Design and Delivery of a Graduate Teaching Assistant (GTA) Program in a UK University: Experiences and Perspectives

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ABSTRACT: The value of postgraduates teaching in undergraduate chemistry laboratories has been a subject of interest at universities in the UK, Europe, USA, Australia, and New Zealand. The role of the teaching assistant (TA) is already well-established in many laboratories in the USA, and such roles have been increasing in popularity in the UK. Postgraduate (PG) demonstrators are however commonplace in UK higher education institutions (HEIs). Despite this, reports of formalized postgraduate programs involving a significant teaching component in the UK are rare. Here, we report on the first example of a Chemistry UK Graduate Teaching Assistant (GTA) program that started at The University of Sheffield in 2010. To the best of our knowledge, this is the first program reported of its type in the UK. For over 10 years, this program has resulted in a cohort of 24 GTAs who work alongside PG demonstrators in the laboratory and graduate with not only a chemistry Ph.D. but also enhanced teaching experience and professional development. Students in the GTA program have taken on a number of valuable roles, which are described herein. Positive outcomes include development of employability skills, contribution to the consistency of teaching, and knowledge transfer through involvement in training other PG demonstrators. The standard and consistency of the efforts of the GTA cohort have been demonstrated by a significant number receiving recognition for their teaching by gaining Fellowship of the Higher Education Academy (FHEA) accreditation, which is often associated with academic staff who are involved in teaching.

KEYWORDS: Graduate Education/Research, Laboratory Instruction, Testing/Assessment, Administrative Issues, Laboratory Management, Learning Theories, Professional Development, TA Training/Orientation

INTRODUCTION

The restrictions of growing teaching requirements and an increasing number of undergraduates have presented a challenge that higher education institutions (HEIs) in the UK are working to resolve.[1−9] UK HEIs are progressively hiring postgraduates (typically Ph.D. students) to provide assistance in the teaching of science undergraduates. In science degree programs in the UK, this teaching commonly takes the form of a demonstration in the teaching laboratory or practical sessions, as well as small-group teaching including tutorials.[1,8−16] Both in the UK and abroad, postgraduate (PG) demonstrators in chemistry have been shown to promote safety procedures, technical teaching skills, and guidance in academic knowledge.[1,5,8,12−14,17−21] Involvement of PG students in chemistry undergraduate teaching has been well-documented in other countries such as the United States of America,[10,11,20−23] Australia,[24,25] New Zealand,[26] and Canada,[27,28] in a variety of academic fields including anatomy,[3] biology,[11,22,29] engineering,[30] law,[25] politics,[2] and psychology.[31] While the titles of these postgraduate teachers vary, they are commonly referred to as teaching assistants (TAs) in North American universities, whereas they are known as PG demonstrators in the UK. These roles and titles vary by institution and country.

In North American universities, a formalized program for teaching assistants in chemistry is common practice and can form part of a student's Ph.D. program.[19] In contrast, chemistry departments in UK HEIs often recruit postgraduate students as paid PG demonstrators, for short periods of time in a part-time and noncompulsory role, to assist undergraduates in teaching laboratories, marking work or delivering tutorials. The differences between the UK and USA are summarized in Table 1. Regardless of country, the teaching laboratory setting is a common location for PG demonstrators to work, offering a situation where they offer help with hands-on demonstration, give small-group technique demonstrations, and can grow into leaders of the lab.[1,4,5,7,8]

Table 1. Differences between Demonstrators in the UK and USA

Description	UK	USA
Title	"Postgraduate Demonstrators"	"Teaching Assistants"
Sections	Lab-based	Can be lab-, recitation-, or grading-based
Qualification level	Typically Ph.D. level	Postgraduate[a]
Subject specialization	Typically chemistry students[a]	Typically chemistry students[a]
Typical teaching duties	Laboratory demonstration	Laboratory demonstration, office hours[b]
Typical marking duties	Marking laboratory work	Marking laboratory work, grading exams[b]
Typical other duties	Can be asked to deliver tutorials	Can be asked to attend relevant undergraduate lectures and proctor exams[b]

[a] Although postgraduate teaching assistants are the focus of this comparison, some institutions offer undergraduate teaching assistantships where subject majors may vary. [b] Roles may vary depending on type of TA role (lab, recitation, or grading/proctoring).

The crucial role played by PG demonstrators/TAs has received increasing recognition across a wide diversity of programs and disciplines.[1−3,10,19,22,23,25,29−32] The benefits of PG demonstrators/TAs in academic departments are many and invaluable, not just from an economic standpoint. The employment of postgraduate students as teachers has been presented as a solution that benefits the students being taught, those delivering the teaching, and the faculty itself.[2−7,32,33] The importance and versatilities of PG demonstrators/TAs mean they are heavily relied upon by various departments because of their strong motivation, extensive specialist knowledge, and outstanding teaching proficiency, together with high adaptability and flexibility, and, undoubtedly, the relatively low cost of hiring.[6,7,32,34] PG demonstrators/TAs are also accepted and valued among undergraduate students.[2,5,8,12,16,18,19,29,32] The PG demonstrator/TA will often have a different educational background or ultimate authority compared to the main lecturer, which can make them more approachable; previous studies report that students value their accessibility, specific knowledge, enthusiasm, and guidance.[12,16,19,29,32] PG demonstrators/TAs can be empowered by the choice of title for their role and can even act as role models for the students they teach.[2,5,12,29,35,36] When evaluating PG demonstrators/TAs, students tended to describe them as "kindly" and "engaged", rather than "formal" and "boring" in comparison to the main lecturers.[19,29,32]

