Utilising graduate teaching assistants to implement active learning at university level

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Abstract
Active learning is recognised as a crucial component of university courses in enhancing performance and retention. However, universities face numerous challenges in broadening the provision of active learning, including time constraints, and a lack of staff training and confidence to develop appropriate activities. This article outlines an approach taken at the University of Southampton to engage a team of graduate teaching assistants (GTAs) in the process of developing, delivering, and evaluating active learning resources to support small-group teaching in chemistry on a Science Foundation Year programme. A team of four GTAs developed nine activities during the 2015/16 academic year, with evaluation supporting their enhancement for 2016/17. The article outlines the progress of this work over two academic years, providing evidence of a positive impact on students and teachers alike.

Introduction
Over recent decades there has been a clear shift from the traditional lecturing style, often referred to as a “sage on the stage” approach, towards more student-centred methods, which actively engage learners in processing information by reconstructing the knowledge they have gained (King, 1993). Certain active learning activities, such as collaborative learning, have been deemed particularly suitable for diverse student cohorts and are linked to reduced attainment gaps (Haak, 2011).

Initially, there was some resistance to change, which still lingers today, with a lack of understanding of the benefits of active learning approaches hindering their implementation in undergraduate curricula (Bonwell & Eison, 1991). There is much qualitative and quantitative evidence of the educational benefits of various forms of active learning (Springer *et al.*, 1999; Michael, 2006; Freeman *et al*., 2014; Prince, 2014), although there are numerous challenges faced by universities which hinder the widespread adoption of such practices.

Besides resource concerns, it appears that a change in the attitude of teaching staff, as well as students, towards innovative approaches needs to take place in order for active learning to become more widespread within HE. Roberts (2016) notes that, at its core, active learning seeks higher level student engagement that involves a shift of participation and responsibility from teacher to student, creating feelings of discomfort both for parties. Similarly, anthropologist Lauren Herckis discovered that the fear of (perceived) public failure and poor student evaluations may deter lecturers from adopting innovative teaching methods. The results of Herckis’ observation of academics have recently been described in an article in The Times Higher Education (Matthews, 2017). This suggests that staff would benefit from support in adopting new methods.

Many UK Higher Education Institutions are confronting the issue of teaching increasing numbers of undergraduates and meeting rising student, societal and governmental expectations, while dealing with mounting resource constraints in the form of funding, facilities, and staffing (Park, 2004; Muzaka, 2009). As academics are expected to devote a substantial proportion of their time to research, administration, and outreach, it is not surprising that teaching innovation sometimes slips down the agenda.

In an attempt to address these concerns, HEIs in numerous countries have adopted a system where graduate students take the role of teaching assistants, typically undertaking laboratory and workshop supervision, and marking lab reports. In the UK, postgraduate researchers typically undertake teaching as part-time paid work. and have taken a wider role in teaching undergraduate students, with many university programmes becoming increasingly dependent on them (Muzaka, 2009,). This emphasises the importance of training and professional development for GTAs.

Many US universities offer dedicated GTA training programmes or apprenticeship schemes, led by senior teaching professionals (Park, 2004; Young & Bippus, 2008). However, Milner-Bolotin (2001) notes that these often require allocation of substantial senior staff time. Given the priority often placed on research, this can create a conflict between time spent on research and that spent on teaching (Gray, 1992), which is also an issue in UK Higher Education (Coate *et al.*, 2001).

Milner-Bolotin (2001) describes a case study that could offer a solution to some of these concerns, suggesting that informal teaching communities of GTAs can start a change in the entire teaching culture of a research-focussed institution.

Project outline and goals

In this article we describe a structured approach to the development of active learning resources through the establishment of a teaching team of GTAs, addressing some of the aforementioned issues around the implementation of active learning. These activities were utilised with a diverse student cohort of Science Foundation Year chemistry students over two academic years, with the approach being potentially transferrable to other disciplines and cohorts.

We had three key goals in implementing this project: 1) to increase student engagement and satisfaction with teaching; 2) to establish a framework for sustainable continuous professional development for GTAs through reflective practice, team work and evaluation; and 3) to minimise time input from senior staff.

