CASE STUDY

Designing a short course for graduate teaching assistants (GTAs) in mathematics: principles and practice

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Abstract

Graduate Teaching Assistants (GTAs) are postgraduate research students who contribute to the teaching of undergraduates while they pursue their own doctoral research. This paper reports on a mathematics-specific 10 learning hour introduction to teaching for postgraduate mathematics research student GTAs. The principles that guided the design of the course are discussed and results from our practitioner research are presented. We found that 'training' could not be delivered in such a short course yet, paradoxically perhaps, education could be achieved, given the qualities of our GTA participants.

Keywords: postgraduates, teaching assistants, GTA, undergraduate mathematics, training course.

1. Introduction

Nowadays, at many research intensive UK universities, postgraduates in mathematics departments are 'graduate teaching assistants' (GTAs), contributing to the teaching of their departments' undergraduates; this has long been the standard situation in universities in North America (Park, 2005). The UK Higher Education Academy has in the past run workshops for mathematics GTAs but cuts in public expenditure led to the demise of this specialist mathematics provision. However, a local initiative, 'the UCL-IoE[*] strategic partnership' in 2014-15, supported designing and running a mathematics-specific teaching course for postgraduate research students which was to take approximately ten hours of their time. This short course was designed through a collaboration between mathematicians (colleagues in the UCL Mathematics Department) and the authors of this paper, both mathematics educators working at UCL Institute of Education (UCL Institute of Education). This course has continued in the subsequent academic years and is now part of postgraduate provision in the Department of Mathematics at UCL.

The course for GTAs focused on three key aspects of university mathematics teaching: marking, tutoring and lecturing and we present results from our analysis of qualitative data that pertain to the fundamental practitioner research question: what did our course participants learn? A brief outline of the paper is as follows: the first part is an introduction to the context; firstly, some background is given to post-graduate student preparation for university teaching, then a description of the course is presented together with some illustrative data and we address the issue raised above 'what did the GTAs learn?'. The final part of the paper is discussion of what 'should' feature in a 10-hour preparation for GTAs contributing to the teaching of undergraduate mathematics leading to our claim

[*] University College London (UCL) merged with the Institute of Education (IoE) on 2 December 2014.

that GTAs cannot be 'trained' in 10 hours, but 'education' – the nature of which shall be discussed briefly below – is possible.

2. Context

World-wide, potential students seek to enrol in undergraduate degree programmes and, in many educational jurisdictions, pay high fees for the privilege; the issue of 'who might be teaching me then?' asked when fees for the majority of home students increased (Cox and Mond, 2010) continues to be relevant. When choosing their programme, these potential undergraduates will get information from universities' websites and other publicity which, amongst other things, promotes the reputation of that university's academics. For example, a promotional video for potential UCL mathematics undergraduates broadcasts that "anyone teaching you is a cutting edge researcher of modern mathematics, which is true for all our permanent staff" and also "all of them [faculty] are research active and all of them teach" (UCL, 2015). While the issue of the relationship between research expertise and teaching expertise is not addressed in this paper, it is the case that potential undergraduates are likely to have some tutorials (and possibly lectures as well) given by GTAs. The GTAs have not yet become experts in their research area, though they are supervised by experts, who do also teach. If a distributed expertise (UCL, 2015) can be said to come from the parent mathematics department, not only in research but also in teaching, then inducting these postgraduates into university teaching as part of departmental practice is consonant with a notion of undergraduate experience given by the promotional video.

2.1. On GTA training

In 2012, in the UK, NUS (National Union of Students) collected and analysed the responses of around 1,500 postgraduate students who teach at their institutions. The survey asked a mixture of quantitative and qualitative questions on a number of aspects of their teaching experience. There were six main areas of focus for the survey: motivations for teaching, the application process, pay and conditions, representation, training and professional development, and feedback. These data provide an overview of how postgraduate teachers are treated in the UK, and in their report, Wenstone and Burrett (2013) were able to capture a detailed picture of what the postgraduates experience when they take on teaching responsibilities at their institution. They recognised that the pressures of doctoral study make time a precious resource for postgraduate research students and the report revealed that much of the hard work of postgraduates is undervalued and underpaid by their institutions, hence highlighting the need for them to be appropriately supported and fairly compensated for it.