Despite a growing body of literature on the development and benefits of the use of PG demonstrators/TAs, only limited research has been presented specifically on their professional development, including the qualities and abilities required for growth into leading teaching professionals.[6,33,36] Some research into demonstrator training programs, including the development of models for general and chemistry-specific training has also been conducted.[13,14,16,22,30] The effect of demonstrator training programs on the interaction between PG demonstrators/TAs and undergraduates in laboratories,[16,22,30] including consideration from a linguistic perspective, has also been explored.[5]

Although the training of PG demonstrators/TAs may require extra work, when advanced course instructions are taken into consideration, optimizing the system can provide long-range benefits to both undergraduate students and traditional PG demonstrators/TAs in chemistry laboratory education[17,20] as well as other fields.[6,11,32] In general, given the extensive provision and discussion of formalized TA teaching models in chemistry education within North America, drawing on these experiences could avoid various potential obstacles to the development of new teaching assistant programs.[1,13,20,22]

The implementation of a more formalized program was an attractive topic for consideration in the development of teaching and learning activities within the Department of Chemistry at The University of Sheffield, a large research-focused Russell Group university in the UK. In this new program, a variation on the role of the traditional PG demonstrator would be created. The bearer of this role would be known as a graduate teaching assistant or GTA, a subject specialist who has a Masters degree in Chemistry and who would be recruited into a program of Ph.D. study. In

Table 2. Description of the Differences between PG Demonstrators and GTAs at The University of Sheffield[a]

	Demonstrating at The University of Sheffield	
	PG Demonstrator	GTA
Teaching commitment	Optional	Required part of program
Selection	Open to all	Selection by interview
Level	Ph.D.	Ph.D.
Years taught	1−3, plus M.Sc. practical classes	1−3, plus M.Sc. practical classes
Teaching times	Occasional (chosen by PG demonstrator)	Entire year
Avg teaching hours	∼18 h across 3 weeks	∼270 h across academic year
Teaching support	Assisting students	Assisting students and PG demonstrators
Teaching duties	Assisting in lab classes	Assisting in lab classes
Marking duties	Marking laboratory work	Marking laboratory work
Other typical duties (optional)	None	Training/mentoring new GTAs and PG demonstrators, course development, liaison with teaching staff
Funding	Paid by the hour	Demonstrating contributes to Ph.D. funding
Duration of funded study	∼3 years	∼4 years
Typical professional recognition level (application required)	AFHEA	FHEA

[a] AFHEA = Associate Fellow of the Higher Education Academy, FHEA = Fellow of the Higher Education Academy.

contrast to a traditional PG demonstrator, GTAs would spend a considerable amount of time teaching in laboratory classes, demonstrating to undergraduates and marking work as a core and required part of their role. GTAs and PG demonstrators would work alongside each other in the lab, but the roles would differ. These differences are summarized in Table 2.

The benefits envisioned by the recruitment of GTAs would extend far beyond an increase in the number of laboratory teaching assistants. Undergraduates in laboratory courses would benefit from high-quality and consistent mentoring, and the GTA cohort would gain employability and academic teaching skills. PG demonstrators would benefit from working with the experienced GTAs, while the department would benefit from the creation of experienced demonstrators who would teach for a greater amount of time than a student in the conventional PG demonstrator role. Through annual recruitment, the GTAs would form a community where support, guidance, and peer mentoring would naturally occur. Here, we describe the design, delivery, and outcomes of this GTA program over the past 10 years, with recommendations and findings for future practice.

ORIGIN OF THE GTA PROGRAM IN SHEFFIELD

Practical laboratories in the Department of Chemistry at The University of Sheffield are delivered as discrete organic, inorganic, and physical chemistry sessions in the first three years of study. The amount of independence increases with progression through the degree, as students become more experienced (Table 3). Each class is overseen by a member of academic staff. All students are timetabled, resulting in several experiments taking place within one laboratory practical session. Therefore, effective and consistent teaching in each laboratory class and experiment is required.

Prior to the introduction of the GTA program, academic and technical staff were supported by three PG demonstrators, to ensure that the concurrent delivery of multiple experiments in one laboratory session ran smoothly. Demonstrators were typically recruited within their subject specialization (organic, inorganic or physical chemistry) on a three-week rotation (Table 2). Duties typically involved a practical demonstration as well as marking of associated prelaboratory, in-laboratory, and postlaboratory work. A brief training session was provided at the start of the academic year (introducing the structure and logistics of the laboratory), coupled with "on-the-job" training from working alongside more experienced PG demonstrators. Many PG demonstrators would opt to demonstrate the same experiments if they undertook further teaching duties in later years. Over time, these PG demonstrator's skills would develop, and this ultimately led to the creation of another experienced PG demonstrator, who then served as the "trainer" for future new PG demonstrators.

Although this process worked adequately, undergraduate students expressed some dissatisfaction with the variation in demonstrating support, which originated from a continuously changing supply of PG demonstrators. The three-week period of demonstrating duties also restricted the support and guidance that a PG demonstrator could offer, owing to their limited time and experience demonstrating in the laboratory each academic year. As demonstrating was voluntary, valuable skills and knowledge were often lost as demonstrators opted not to teach in higher years of their Ph.D. or once they had graduated. Consequently, it became clear that a longer-term demonstrating solution was required, to preserve continuity and to ensure that this valuable knowledge was not lost.