Implementation

The Science Foundation Year is a one-year programme aimed at students who have non-traditional academic backgrounds for study on science programmes at degree level. The course covers biology, chemistry, and maths, and features whole-cohort lectures and smaller group (<20) workshops facilitated by DR and 2-3 GTAs from a rotating pool of 4. There are three one-hour lectures in chemistry each week, which feature a high degree of interactivity and employ a 'partially flipped' format (Read *et al*., 2016). Workshops run for two hours after the week's lectures are complete, and typically feature worksheet-based problem sets which students work through with support from peers and GTAs.

After the first year of the programme (2012/13), there was a strong focus on enhancement of the lecture and laboratory components of the chemistry course, resulting in a lack of development of the workshops. This issue was brought into sharp focus by student comments on module evaluations at the end of 2014/15:

> *"I feel that the workshops could be made more useful by including different types of activities; e.g. more discussion, games, quizzes etc."*

> *"Workshops were not useful and about half of students commented that they just felt rushed through examples and either didn't understand any better than when they went in or were more confused when they left."*

These comments highlighted the need for a new approach to workshops in 2015/16, but progress was hindered by a lack of staff time to design and develop new resources. To solve this problem, a team of four GTAs (two postgraduates, one teaching fellow and one technician) was established in January 2016 with the aim of developing resources for deployment in workshops during semester two. DR provided initial training, in which the rationale was explained and a framework for developing activities was introduced. There was a particular emphasis on planning and evaluation, with the aim of giving GTAs the opportunity to develop their teaching skills. The stages of the approach, through design, delivery, and evaluation, are outlined below.

Preliminary discussion
The GTA team collectively discussed the forthcoming workshop schedule, allocating workshops to individuals based on topic preferences. Each GTA worked on a four week cycle such that each designed and delivered an activity during their allocated week in turn, with one new activity being introduced each week.

Planning and design
DR created a pre-activity form for GTAs to complete during planning, which prompted them to define the intended learning outcomes and to indicate how their achievement would be monitored. An extract from a pre-activity form is shown in Figure 1. The GTA would then create the activity, creating and printing resources. A meeting was convened each week in which the activity would be presented to peers, with a thorough discussion of all aspects of planning. Feedback informed refinements to the activity prior to delivery during that week's workshop.

Name: STEVE BARNES Workshop: 12/02/16 Title of activity: "Back and Forth: Structure and Spectra"

What are the learning outcomes for your activity? *i.e. After this activity, students should be able to describe/explain/evaluate etc....* *After this activity students should be able to:* *LO1: Predict the infrared, mass spectrum, and ^1H NMR spectral data observed upon analysis of simple organic molecules.* *LO2: Deduce the structures of simple organic molecules from infrared, mass spectrum, and ^1H NMR spectral data.*
How will you introduce the activity to make it clear to students what they need to do and what they are learning? *To introduce the activity, I will give a very brief talk instructing the students on how the activity works. I will explain what information they need to convey on their worksheets, and how this can be used to identify a compound's structure.*
Briefly explain how your activity works and how it addresses the learning outcomes? *In groups, students will be given the structure of an organic compound. As a group, they are required to deduce the spectroscopic data that would be obtained upon analysis of this compound, including IR absorption peaks, potential fragmentation peaks from a mass spectrum, and the peaks expected in a ^1H NMR spectrum. The students should list this data in the tables provided, but they have the opportunity to sketch them if they would like.* ***(LO1)***

Figure 1 Extract from a pre-activity planning form

Activity: **Back-and-Forth**

	Yes, a lot	Yes, a little	Not much	Not at all
Did you enjoy the activity?				
Did you understand what you had to do?				
Did you learn from the activity?				
Would you recommend this activity is used in future?				
What was good about the activity?				
What would you improve about the activity for next time?				

Figure 2 Post-activity student evaluation form

Delivery

Students were briefed to work in groups (some activities required specific numbers per group) and to engage in discussion throughout. The lead GTA and at least one other (and DR) would circulate, offering help where needed, although the goal was to hand as much responsibility for learning over to the students. In most cases, the activities were designed to be self-paced, meaning that students would complete tasks at different times. As such, it was important for the GTAs, most notably the lead GTA, to talk to each group as they finished to ensure that they had indeed achieved the learning outcomes, and to address any lingering concerns or questions.