In the North American context, where GTA contribution to teaching is standard and includes lecture courses as well as tutorials, the issue of their preparation for teaching has been discussed for some decades (e.g., Border, Speer and Murphy, 2009; Carroll, 1980). Border et al. (2009) classifies the models that have used to describe the GTAs induction as: "orientation", "transitional" or "recurring" programmes (pp. 26-27). Orientation programmes, generally held prior to the GTA starting to teach, induct the graduate student to the ways of the department, including the syllabus of the course s/he is to teach; transitional programmes, lasting longer and typically meeting throughout a semester, included input on teaching styles, yet rarely on subject specific pedagogy; recurring programmes offered on-going support over the years of the GTA's graduate study.

2.2. On subject specific training

In November 2005, the Education Committee of the London Mathematical Society carried out a survey of staff training in mathematics departments at UK universities. As reported in Cox and Mond (2010), the responses received from 25 higher education institutions in the UK, with a majority of the providers offering single-subject mathematics degrees, indicated that the training of new staff was almost entirely generic. Two providers reported satisfaction with this generic training, while the remainder were critical, some extremely so, inasmuch as the taught part of the generic training courses was considered irrelevant to preparing their GTAs.

While generic courses for GTAs may be increasingly sensitive to disciplinary differences, problems can arise if these courses do not offer contextual support needed by GTAs. Cox and Mond proposed that preparation for teaching at higher education level should contain both generic and discipline-based components. As they found that often participants in generic preparation for teaching courses felt that many of the issues central to their teaching are peculiar to mathematics and cannot be addressed in a generic programme aimed at practitioners of all subjects. Based in part on their experience of running such a scheme in the Mathematics and Statistics Departments at the University of Warwick, UK, where it has been successful both in training new staff, and as a means of focussing departmental interest in teaching, they produced a booklet which aims to guide UK mathematics departments in providing training for new lecturers. At our institution, University College London (UCL), not only new lecturers, but also ‘Teaching Assistants’ – usually postgraduate research students (GTAs) – are required to be ‘trained’. The training is offered through ‘Gateway workshops’ designed to prepare postgraduate students with no prior experience for their teaching responsibilities by introducing approaches to teaching and learning. Our mathematics-specific course discussed in this paper is in lieu of the generic ‘gateway workshop’. While we recognize that the training needs of GTAs are different to those of new lecturers, the literature reviewed above was influential in the design of our short course.

Suggestions for how to best approach the training and the professional development of university mathematics teachers have been made by mathematicians (as above), but also by mathematics educators. Our short course benefitted from the collaboration between the mathematician colleagues (see acknowledgements) and the mathematics educators (the authors of this paper). Influential in this respect was the work of Alcock and Simpson (2009), aimed at providing mathematicians with an accessible introduction to some ideas from mathematics education research. Hence, influential in the design of our short course was our awareness of and familiarity with the considerable body of research on learning to teach mathematics to undergraduates. Key sources include: the notion of concept image (Tall and Vinner, 1981); promotion of undergraduates’ active engagement with mathematics beyond mere applications of techniques (Mason, 2002); recent work on how young people transition to learning university mathematics (Grove, Croft, Kyle and Lawson, 2015); investigations in to tertiary mathematics teaching and learning (Nardi, Jaworski and Hegedus, 2005). All these sources, as well as others offered insight into the problems of assisting students to learn mathematics that we could interpret and use for inducting GTAs into teaching undergraduates.

3. Our short course for mathematics GTAs: Design Principles

Research, such as referenced above, informed the subject- and phase-specific pedagogy of the course discussed in this paper. This background was employed to design and deliver a course for postgraduate or postdoctoral researchers from a range of mathematical disciplines; this was a considerable challenge especially as the course was intended to take less than 10 hours of their time.

GTAs in the UCL Mathematics Department have one of three different roles: (1) the GTA is the tutor for a small group (five to seven) of first year undergraduates; (2) the GTA marks weekly homework sheets (set by the module’s lecturer) for students attending a particular module; (3) occasionally, a GTA gives a lecture in his/her specialism for advanced undergraduates. GTAs are entitled to have access to lecture notes and problem sheets with solutions in advance (although this is not always the case). Such resources are usually designed by the module leader, a member of staff in the mathematics department.