A proposal was developed by the then Head of Department (M.D.W.) who suggested that prospective Ph.D. students could have the opportunity to apply to a new role known as a graduate teaching assistant (GTA). The significant difference from the PG demonstrator role would be that, rather than employing a number of PG demonstrators on a three-week rotation, a GTA would deliver a larger, annual amount of teaching. Teaching would be an integral part of their period of

Table 3. Style of Laboratories Undertaken by Undergraduate Chemists in The University of Sheffield

Undergraduate Year	Style of Practical Work
First year	Guided enquiry "cookbook" style (individual/some pair work)
Second year	Guided inquiry "cookbook" style, including development of open-ended skills (individual/some pair work)
Third year (B.Sc.)	50:50 guided higher-level skills development (individual/some pair work): open-ended inquiry and team research
Fourth year (M.Chem.)	Individual project within a research group

Table 4. Typical Skills Gained by the Graduate Teaching Assistant (GTA) Cohort, with Evidence of How They Can Be Achieved

Employability Skills Gained	Evidence
Teaching skills	~1000 h of laboratory or classroom teaching and marking/grading over 4 years.
Communication and presentation skills	Delivering teaching in large- and small-group settings, through PowerPoint, chalk-and-talk, and verbal presentations, also providing verbal and written feedback.
	Teaching international students or delivery in an international setting allowed GTAs to develop their communication skills with students who do not have English as a first language.
Leadership and confidence building	Leading teaching activities, demonstrating individual skills. Delivering training for PG demonstrators built confidence.
Teamwork	Liaison with staff and students/team meetings and working with the GTA community.
Thorough subject knowledge	Repeat teaching of content across multiple years.
Planning and organization	GTAs are capable of balancing their teaching duties with their research, also planning teaching and training activities.
Dissemination of work	Delivery of training program to PG demonstrators. Presentations in internal and external settings about GTA experiences and discussions with staff and students.
Evaluation of teaching materials	Development or improvement of teaching activities/resources.
Accountability	Marking, completion of paperwork, working with staff.
Evaluation of teaching practice and accreditation	Liaison with staff and other GTAs, application for FHEA accreditation.

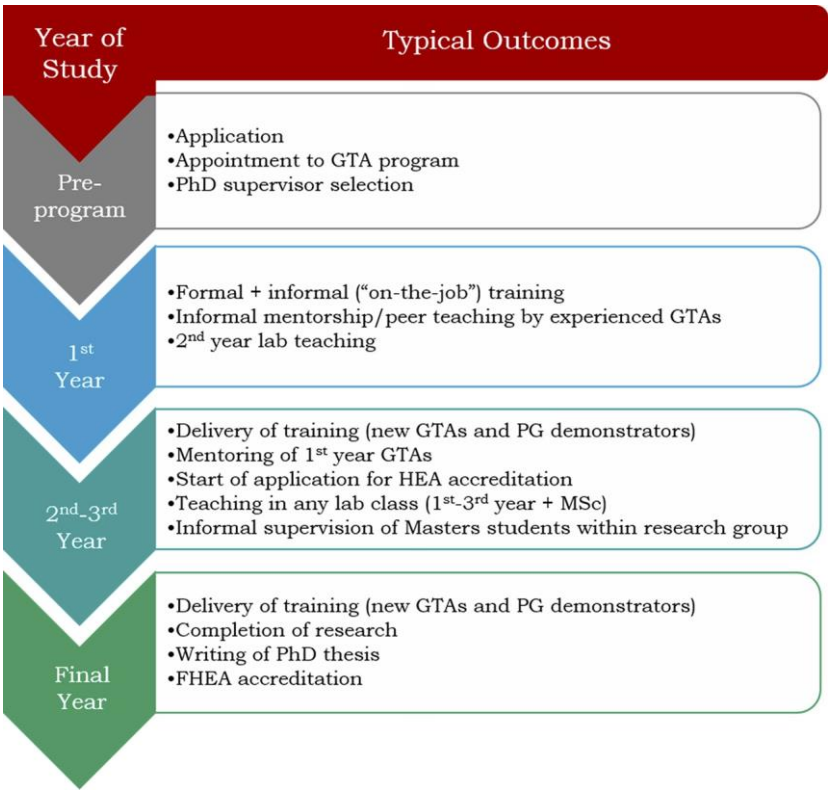

Figure 1. Typical outcomes from each year of The University of Sheffield Graduate Teaching Assistant (GTA) program.

study, rather than an additional source of income for occasional durations (Table 2). Consequently, their Ph.D. would change from a 3-year to a 4-year program, where the GTA would demonstrate for approximately 2 days per week over the duration of their Ph.D. The envisioned benefits to this program were bilateral. It would attract high-quality prospective Ph.D. students who were interested in teaching, its methodologies, and theories and, consequently, enhance the quality and consistency of demonstrating within the department. It also allowed opportunities for the development of many skills that the GTA may not usually gain during their Ph.D., such as significant teaching experience, delivery of subject matter, and development of pedagogical teaching methodologies (Table 4). The GTA role would also enhance professional development through employability skills, such as communication, teamwork, networking, planning and organization, troubleshooting, and problem solving, together with developing their academic knowledge.[2,5,15,37] It was envisioned that the experience of being a GTA would also be valuable for career preparation, especially for progression into teaching-based careers, although an intention to follow this career pathway was not a prerequisite to become a GTA. The value of teaching programs in the preparation for academic careers has been reported elsewhere.[19,33,37]

STRUCTURE OF THE SHEFFIELD PROGRAM

It has been seen that in many effective North American TA models, a fair and transparent selection system comes first, followed by a comprehensive training plan, supervision, and mentoring.[1,7,12,13,16,19,22] Particular attributes of demonstrators (i.e., subject knowledge and development of teaching experience over time) have previously been shown to impact students' performance, and a selection process was decided to be incorporated as a valuable part of a formalized GTA program in Sheffield.[1,12,14,38] The selection procedure for GTAs must show fairness and transparency as well as consistency. This will impact the validity of a GTA as a respected teacher, which in turn will enhance student learning.[7,38] The selection criteria must be appropriate and reflect the candidates' knowledge and teaching experience, as well as their enthusiasm to teach.