Evaluation

A short evaluation form (Figure 2) was distributed to the class after completion of the activity to gather feedback. The aim was to facilitate reflection on the part of the GTAs regarding the strengths and weaknesses of the activity and to support further development for the following academic year, as well as giving them insight into students' perceptions of the activity. The GTAs were encouraged to compile a summary of student evaluations before completing a post-activity reflection form. Questions on this form prompted GTAs to critique the activity, comment on how students coped with and learned from the activity, and identify changes required for the following year. Other GTAs and DR also provided feedback on the activity after the workshop.

Student response

Due to external pressures on the GTAs, the post-activity evaluation was not always fully documented. Student responses (n = 157) on evaluation forms collected across 5 out of 9 activities are summarised in Table 1. It is clear from these data that the students responded in a positive manner to the activities introduced by GTAs. This was evident to anyone attending the sessions, where students worked together in a purposeful manner as they tackled these activities. A key goal of this project was to increase students' engagement and satisfaction with teaching. As the nature of these activities required students to engage fully in order to learn from them, and indeed to enjoy them, the data in Table 1 can be considered to be a proxy for student engagement. Written comments provided further feedback to support activity refinement, with a common request being the introduction of more challenging examples. While, it is not possible to quantify the impact of these activities on individual students' learning, the following comments given in end of year module evaluations hint at the benefits of this approach from the student perspective:

"(The GTAs) are all very enthusiastic, and are a great help in explaining things. The resources they have formulated have also often been very helpful."

Question	Yes, a lot	Yes, a little	Not much	Not at all
Did you enjoy the activity?	64 %	30 %	5 %	0 %
Did you understand what you had to do?	76 %	20 %	3 %	1 %
Did you learn from the activity?	73 %	24 %	2 %	1 %
Would you recommend this activity is used in future?	78 %	18 %	1 %	3 %

Table 1 Summary of student evaluations collected from 5 of 9 activities (n=157)

"…the (GTAs) are excellent in the workshops and the activities they devise for students are on the whole very useful."

"The exercises provided by GTAs have deeply enriched our learning environment. Their collaborative activities have provided opportunities for dynamic conversation about theory, consolidating my understanding of the most complex material."

Increased student satisfaction was also reflected in responses to questions about feedback provision on the module evaluation survey, which increased from 4.0/5 in 2014/15 to 4.7/5 in 2015/16.

Impact on GTAs

It was clear that the GTAs' confidence in developing and delivering activities increased throughout the semester, and they demonstrated continual development of their teaching skills, with one GTA currently working towards associate fellowship of the HEA based on their work on this project. Further work would be required to ascertain the nature of beneficial impacts on the GTAs, but the following comments hint at the value they perceive themselves:

"Developing resources for the science foundation year workshops was an insightful, valuable, and enjoyable experience. It gave me the chance to be creative whilst also allowing me to learn more about the theory involved in developing educational resources. The skills I have gained and established working as part of a team of GTAs have undoubtedly helped me grow both as an educator and as a chemist." (SMB)

"The entire process was both educational and enjoyable to me, from the weekly group meetings to evaluating student data and discussing with the team how each activity went. Not only did I enjoy the community feeling, but I also learned how to critically reflect on my teaching. This has enabled me to begin to foresee the difficulties students might face and use this to develop suitable activities." (ITI)

The activities

In total, 9 activities were generated by the GTA team throughout the semester, and these are summarised in Table 2. In most cases, these activities were enhanced prior to delivery in 2016/17 on the basis of feedback received in 2015/16 and they are now embedded in the schedule for teaching, demonstrating sustainability beyond the tenure of the GTAs who created them.

Conclusions

We have demonstrated that GTAs can be empowered to design, deliver, and evaluate resources to support active learning in smaller group teaching sessions. Students have responded positively to the activities, and the GTAs themselves report beneficial impacts on their own skills development and confidence. Furthermore, the approach has had limited impact on staff time, beyond the initial training provided, with the GTAs evidently providing effective peer support within the team. It is planned that this approach will be expanded to include the generation of active learning resources for use in teaching at different levels in Chemistry at the University of Southampton.