In designing our short course so that it is a learning experience, there are a number of aspects we considered to be fundamental: 1) opportunities for *practicing* marking and lecturing with peer feedback and tutor guidance (as in Nardi, Jaworski and Hegedus, 2005); 2) opportunities for *reflection* on their practice (as in Kahn and Kyle, 2002) both in their mini-lectures (see below) and their tutorial opportunities; 3) a safe environment to try out ideas; 4) skilled tutor input within discussions to pin down and possibly offer a conceptual framework for their thinking (as in Tall and Vinner, 1981). These four principles are adapted from both generic and subject-specific literature on good practice of training design we drawn on from the literature we reviewed.

3.1. The course we ran

What we saw can be achieved in 10 hours was a lively collegiate atmosphere of postgraduates engaging with teaching undergraduates mathematics through addressing key areas of marking, tutoring and lecturing. The course was thus oriented around these types of teaching task, from which observational data and reflections were collected. The course is held annually during the Autumn term with, on average, 14 participants.

3.1.1. Marking

As the initial focus of the conversations about marking would be on the mathematics itself, we would thus start by tapping into the GTAs' strength, namely their subject knowledge. While initially the intention was to let participants choose whether to focus on teaching real analysis, number theory or mathematical methods, in practice it was not possible to give this amount of choice. So the course used real analysis – a foundational area of undergraduate mathematics with which all participants were familiar – as the content area from which to develop teaching.

From past years' Real Analysis 1 exam scripts, parts of students' answers to a few questions were cut and pasted onto a large sheet so several students' answers could be compared. The GTAs were invited to work through a selection of undergraduates' solutions to past exam questions and mark them, while engaging with the marking scheme at the same time. The marks given by GTAs to each question were then compared and a lively discussion and justification followed for the rest of the session. With mathematics problems as the starting point, a variety of aspects of teaching and learning cropped up from the discussion about: solutions, the range of possible answers, how many marks each step in the solution would score, accuracy of written language, formative feedback, etc.

3.1.2. Tutoring

The purpose of this session was to encourage a conversation amongst the GTAs, voicing their opinions and views on how to best run tutorials, mainly based on their own experiences as undergraduates on how they benefitted from attending those sessions and, on reflection, on what they would have liked to experience. Throughout the session, the GTAs views were backed up by tutors sharing their own experience and disseminating principle of researched good practice.

3.1.3. Lecturing

Participants were asked to prepare a mini-lecture (5-10 minutes) either on a topic that arose from the marking session (e.g., Rolle's theorem, or a fiendish counter-example to an intuitive 'truth') or another early undergraduate topic, to peers and tutors. After each mini-lecture there was a discussion on the content and presentation. Data were of the form of notes and photos from the presentations and notes of points of discussion.

4 Our short course for mathematics GTAs: What happened in practice

4.1 Sources of data

Towards the end of the Autumn term, the GTAs fill in a pro-forma (see appendix) aimed at helping them reflect on their experience of giving tutorials. Their responses (100% response rate, due to the small size of the group) contributed to the design of the last session of each of these courses, with an aim of drawing together some general principles for 'good practice' in undergraduate tuition.

In the following we present examples of GTAs comments taken from their responses to the pro-forma questions, together with the data we collected throughout the delivery of the courses over the past three years (our reflective notes after each session, photographs of GTAs' board notes and scripts they marked, our notes of GTAs' comments and contributions in sessions).

4.2 Samples of data

4.2.1 Marking

Excerpts from students' exam scripts provided a fruitful starting point of a rich discussion about many aspects related to understanding, learning and teaching mathematics. Some of the GTAs expected a high level of precision of how undergraduates employed the mathematical notations and symbols: for instance, the absence of quantifiers was thought by the GTAs to be sanctioned. Another example, paraphrased from notes: one of the participants, GTA1, argued that an undergraduate examinee should be penalised for not stating explicitly that 'N' should be an integer when using 'N' in a certain definition. The other participants and tutors, had a discussion about implicit meaning, given the practice (i.e. use of notation of the lecturer) and the pressure of an exam; the consensus was that GTA1's judgment was tough on the student.

The importance of and awarding of partial marks was discussed at great length during the session, with the aim of raising GTAs' awareness about striking a balance between awarding marks for the correct reasoning and validity of the argument put forward and penalizing presentations of written solutions which were not accurate or rigorously presently.

4.2.2 Tutoring

The GTAs found the tutorial a very useful session. They learned from listening to others sharing their experiences about how to interact with students, learning about the subject-specific pedagogical aspects of preparing and conducting a tutorial, what they tried and how it worked, why or why not. The discussion challenged the GTAs' initial view about tutorials *being more than just teaching mathematics, but also about supporting students and understanding what they need help with* (GTA2), while the following aspects were raised through discussions as aims for tutorials: establish a friendly environment; help the students prepare and practice; encourage discussion about a specific mathematics topic; offer explanations so they understand – rather than just present an answer; provide feedback on the students' work; be prepared to answer all sorts of questions.