Although several TA programs have been described in detail for USA higher education institutions, the differences between the UK and USA systems meant some adaptations for the Sheffield GTA program were required. For example, the Sheffield GTA program only recruited prospective Ph.D. students, as it is typical for UK HEIs to employ students as PG demonstrators/TAs who have already gained a B.Sc. or Masters degree in their subject/major specialization. This differs from some USA/European universities where TAs may be upper-year undergraduates, possibly because the institution may not have a postgraduate population. Another difference is cohort size; universities in the USA deliver large-scale departmental training programs as they recruit large cohorts of TAs each year. By contrast, in Sheffield only three or four GTAs are recruited each year; this smaller number allows for an apprenticeship/peer teaching training approach. Regardless of level, universities have recognized the importance of training and empowerment of PG demonstrators/TAs and are working to achieve a skilled workforce of demonstrators for undergraduate students.[13,18,19]

The aim of the selection process for the Sheffield GTA program was planned to be a variation on that of a regular funded Ph.D. student. A formal application preceded an interview process with a panel of academics, which included a discussion about a hypothetical teaching scenario. The

selection process aimed to typically recruit three or four Ph.D. students per year; the emphasis was on recruitment of students who would be good teachers, rather than on the selection of candidates whose research projects were evenly distributed between each subject section (inorganic, organic, physical). Although prior teaching experience was not a prerequisite, many applicants already had an interest in teaching and supported outreach activities, either before university, or during their own undergraduate years. Successful applicants then selected a supervisor of choice, subject to both supervisor and departmental approval.[39]

During their period of study, GTAs undertook a mixture of teaching and research. A GTA in the Sheffield program undertakes approximately 2 days of teaching/demonstrating duties throughout the two semesters of the academic year, totalling ca. 270 h per year. This includes pre- and postlaboratory marking. Teaching hours and duty allocations vary slightly each year, depending on a number of factors, including student cohort sizes and numbers of PG demonstrators. With the exception of the changes discussed in ref 39, there is no differentiation in the number of demonstrating hours between GTAs in different years of study.

In their first year, GTAs generally begin their teaching in a teaching laboratory session aligned to their area of research, preferably starting their demonstrating career in a second-year class. This route is considered an optimal strategy, to minimize pressures encountered by teaching new undergraduates, who are settling in during their first year and require more training and moral support versus the challenge of more advanced skills taught to more experienced third-year undergraduates. For the first few months of demonstrating, new GTAs are trained and mentored by GTAs from a higher year allocated to the same laboratory, who can provide informal advice and exemplary practice. This training takes the form of an "apprenticeship" model, through the provision of hands-on training and direct mentoring. The positive effects of such "peer training" have been reported previously in both chemistry and other fields.[3,17,20,21,23,30] The training offers the new GTA the chance to ask questions and become familiar with expectations in a less formal, and applied, working environment. Even with the additional support provided by the recruitment of three or four GTAs per year, a number of PG demonstrators are still required and are employed as usual on three-week rotations to work with and alongside the GTA cohort.

After their first year demonstrating in a second-year lab, GTAs generally move to teaching laboratories in other years and/or areas (inorganic, organic, or physical), to gain experience in different teaching settings with varying levels of inquiry (Table 3). As their experience developed, they would assist in mentoring new GTAs who joined the program and help deliver training for both GTAs and PG demonstrators who they would be working with. The final year of the program typically focused on finishing their Ph.D. research, writing up their thesis, and applying for professional recognition for their teaching practice (Higher Education Academy (HEA)) accreditation, see below.[44] A typical progression through the program is summarized in Figure 1.

The basic responsibilities of GTAs are similar to those expected of a paid PG demonstrator as explained previously. All GTAs and PG demonstrators, regardless of status, are expected to assist in the safe and effective delivery of teaching in the undergraduate laboratory that they are working in. The nature of the laboratory work varies in each class with the undergraduate year group and individual experiment but broadly includes providing students with skills for experimental techniques, both practical and theoretical as well as fostering confidence in the laboratory (Table 3). Support is given to undergraduates in several ways: verbally through "in-lab" teaching through short presentations and discussions, through individual guidance, or in small groups (3−4 students) together with some larger group activities through "in-lab" announcements. Other support is given through written feedback for pre- and postlaboratory report submissions.

BENEFITS OF THE GTA PROGRAM

The Sheffield GTA program began in the 2010/2011 academic year starting with three GTAs, one in each subject area. GTAs have become an integral part of the chemistry teaching team in Sheffield. Owing to their sizable teaching commitment, GTAs are often the most experienced demonstrators in a laboratory session and become very well-acquainted with specific experiments and pieces of equipment. They are a source of valuable information and tips for less-experienced PG demonstrators, new GTAs, and even academic staff who are supervising the session. The consistent presence of the same individual for an entire term, or cohort, also has positive impacts: The GTA gains valuable experience which can be passed on to others, academic and technical staff benefit from a reliable and experienced demonstrating assistant, and undergraduate students have a recognizable face and a reliable source of information and advice throughout their time in the laboratory.