Week	Topic	Activity description
	Free radical halogenation	Card activity requiring groups to piece the mechanism together with commentary.
2	Aromatic chemistry	Incomplete concept map of organic reactions with cards which students need to sort and place correctly.
3	Mass spectrometry, IR and NMR spectroscopy	Two-part activity involving i) prediction of MS, IR and 1H NMR spectra for a given compound and ii) identification of compound based on another group's predicted spectra.
4	Acidity and pH	Card sort activity to assist students in structuring complex concentration/pH calculations.
5	Organic functional groups	Students generate flashcards based on a template to illustrate the properties of different functional groups.
6	Period 3 elements	Students are provided with a series of simulated student statements which they have to label as true or false, with a full explanation for their answer.
7	Chemical kinetics	Students consider the shapes of concentration vs time graphs for a range of reactions, discussing the underlying mathematical relationships and relating them to chemistry.
8	Chirality and optical isomerism	Students consider the structures of compounds which exhibit optical isomerism, including an activity using small mirrors to visualise mirror images of enantiomers.
9	Buffers	Card sort activity to assist students in structuring complex calculations relating to the pH of buffer solutions.

Table 2 Summary of active learning activities created during semester 2, 2015/16

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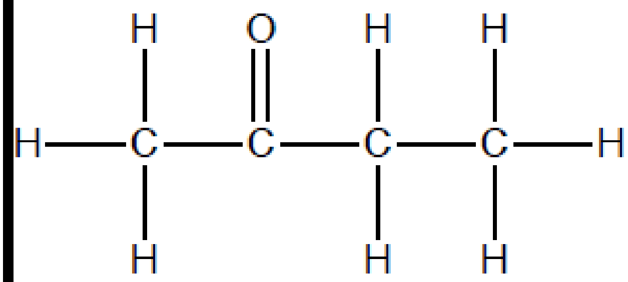
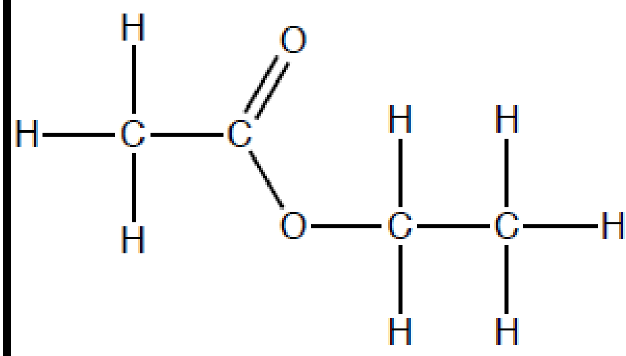
Appendix 1 - "Back and Forth: Structure and Spectra" – Activity Overview

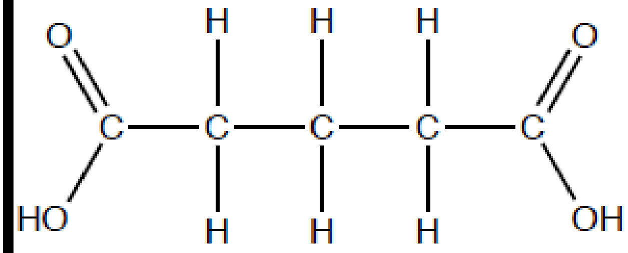
What are the learning outcomes for your activity? *i.e. After this activity, students should be able to describe/explain/evaluate etc.…* *After this activity students should be able to:* *LO1: Predict the infrared, mass spectrum, and ^{1}H NMR spectral data observed upon analysis of simple organic molecules.* *LO2: Deduce the structures of simple organic molecules from infrared, mass spectrum, and ^{1}H NMR spectral data.*
How will you introduce the activity to make it clear to students what they need to do and what they are learning? *To introduce the activity, I will give a very brief talk instructing the students on how the activity works. I will explain what information they need to convey on their worksheets, and how this can be used to identify a compound's structure.*
Briefly explain how your activity works and how it addresses the learning outcomes? *In groups, students will be given the structure of an organic compound. As a group, they are required to deduce the spectroscopic data that would be obtained upon analysis of this compound, including IR absorption peaks, potential fragmentation peaks from a mass spectrum, and the peaks expected in a ^{1}H NMR spectrum. The students should list this data in the tables provided, but they have the opportunity to sketch them if they would like. (**LO1)*** *When they have finished predicting the spectroscopic data for their compound, one of the demonstrators will be required to check their answers (an answer sheet will be provided). Provided everything is correct, the students will pass their data sheet on to another group. That group will then use the data to predict the structure of the original compound. **(LO2)***
How will you know whether or not students have met these learning outcomes at the end of the activity? *If students have the correct data listed in their tables, and obtain the correct structure, then it will be evident that the students have completed the task to a good standard, and understand the concepts involved. Demonstrators should also ask students how they deciphered structures as well, to ensure student understanding has been achieved.*
What do you anticipate that students will find difficult about this activity and how do you plan to support them? *This is by no means an easy task; spectroscopy is one of the most complicated topics in the foundation year syllabus. It is likely that many students will struggle with both aspects of the task, and as such the demonstrators should be vigilant in noticing when students are struggling. The first part of the task should not be too bad; so long as the students utilise their data sheets, they should be okay in predicting the data for the molecule. When the students come to deducing a compound's structure, the large amount of data may seem intimidating, and students may not necessarily know where to start. It is therefore a good idea to prod them in the right direction with this, and encourage them to take the activity step-by-step rather than trying to figure everything out all at once.*



