.

6. Conclusion

We believe the SECI and interview data are consistent in that an instructor's comfort and confidence levels should be directly related to his/her willingness to encourage questions and comments during class, being available and encouraging out-of-class consultation, and presenting material beyond the text. Thus, we believe The Course has increased the confidence and comfort levels of the GTAs taking it (132 as of Fall 2007), with related impact on their teaching practice.

There is also the question of effects on student maths achievement. Does taking The Course affect the GTAs ability to enhance the learning outcomes of their students? Unfortunately our department has no uniform grading system, even in courses with multiple sections and uniform departmental exams. Each individual instructor has compete autonomy with regard to marking all exams, including uniform finals, and assigning each student's final course grade. So comparing instructor grades yields no valid comparison of instructor effect on student learning. This is an entrenched part of our departmental culture with little indication of changing any time soon, even though the assessment of student learning outcomes is a major, often heated, topic of discussion within our university in general and within our department in particular. Under more

controlled circumstances such comparison between GTAs taking The Course and those not taking it might prove interesting.

We believe that the course should be required of all our graduate students. But there is resistance on the part of some of our faculty members whose primary interest is in traditional mathematics research. Our current director of graduate programmes seems to have little regard for the course and is very quick to waive this course requirement for any student whose research advisor asks that it be waived. The attitude of several of our research mathematicians is that this course is a distraction for their students who are preparing for careers in mathematics research. In fact, the only way we could get the course approved by our department's graduate programmes committee was to not require it for any student entering our programme with 18 or more graduate credit hours in maths, and that it require minimal out-of-class time on the part of the students taking it.

Has the course had any effect on the recruitment and retention of mathematics students at either the graduate or undergraduate levels? Both our graduate and undergraduate mathematics enrolments have increased in the last few years. But this could be attributed to several different factors. For example, we have enhanced our recruitment efforts at both levels and have made significant increases in our mathematics scholarships at both levels. We have also significantly increased our GTA stipends. We suspect our enrolment increases are due to a combination of all these and other factors. However we do believe that creating a culture of collegiality, both for undergraduate majors and GTAs within the department is important for recruitment and retention at both levels, and The Course is one contributing factor to creating that culture.

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