Owing to the difficulties in accurately evaluating teaching performance quantitatively, it is important to note here that the outcomes of the GTA program have been assessed at the anecdotal level. The large number of variables associated with our GTA program delivered across several years meant that quantitative and qualitative data were not acquired. The literature documents issues traditionally associated with reliably assessing teaching quality and student progression through varying methods as discussed in detail relating to student evaluation of teaching (SET).[40−42] Variables included a lack of any one student group in any one academic year that was taught solely by GTAs, together with the variation in each GTA's teaching style, subject specializations, and student cohorts taught. Some reports state that for conclusive evidence to be presented through SET more evidence is still required.[40−42] Here, we present anecdotal evidence collected over a sustained period through regular GTA meetings and annual reviews for context.

After the implementation of the GTA program, GTAs were quickly valued by the undergraduates as well as the academic staff. Anecdotally, undergraduate students liked GTAs, because they felt they had someone with laboratory experience they could identify with (and often knew from previous laboratory sessions) to consult. This was not only because the GTA was a recent graduate of a chemistry degree that they were studying, but also the GTA was more accessible and less intimidating than the very busy academic.[2,29,32] GTAs are popular sources of information and advice for students, including on future years of study and career pathways. This is particularly the case during undergraduate laboratories because GTAs interact with students to enhance and support safety, provide guidance, develop procedural skills, and teach chemical concepts. PG demonstrators gained additional marking support and training from the GTAs, which allowed marking to become more

consistent. GTAs are a valuable source of experience to their peers who may be new to teaching a particular lab session.[17,20,21,23,30] In recent years, this has been exemplified following the involvement of the GTA cohort in training new PG demonstrators, as described below.

It became apparent to academic teaching staff that GTAs were very keen teaching assistants in each of the laboratories, who wanted to develop their experiences, and quickly became involved in other valuable teaching-related duties. A permanent role on the departmental academic laboratory committee was created for a senior GTA, allowing them to contribute to teaching decisions on a departmental level. GTAs often take the initiative to develop or improve teaching methods or practices for experiments that they demonstrate.[8] Following staff approval, improvements made by GTAs are subsequently adopted by other PG demonstrators, resulting in a culture of change and improvement across the department teaching laboratories. A range of additional outputs have been created as a result of GTA involvement, some of which are listed below:

- Updated experiments based on informal feedback from staff and students.
- Improvement of mark/grade schemes (and therefore marking consistency) through observations made during marking.
- Implementation of improved experimental procedures with minor edits or the creation of new assessment questions for consideration by staff.
- Updated Sheffield practical technique student guide, including its transfer to a more accessible electronic version for students and staff.
- Design and implementation of a small-group teaching activity to help students understand the basic theory behind inorganic NMR spectroscopy.
- Production of guides to assist students with scientific writing, including methodology, writing an experimental section, and guidance documentation on how to keep a laboratory notebook.
- Presentation by a senior GTA about their perspective of the Sheffield GTA program to an external audience at a leading UK Royal Society of Chemistry (RSC) Annual National Educational Conference.

A sense of community at Sheffield is instilled from the beginning of a GTA's induction into the program, which includes introductory meetings with all GTAs on the program and the pairing of each new member of the team with a more experienced GTA for the first few weeks of their teaching. The small GTA cohort size at Sheffield also helps to build a supportive community. The establishment of a community among teaching assistants has been reported elsewhere;[16,17,20,23,30] its presence, impact, and importance should not be understated.[21] As a team, developments, pedagogical issues, and experiences are frequently discussed with other GTAs on the program during formal or informal meetings. This has resulted in a supportive and diverse community which shares best practices and advice, regardless of year of study, area of expertise, or demonstrating level.

Within a year, it was clear that the GTA program in the Department of Chemistry had had a positive impact; to date, 24 GTAs have been recruited. During the time of the program, the role of the GTA has evolved and developed. GTAs have been encouraged to obtain professional accreditation for their teaching abilities. The University of Sheffield facilitates development of staff and postgraduate students' skills in teaching and learning through AdvanceHE Higher Education Academy (HEA) accreditation, delivered through the university's Elevate professional development initiative.[43] HEA accreditation is an international standard and reflects the quality of the teaching and learning activities that the recipient contributes to, providing them with a demonstrable output and professional recognition of their teaching quality and efforts.[44,45] Successful applications for HEA accreditation by Chemistry GTAs have grown from 1 in 2016 to a total of 14 to date, all at a level of Fellow of the Higher Education Academy (FHEA). The level of Fellow is the same as that required by new lecturers at The University of Sheffield. The presence of numerous GTAs obtaining this equivalent recognition allows for an increased consistency between laboratory teachers at every level.[46] Professional recognition also confers an additional advantage for applications to future academic positions in higher education, where HEA accreditation is typically valued. This is in addition to the recognized effectiveness of teaching programs in the preparation of graduating students as "future faculty" in both chemistry and other subject areas.[8,10,16,19,22,30,37,46] Furthermore, to date, two PG demonstrators have successfully gained FHEA status, and at least five have obtained the Associate Fellow of the Higher Education Academy (AFHEA) accreditation. The number of GTAs and PG demonstrators being accredited for their teaching indicates a positive culture toward teaching excellence.