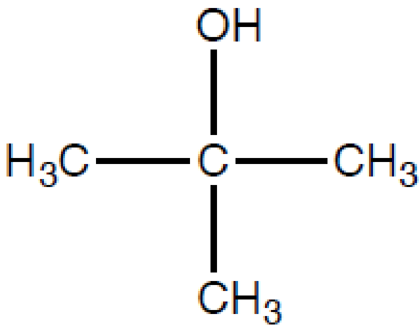
butan-2-one
$M_R = 72.1$



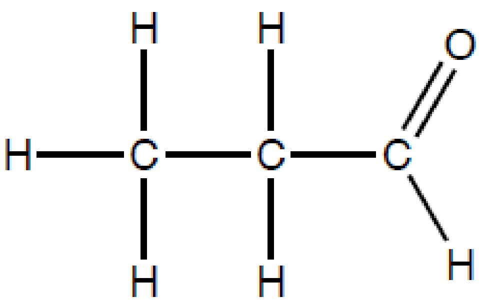
ethyl ethanoate
$M_R = 88.1$



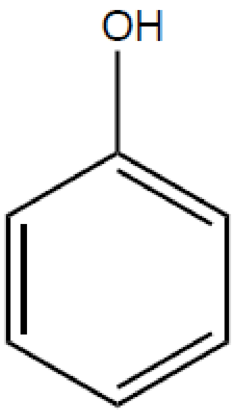
pentan-1,5-dioic acid
$M_R = 132.1$



2-methylpropan-2-ol
$M_R = 74.1$



propanal
$M_R = 58.1$



phenol
$M_R = 94.1$

Appendix 2 – “Back and Forth: Structure and Spectra” – Student Materials

BRIEF

You will be given the structure of an organic compound. As a group, you are required to deduce the spectroscopic data you would obtain upon analysis of this compound, including IR absorption peaks, potential fragmentation peaks from a mass spectrum, and the peaks expected in a ^{1}H NMR spectrum. You can either list this data, or you can have a go at drawing the spectra yourself!

When you have finished predicting the spectroscopic data for your molecule, you will pass your data sheet on to another group. That group will then use your data to predict the structure of the organic compound you were given.

By working on this task a group, you have the opportunity to predict spectroscopic data based on a structure, and to deduce structure based on spectroscopic data, which are two key skills in practical chemistry!

SPECTROSCOPIC DATA

Infra-Red Absorption Peaks (IR Spectroscopy)

Wavenumber / cm^{-1}	Peak Width

EXTENSION

How many peaks would there be in the ^{13}C spectrum of your compound?

Fragmentation Peaks (Mass Spectrometry)

m/z value	m/z value

^{1}H NMR Data

Chemical Shift / ppm	Integral	Splitting	Peak Present in D_2O?

DEDUCING A STRUCTURE

What can be inferred from the IR data?

What can be inferred from the mass spectrometry data?

What can be inferred from the 1H NMR data?

Based on this data, the structure of the unknown compound is…