In the following, we illustrate how some of the GTAs reflected on efforts to implement these aspects in their tutorials.

Encourage discussion about the mathematics: "We discuss and collaborate on the problems we solve and I encourage them to explain their work to each other", said GTA3. Others expressed their concerns about not being very successful in using discussions to the benefit of all of their students, as reflected in GTA4's comment: "the discussion was mainly on the part of the students who understood the topics completely, and were therefore confident talking about it. The students who had any doubts preferred to remain quiet mostly". GTAs expressed frustrations with students' preoccupation with the correct answer and admitted that "in so far as is possible I have tried to; however most of the students are focused on the correct answer and nothing else"; GTA5 encourages students to answer questions and not being afraid of being incorrect, which he identifies as a common issue amongst undergraduates, while GTA6 "would like to learn how to get the students to converse more with each other".

Be prepared to answer all sorts of questions: As a pre-requisite to preparation for tutorials, the GTAs' comments highlighted the need to have access to lecture notes in order to appropriately support students' learning: "however, both courses I was supporting changed this year so I was not always clear on what they had covered in class until I had seen their notes" (GTA7), while another, GTA8, found it very useful to have access to the module resources: "we've discussed homework problems, proofs and examples in their lectures, textbook recommendations and online resources".

This short course raised an awareness amongst the GTAs that familiarity with the subject matter content of the modules and being able to solve the weekly problems set does not suffice as preparation for tutorials. Unpacking their own understanding, reflecting on the reasoning involved at each step prepares them better for tackling students' various questions: "I feel I could have been a bit more prepared for some of the questions they gave me, some of the nuances that are not directly relevant to solving equations were sometimes lost on me" (GTA9). Another student commented that the subject matter of the course studied by her students was very easy and that most of the time students' questions were very easy, although on occasions, when harder questions were asked by the students, she wished she could anticipate those. GTA10 soon realised that "if you just present an answer on the tutorial, instead of doing the things mention above, the tutorial becomes boring and you are just repeating the things they already saw in lecture and you are not doing anything relevant to help them".

On reflection, through whole group discussion, the GTAs came up with a number of suggestions that would benefit their preparation for tutorials: work through the problem sheet thoroughly, discuss potential problems undergraduates might have with other tutors and in this respect, cultivate a community of tutors for supporting each other.

Feedback on students' work: The mathematical dimension of tutorials was of a high interest to the GTAs. The issues they raised were related to the standard of precision, logic and use of new concepts is different for those who need support, those who are getting along and those who are really good. The importance of developing questioning skills was also discussed, to support students' understanding, particularly for those students who breeze through the problem sheets in order to challenge them on points of detail.

4.2.3 Lecturing

Samples of board work are shown in figures 1 and 2.

It was satisfying to have been immersed in details of undergraduate mathematics with the participants, all of whom are potential university lecturers in mathematics, who contributed to group discussions lead by the project team enthusiastically and perceptively. In particular, their presentations embodied some of the challenges involved in giving mathematics lectures. Examples raised included: coordinating board writing with talking to students, positioning themselves at the board to allow for clear visibility of the board notes by all students in the room, erasing board notes as a result of mathematical simplification was realized to not be helpful to students, splitting the work area of large boards and the 'flow of the board work' in general to make it easy to follow, pace of tutor's handwriting versus students' handwriting, and use of different colour pens to emphasise main points (as in figure 1) also emerged as important issues to consider in teaching.

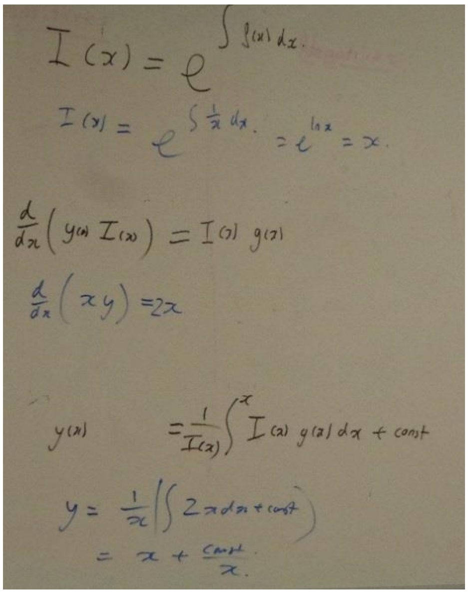

Figure 1: Emphasising main points.

