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Graduate Teaching Assistants; Critical Colleagues or Casual Components in the Undergraduate Learning Laboratory? An Exploration of the Role of the Postgraduate Teacher in the Sciences.

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Graduate Teaching Assistants; critical colleagues or casual components in the undergraduate learning laboratory? An exploration of the role of the postgraduate teacher in the Sciences.

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Abstract :
Laboratory training is key to many science subjects and those that teach the practical laboratory skills maintain a pivotal role in undergraduate science training. Graduate Teaching Assistants (GTAs) are regularly used in higher education institutes to teach these practical lab skills. The GTA can be involved in both laboratory teaching and assessing all levels of undergraduates. This varied and challenging role requires support from the institute and if appropriately provided the learning experience can be rewarding not only for the undergraduate, but also for the GTA. In this review, the critical role of the laboratory GTA will be examined, their support requirement highlighted. Additionally, the multi-dimensional benefits of GTA facilitated research-orientated laboratory learning outlined.

Keywords: Graduate Teaching Assistant, graduate training, laboratory teaching and learning, support, mentoring.

Research Question: How can Graduate Teaching Assistant teaching training be supported, and their research skills integrated into the undergraduate curriculum, to enhance laboratory learning?

Overview

This review will examine the important role of the Graduate Teaching Assistant (GTA) in the Sciences, specifically addressing wet-laboratory teaching. The majority of all science based GTA teaching duties focus on laboratory teaching at the undergraduate level, particularly the early undergraduate years. The rationale for this will be considered and the absolute need for appropriate GTA teaching training extrapolated. Examples of current training practice in the Sciences will be described and evaluated. Subsequently, the potential to celebrate the inherent research skills of the appropriately trained GTA in the undergraduate teaching lab will be investigated. This alternative approach would centralise the GTA in the learning environment and also drive contemporary pedagogical approaches to undergraduate laboratory learning. Finally, recommendations for practice and benefits to adopting this research-based approach to laboratory learning will be detailed.

Introduction

The role of the practical laboratory session has been, and continues to be, central to science education (Hofstein & Lunetta, 1982 and 2004). Every student undertaking a science based degree will, at some stage, don a white coat and safety glasses and enter into the undergraduate teaching lab. In comparison to lecture based teaching there has been limited research into the roles and duties of those tasked with 'teaching' practical scientific skills, despite the regularity of this scene and the number of students that pass through undergraduate teaching labs. Frequently these duties fall on the shoulders of graduate teaching assistants (GTAs) who themselves are oftentimes students, albeit postgraduate.

The increasing rise in the use of GTAs can be aligned to the reduced budget in the higher education sector, and the mantra of 'do more with less'. In simple terms, a GTA is much cheaper than a full-time lecturer. It makes economical sense to have several GTAs running undergraduate teaching laboratories; thus reducing the institutes salary spend and relieving the over-stretched academic allowing him/her to concentrate on more 'scholarly' activities (Park, 2002). The GTA is, therefore, often faced with large classes of early undergraduate students, whom themselves are dealing with a considerable educational and life transition (Scott & Maw, 2009). Although it may make economical sense to allow GTAs to teach undergraduate laboratories, it does not make ethical or pedagogical sense for a number of reasons. The GTA can be placed in an uncomfortable position; coming from a pedagogical no-mans-land. They must span the chasm of student and academic, often times with little or no training, resulting in ineffective teaching (McKiggen-Fee et al., 2013).

Teaching effectively versus equal teaching effectiveness

Without suitable GTA training the undergraduate student laboratory learning can suffer, through no fault of the GTA. The GTA is simply not prepared, or supported, to take on the demanding role of the 'novice academic practitioner' and hence the usefulness of the learning experience is questionable (Knottenbelt et al., 2009). The effectiveness of laboratory teaching has been anecdotally investigated for many years; however, deep evaluation in the literature is limited. Skeffs (1988) early attempt to document the factors influencing clinical teaching can be aligned to laboratory teaching (see Table One). The academic has a key part to play in many of these factors and without prior training, or experience, the undergraduates learning will not be complete. For example, one of the key aspects of learning is timely and appropriate feedback (Higgins et al, 2002). Without prior training and guidance in the provision of suitable feedback, and the mechanisms involved in providing feedback, the 'novice academic practitioner' may not feel comfortable in giving feedback to undergraduate students. This can result in a poorer learning experience for the undergraduate student, particularly in hands-on, skill-based subject areas (Mahmood & Darzi, 2004).

Table 1: Skeffs' (1998) seven component framework to enhance teaching effectiveness in the clinical setting.