Since graduating, six GTAs have subsequently progressed into HE and secondary teaching careers, while others have entered a variety of fields including moving to industry or outreach, remaining in university research, and working for the National Health Service (NHS) (Figure 2). This variety in career pathways demonstrates that the GTA role does not restrict holders to education-based careers and that their GTA experience has developed a valuable skill set that offers many diverse opportunities.

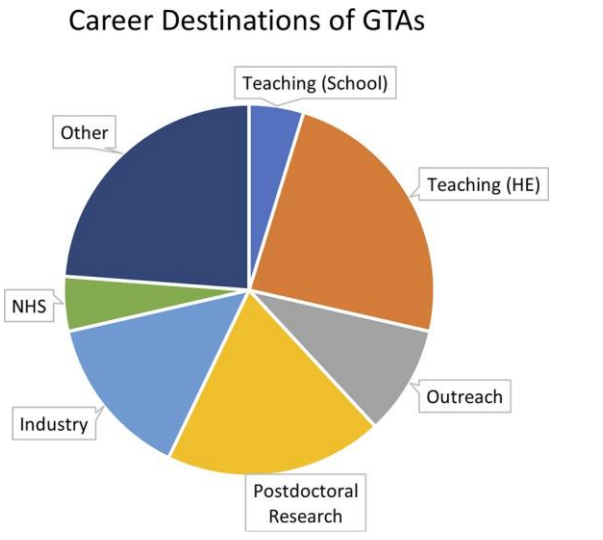

Figure 2. Pie chart showing the career destinations of graduates from the GTA Ph.D. program between 2010 and 2021 (n = 21). Career fields accurate at date of publication.

INTERNATIONAL OPPORTUNITIES FOR GTAS

GTAs who are working internationally, or who are working with international students, need further support owing to a potential language and cultural disparity.[16,30] However, these opportunities can enhance the learning experience for both GTAs and undergraduate international students. This aspect of the GTA role is encountered in the diverse student cohort in Chemistry undergraduate laboratories in the UK. More significantly, a unique opportunity became available for the Sheffield GTAs to teach laboratory chemistry abroad. The Department of Chemistry at The University of Sheffield delivered a joint (3 + 1) B.Sc. degree with Nanjing University of Technology (NJTech) in the People's Republic of China.[47−49] In this joint program, the first two years of the Sheffield B.Sc. degree course were taught in China over three years, where both lecture and laboratory classes were delivered in English by Sheffield academics. Thereafter, these Chinese students traveled to Sheffield to join the home students, in the third-year cohort, completing their final year of study together. Once established in China, the manager of the program requested more staff to help with laboratory delivery and assessment. Owing to their extensive teaching experience, GTAs were chosen by the Head of Department to help with the delivery of the program abroad. Each year, three GTAs were given the opportunity to apply for this international role. This GTA-specific opportunity involved spending two intensive weeks in China, assisting full time with laboratory teaching, marking, grading, moderating, and delivering feedback sessions and tutorial classes. The GTAs also served as ambassadors for The University of Sheffield, acting as role models for the students. The same GTAs also taught the Chinese students during their studies in the Sheffield teaching laboratories and assisted with welcome events when the students arrived in the UK. The consistent presence of GTAs throughout the NJTech student's degree provided them with familiar faces with whom they had already built up an academic rapport during their year of overseas study. In total, during the past 6 years, 16 out of the 24 Sheffield GTAs taught in China as part of the program, providing valuable professional development and experience, by teaching in a different educational setting and to students with English as a second language (ESL).[16,30] This unique opportunity also provided valuable evidence for one of the case studies required for FHEA accreditation.

TRAINING OF POSTGRADUATE (PG) DEMONSTRATORS BY EXPERIENCED GTAS

General Introduction: The Importance of Training

Training demonstrators and markers how to work in the lab and how to mark student work has benefits for teaching output and the student experience.[13,22,30] PG demonstrators spend considerably more time in contact with undergraduates than academics do, and it is therefore important to ensure they have quality training to take on this role. Despite this, there is a widespread problem throughout academia regarding the training of PG demonstrators.[12,16,20,30,34] Chemical education research shows that often universities place demonstrators in front of undergraduate students with little or no training on how to teach.[4,50] The challenge must be repeatedly tackled every year to bring all demonstrators, many with no teaching experience, up to the same level of proficiency in order for them to teach in the undergraduate teaching laboratories.[16] As discussed in the Introduction, North American universities have recognized the important role that their PG demonstrators/TAs play, and many departments have been striving to design and develop effective PG demonstrator/TA training programs that would ensure undergraduate students have a positive learning experience.[7,16,30] The training delivered gives direct, explicit, and consistent advice, allowing demonstrators to understand how to deliver their teaching.[12] However, there are far fewer advances in the UK, despite recognition that demonstrators are powerful tools to increase the effectiveness of chemistry learning, due to the considerable amount of contact time they spend directly with undergraduates versus academic members of staff who have many other duties and less flexibility.[12,15] In order to feel confident and competent in the laboratory, PG demonstrators/TAs both want and need preparation and supervision. Currently, there is a huge disparity between the investment made in sufficient training, and the sizable responsibilities given.[30] In order to be effective, the training that is offered must be more comprehensive than a simple orientation activity.[12,13] Training has been shown to be most effective when it includes sessions regarding laboratory practice, prelaboratory briefing sessions, formal and/or informal mentoring during the semester, promotion of a learning culture where demonstrators share ideas and knowledge, and debriefing or "lessons learned" sessions at the end of the semester. These findings were considered to help inform the design of a training program for PG demonstrators at The University of Sheffield.[14]