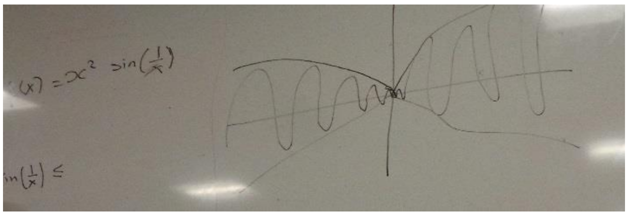

Figure 2: Lack of accuracy when using visualization.

Discussion about the use of diagrams to support explanations or illustration of mathematics results also arose naturally during the presentations. While visualization is to be encouraged, one instance where a diagram was used (figure 2) led to a debate about how the lack some level of accuracy does not support understanding, and how an explicit link to its symbolic representation is also required.

Consideration of suitable notation and being explicit about the oral language associated with symbolic reasoning became apparent by sitting in each other's lecture. Mathematical notation received yet again a particular attention: being explicit about how to read a particular new notation introduced and not taking for granted mathematical terminology that undergrads might not be aware of (such as: lemma, corollary, etc.). Similarly, the GTAs presentations alerted them to the conventions of mathematics which undergraduate might find it challenging: such as the need of assumptions and conventions to be made explicit.

The atmosphere of the feedback sessions was very collegial, which is a good environment for the mutually supportive and insightful peer comments to be taken in.

5 Discussion: education versus training

We were struck when we[*] started on this project how casually the word 'training' was used within the mathematics department for the induction into teaching we were planning for their postgraduates, yet the observation was a prompt to consider differences between education and training that were relevant to this context and lead to the claim ('not enough time for training') proposed above. It is worth noting that in all teacher preparation courses there are aspects that are more akin to training and other aspects deemed education. For example, in a year long postgraduate teacher preparation course (PGCE), based in a university with school practicum, the pre-service teacher could be said to be trained to take a register, know the content and progression of the National Curriculum, the current statutory requirements for 'special needs' etc. On the other hand, pre-service teachers on such a PGCE course could be said to be educated into ways of thinking about students through

[*] Authors together with colleagues named in the acknowledgements.

being asked to interrogate different theories of learning within their school experience, and also educated into developing a reflective practice that includes personal and academic writing, reflection on literature and dialogue with peers and tutors that widen their views on relevant issues (such as what mathematics should be in the curriculum). It seems ironic, given the relative demands of training and education, as illustrated above, to say that we do not have enough time to train the GTAs, though we have an opportunity to educate. However, for our GTAs, we aim to explain why, firstly, by considering the meanings of the two key terms, then considering the participants and data from the course.

There is frequent confounding of education and training in common parlance; a quick internet search brings up a host of 'education & training' websites, for instance. This lack of discrimination between the terms 'education' and 'training' concerned Robert Dearden in the context of 'vocational education and training' schemes being set up in the 1980s.

> Training typically involves instruction and practice aimed at reaching a particular level of competence or operative efficiency. As a result of training we are able to respond adequately and appropriately to some expected and typical situation. … in every case what is aimed at is an improved level of performance … brought about by learning. (Dearden, 1984; p. 58-59)
>
> [Education] is very much a matter of conceptual insight, explanatory principle, justificatory or interpretative framework and revealing comparison. It also involves a degree of critical reflectiveness and hence autonomy of judgement, … Being concerned with understanding does not exclude from education any concern for feeling and desire, attitude, action or activity, but they will not be fostered apart from understanding. … A necessary condition of understanding many things is participation in them or experience of them. Education is not a purely intellectual affair. (p. 62)

Dearden's clarifications of the respective terms, training and education, can be applied to the case of our course for GTAs together with the observation that assessment or evaluation is also a part of a training cycle, which can be expressed as: find out the training needs, plan training, deliver training and assess whether participants have achieved the desired outcome. If not, adapt and try again.

So a 'training' has not been achieved on the course because there was not opportunity to check performance and response in typical teaching situations and 'try again' if the performance was wanting. For example, the Marking session of the course aimed to prepare a GTA to mark and to respond to undergraduates' written work by giving participants a range of undergraduate responses to some of last year's exam to mark. There was a great range in many of the marks given by participants and a lively discussion ensued justifying the marks given. This debate constituted (part of) the GTAs education, as it involved interpreting, developing autonomy of judgement and justification. But it was not a training, as there was no opportunity to have the participants mark another batch of exam questions and check that they had followed the principles which came from the discussion in the session and which conformed to international mathematical community represented by the mathematics department.

On the other hand, Dearden's characterisation of education suggests that understanding – in this case, how GTAs understand teaching mathematics to undergraduates – includes experience as well as affects like feeling and attitude. At this point a brief introduction to the course participants is appropriate: each of them has won a place at a prestigious mathematics department to do mathematics research, every one of the participants communicated within our sessions a genuine interest in teaching undergraduates mathematics, each one of them prepared thoroughly for a mini-lecture in front of peers and tutors in which all of them contributed supportive insightful comments. They were an exceptionally well-motivated group of people who came together with a common interest in mathematics and all of whom had studied undergraduate mathematics. Returning to

Deardon's characterisation of education, the GTAs experience of participating in mathematical culture and their current career trajectory, positioned them to have, for instance, conceptual insight in the mathematics education domain. An example of this occurred following GTA11's mini-lecture on integrating factors (illustrated in figure 1) when the notion was raised that a set of suitably designed problems could get students to discover/invent the integrating factor formula without the lecturer 'giving it'. This insight is in the spirit of Bob Burn's (2013) investigative approach to first year analysis and illustrates that our course provided an opportunity for this insight to be realised thus educating them about different forms of mathematical instruction in context. Another aspect of education offered by the course was in post-discussion consolidation. In the feedback session we summarized points from the sessions of the course and offered some general principles, for instance, on different roles of examples in mathematics learning. Thus education might well have taken place as the participants had a contextual entry to general principles, but training did not as performance was not monitored.

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Appendix

Mathematics postgraduate research student TA
pro-forma on tutorials

Your feedback on this form will contribute to this last session, so please fill in the form below and return it by email to ___ as soon as you possibly can.
Thanks.

1. General info

1. Your name:
2. What is your research area?
3. Were you a maths undergraduate in the UK? **Yes/No**
   - If **Yes**: at UCL? Yes/No.
   - If **No**, which country?
4. Did you have your own tutorial group throughout this term?
   Yes/No
   - If **Yes**, please omit item A ('no Autumn term tutorial group') and fill in item B.
   - If **No**, please omit item B and fill in item A.

2. Item A (on Autumn term tutorial group)

Did you take a tutorial group at least once this term?

Yes/No

- If **Yes:**

Who is the usual tutor for this tutor group? Is s/he your PhD supervisor? Which course(s) did the tutorial support? In which week of the course did you take the tutorial? What topic(s) did you plan to address? Roughly, for how many hours did you prepare for each tutorial?

If **No**, please explain, briefly, why this did not happen and whether you can arrange to take a tutorial session next term.

3. Item B (you had your own tutorial group in the Autumn term 2016)

Which course(s) did the tutorial support? Did you take the tutorials every week this term? If not, can you please briefly explain why not? Roughly, for how many hours did you prepare for each tutorial?

4. Aims for tutorials

The following points were raised by yourselves at the initial 'TUMIPS tutorial session'. Please fill in the right hand column.

Aim for tutorials raised at the initial 'TUMIPS tutorial' session at the beginning of term. I aim to:	*Your appraisal* with some exemplification *of whether or not this was achieved, and, if applicable, what you'd like in terms of support or instruction.*
1. Establish a friendly environment;	
2. Explain so they understand - rather than just present an answer - at a pace the students are comfortable with;	

3. Feedback on the students' work;	
4. Encourage discussion about the mathematics;	
5. Get the students to develop their own strategies for problem-solving which includes understanding what it is to prove something;	
6. Be prepared to answer all sorts of questions;	
7. Support students going up to the board to explain their solutions;	
8. Be enthusiastic about mathematics;	
9. Help the students prepare and practice.	

5. *Lastly, please tick in the appropriate box:*

	Strongly Disagree	Disagree	Agree	Strongly agree
a. The tutorial session(s) seemed to go quickly.				
b. Giving (a) tutorial(s) is a waste of my time.				
c. I now understand better why some students find their mathematics courses difficult.				
d. The students were not adequately prepared for the tutorial.				
e. I used what the students said or wrote to help explain to them.				