Our training program has included many of the important attributes that have been proposed for GTA and PG demonstrator training in recent literature. These include the importance of supporting the undergraduates for their practical skills (psychomotor experiences), their understanding of theory behind the practical work (cognitive experiences), and, very importantly, how to interact with students in the laboratory, inspire confidence, and work in a safe environment (affective experiences). This has been discussed in the literature as the meaningful learning theory.[14,18] It has been noted that successful teaching leads to improved self-efficacy as well as professional development.[17]

Our training program was developed during two academic years with the aim to support PG demonstrators in their confident delivery of their teaching and to maintain standards across all the laboratories. Up to the end of the 2016/17 academic year, there had been some initial training for both GTAs and PG demonstrators. A 3 h session, led by a member of the academic teaching staff, covered how to mark a first-year postlaboratory report, by following a model answer and mark/grade scheme. The style of teaching and assessment varies significantly throughout the undergraduate degree program, as students become more independent learners and gain experience as practising chemists. Therefore, a single example could not account for the wide variation between laboratories and different year groups that demonstrators may be assigned to, requiring the training program to be more comprehensive.

As explained previously, a number of other UK HEIs have also proposed the need for more in-depth training of PG demonstrators/TAs.[1,10,20,30] For the 2017/18 academic year, it was decided that further training was required for PG demonstrators, and it was at this point that three experienced GTAs were formally invited to be involved with the delivery of a training session. Three GTAs delivered an optional training session, based on a variety of experiments that were being

Table 5. Outline of Training Program Delivered to Postgraduate Demonstrators

Session	Theme	Delivered By	Typical length	Typical Content
Introductory	Preparation for demonstrating	Academic manager for postgraduate demonstrators	0.5 h	Familiarization with teaching laboratories, use of manuals, expectations
	Logistics	GTA	0.5 h	Key personnel, timings, lab structure, demonstrator distribution, pre/postlaboratory arrangements
	Pedagogy	GTA	0.5 h	Attributes of effective demonstrators, good practice, key points to consider, discussion with experienced GTAs
Specific training	Experiment-specific training	GTA	1.5 h	Aims and objectives, key techniques, timings, possible hazards, common mistakes, assessment, seeking further advice

delivered in the laboratory, focusing on the use of a mark/grade scheme, and how to give good feedback. The session was well-received by the attendees who gave positive verbal feedback to the session leaders. The standard of demonstration was anecdotally deemed by teaching staff to have improved through laboratory committee discussions. During their monthly meetings, the GTA team reflected upon the training, and it was decided to extend the training the following academic year. It was proposed that the new training would be more formalized and mandatory for anyone with demonstrating responsibilities to ensure full attendance.

The 2018/19 academic year training program began with an introductory session for all demonstrators, with a presentation of a global overview of their duties hosted by the academic manager for PG demonstrators and GTAs. The session then focused on the explanation of the structure of the laboratories and introduction of the individual laboratory managers, logistical matters (i.e., where to pick up teaching materials, timesheets, and payment claims), and introduction of the experienced GTAs who would deliver the specific training. Due to the success of their involvement during the previous year, GTAs were formally invited to lead the training, empowering the GTAs by giving them the opportunity to plan and design the training program.[36] Facilitation of demonstrator training by TAs has been reported at other universities.[23,30] Consequently, the GTAs could pass on their expertise and be introduced to the PG demonstrators that they would be working with during the academic year. If a PG demonstrator was absent, individual training was arranged before they commenced their demonstrating duties. The remainder of the session not only focused on the educational and pedagogical reasons for the importance of training[14,18,30] but also on the "hands-on" breakdown from a GTA perspective of the laboratory teaching structure and laboratory committee, required preparation, expected behaviors and emphasis of the important attributes of being a good demonstrator. These attributes include what needs to be prepared before a session and how a demonstrator should behave in the laboratory, and they emphasize interaction, promotion of safety, facilitating students to reason through discussion, and respect.[12] The focus of the session then developed into a breakdown of how to mark reports with examples of the confidential mark/grade schemes, together with specific marking tips such as consistency during marking, and what constitutes good quality feedback, with examples of appropriate comments for context.[17,19]

Specific Training Carried Out by Experienced GTAs for Each Experiment and Laboratory Session

The introductory session described above was followed by mandatory, specific training sessions, for each of the laboratory practicals taught during the academic year. These sessions took approximately 1.5 h and were delivered around 1 week before the specific practical(s) were due to begin (Table 5). The sessions were delivered by GTAs who had the most experience with running the laboratory experiments and went into considerably more detail than the introductory session.[23,30] Key concepts from the introductory sessions were reinforced, and specific details were then discussed about how the laboratory runs, the timings, and other logistics (e.g., individual or pair work). The training detailed how to interact with the students effectively and how each of the demonstrators would be distributed throughout the laboratory on the day. Other important guidance was given, such as what a demonstrator should do the week before the next experiment(s), such as marking and preparation. Further information discussed the breakdown for each experiment, including the background theory, what the experiment entails, key safety points, and common mistakes. General and specific marking information, with an emphasis on how and where to seek assistance, was provided. A list of GTAs that have previously demonstrated that specific experiment was also included, so demonstrators knew who to seek advice from. All presentations were archived, so that they could be updated and used in future training sessions.

Training Program Outcomes and Improvements

The tailored sessions were very well-received by attendees, who thought the sessions were very detailed and appreciated the breakdown, best practices, and student "sticking" points given for each experiment. Attendees also appreciated support in understanding the mark/grade schemes together with marking guidance and how to give useful feedback to the students. Although discussion on best practices for key laboratory techniques was well-received, photographs of unfamiliar setups or equipment were recommended for future sessions. A further improvement would be the creation of an opportunity for demonstrators to familiarize themselves with the teaching laboratories before the start of the training, including the opportunity to carry out the practical themselves.[13] In line with programs reported elsewhere, a more comprehensive training program was anecdotally seen to improve the quality and consistency of teaching, marking, and feedback, based on informal feedback from staff.[20,29] Overall, a structured training program of this nature was considered a useful strategy to train a PG demonstrator cohort, regardless of experiment, experience, or year that they are teaching. Such a program helps to create consistent and effective demonstrating across the entire undergraduate laboratory course. This initiative allows less experienced PG demonstrators to gain both general and experiment-specific tips, knowledge, and best practices from experienced GTAs who have demonstrated the experiment many times before. This form of peer teaching is encouraged with many programs, as it allows PG demonstrators to link with the experts in the laboratory and builds

important relationships as part of a community.[3,8,17,20,21,30,34] It also allows valuable professional development for the GTAs (Table 4).[23] It is suggested that delivery of the training program should take place during the summer prior to the new academic year starting, ensuring there will be a cohort of well-trained PG demonstrators ready to support undergraduates. With the groundwork in place, it is hoped that this training style will continue in the department for the foreseeable future.

LIMITATIONS OF THE GTA PROGRAM

Despite the benefits of the GTA program described above, some limitations have been observed. The large time commitment required for demonstrating means that the program may not be compatible with some research arrangements, for example, a student whose program of study is split across multiple departments, or where there are other significant, less flexible research commitments for the Ph.D. students. As discussed in the literature, GTAs (and demonstrators in general) occupy a unique position between students and teaching staff, and the perceived role of a demonstrator has been shown to vary among students, faculty, and the holders of the role.[2,5,7,12,26,29] Several UK-based studies have identified problems with the PG demonstrator/TA system, including issues with pay, working hours, and a lack of feedback or training, while in the USA the legal employment status of graduate students has been previously examined.[7,51,52] The nature and discrepancies in perception of the role may potentially lead to issues in workload, teaching allocation, and time budgets.[7] These critical issues should be explored and resolved as fully as possible, prior to the implementation of any GTA-type program. Supervisors of any GTA student also need to understand the nature of the scheme and its time requirements, so that they are fully aware of the additional commitments that their Ph.D. student will have on top of their primary research.[2,9] Other responsibilities that could be placed upon the GTA, such as supervision of project students, need to be carefully planned to ensure an adequate balance between teaching and research.

CONCLUSIONS

The GTA program in the Department of Chemistry at The University of Sheffield that has been running for the past decade has been well-received by both academic and technical staff, as well as by undergraduate students who have embraced the consistency of a team of experienced GTA demonstrators. PG demonstrators have benefitted from working alongside GTAs, and the development of a specialized training program has helped to enhance the ability and experience of all PG demonstrators.

By working closely with the laboratory managers and technical staff, GTAs have enhanced the delivery of the laboratory program to undergraduates. GTAs not only have been a teaching assistant in the laboratory, but also have become competent teachers, contributing to the development of the laboratories, training and supporting students, developing new practical resources, and representing their cohort and peers in both internal and external settings. GTAs have enhanced their own career prospects through professional development (Table 4 and Figure 2), gaining valuable employability skills, both in Sheffield and, for a majority of the GTA cohort, when teaching abroad. Many of the GTAs have already gained FHEA accreditation. Teamwork skills have been strongly developed through the establishment of a close-knit community, which has, in turn, resulted in stronger support for all PG demonstrators in the department. This is an aspect of the GTA role that has also been recognized in other HEI programs.[21,23]

GTAs can bring strength to undergraduate laboratory teaching as teachers and as peers, and they are excellent role models for the undergraduate cohorts. We feel that a GTA program, as described in this publication, that contains fair and comprehensive recruitment and training, would be of value to other HEI chemistry departments. A program of this type may benefit HEIs who struggle with demonstrator recruitment or with recommendations on the number of teaching hours that postgraduate students can undertake.[53]

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

The following people participated in the GTA program: Ahmet Cankut, Christopher Parks, Richard Plenderleith, Christopher Gibson, James S. Wright, Benjamin Peerless, Phil Reeve, Jonathan Simmons, Alex Fields, David Griffin, Thomas Roseveare, Bethany J. Crowston, Zoe Smallwood, Jenna Spencer-Briggs, Rachel Mowll, Thomas Hogg, Emma Owens, Eren Slate, Matthew Watson, Sam Ivko, Sally Morton, Heather Carson, Francesca Dennis, Charlotte Kiker. Thanks to all the academic and technical staff who worked closely with the GTAs during their role: Tom Anderson, Richard Bottomley, Jenny Burnham, Colin Crook, Alison Smith, David Towers, Sam Parkin, Ed Warminski (Sheffield), as well as Haijan Shi (Karen) and Li Hi Qi (Shirley) (NJTech). With special thanks given to GTAs that helped develop and deliver the tailored training sessions, without their hard work the training program would not have happened: Heather Carson, Francesca Dennis, Sam Ivko, Charlotte Kiker, Sally Morton, Emma Owens, Eren Slate, Matthew Watson.

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