Component	Explanation	Alignment to Lab teaching
Learning Climate	Atmosphere of the teaching environment.	The lab is a learning environment where students fell free to ask questions and learn from peer and academic engagement.
Controlling the Teaching Environment	The focus and the pace of the content are appropriate.	The experimental goals are achievable, suitable and the skills are demonstrated at the appropriate time.
Communication of Goals	The learning outcomes are clearly communicated.	The experimental lab skills are clearly defined and mastery is assessable.
Understanding and Retention	Students display a deep understanding of the content.	The required experimental skill set and theoretical knowledge is achieved and demonstrable.
Evaluation	The learners can demonstrate they have achieved the learning outcomes.	Student learning is aligned to the evaluation protocols.
Feedback	Information is provided to the learner in order to improve the learners understanding.	Students should receive formative and summative feedback on both their technique and scientific record keeping and reporting.
Self-Directed Learning.	The learner identifies gaps in their learning and acts, under their own initiative, to close these gaps.	Students reflect on their theoretical, laboratory and communication skills and identify areas that require further study.

More recently, Herrington and Nakhleh (2003) explored the influence of the GTA in the effectiveness of undergraduate laboratory learning, focussing on the chemistry laboratory. The authors built on the previous works of Lazarowitz and Tamir (1994) and Pickering (1998) who noted the most important person in the undergraduate teaching lab was the GTA, and one of the primary reasons why laboratory teaching styles have remained static was the failure to consider this important role maintained by the GTA. Herrington and Nakhleh (2003) based their measure of learning effectiveness on the promotion of positive change in the undergraduate student. To evaluate this change, students were initially surveyed on their understanding of the qualities of an effective GTA and how an effective GTA can enhance their learning experience. Interestingly, the results of this study coded onto three key themes, as outlined in Table Two. 'Knowledge' was broken into two broad areas, one of which was knowledge of teaching and learning approaches suitable to undergraduate teaching labs. Again, without prior training in these areas, many GTAs would have limited knowledge of learning theories and would most likely revert to the teaching method they are most used to, i.e. the way they were taught as an undergraduate. This chimes with Pickerings (1998) ideology that GTAs are not generally considered for specific pedagogical training and hence the closed pedagogical circle, resistant to change, is destined to repeat itself. Furthermore, the other themes of communication and affective domain as identified by Herrington and Nakhleh (2003) could also be improved through suitable and timely GTA training and support.

Table 2: Summary of Herrington and Nakhleh (2003) three themes of effective GTA teaching in the chemistry laboratory.

Theme	Additional Information
Knowledge	Understanding both technical/scientific and teaching/learning concepts.
Communication	Explaining complex concepts in simple language.
Affective	Interested and engaged in student learning.

Training and supporting the laboratory GTA

Despite the omnipresent GTA in the undergraduate teaching laboratory there is evidence to suggest that many GTAs are still under prepared to teach; DeChenne and co-workers (2012) noted that 37% of Chemistry GTAs and only 15% of Biology GTAs receive some professional development before beginning their teaching in the US. More generally, in the UK, 20% (n=1500) of all GTAs receive no training prior to commencing their teaching duties (Wenstone, & Burrett, 2013). Aligned to this figure, Scott and Maw (2009) noted that UK bioscience GTA training was compulsory in 74% (n= 35) of the higher education institutes surveyed. However, the standard and relevance of the training provided was mixed; for example >60% of GTAs received training in lab safety whereas <50% received training in student assessment and grading. GTA teaching training should not only take place at the end of a GTAs personal postgraduate research journey, as the GTA rushes to 'tick as many training boxes' as possible in the hope to gain employment (Beaton et al., 2013). It should form the cornerstone of the postgraduate training programme, ideally at the start. One potential method to achieve this is to incorporate pedagogical training into a structured PhD model for doctoral studies.

A structured PhD may offer a suitable compromise between the need for structured training in specific areas and the requirement for novel research as part of doctoral education. There appears to be a move towards this approach to doctoral studies in recent years. At a European level the structured PhD has gained in popularity over the traditional approach to PhD research; in 2007 around 25% of HEIs offered structured PhD programmes, by 2010 this had risen to almost 66%. Some European countries do, however, lag behind. For example, in Ireland the structured PhD is quite a new development with the IUA (Irish Universities Association) outlining the context of an Irish structured PhD programme as recently as 2009. (Anon, 2011). There are many examples of institutes, particularly research-orientated universities, providing structured GTA development programmes. For example, St. Andrews University is one of several UK universities that offer GTA specific teaching and learning modules. Topics covered in these modules include learning theories, reflective practice, equality and diversity, internationalisation, effective teaching and curriculum design. These modules are accredited with the HEA (Higher Education Authority, UK) and align to the UK Professional Standards Framework Descriptor 1. This allows GTAs that complete the course to apply for recognition as an Associate Fellow of the Higher Education Academy (McKiggan-Fee, 2013). Supplemental support can also be provided to the GTA thorough academic supervision and peer mentoring (Park, 2004). Many institutes provide additional 'guidelines of best practice' regarding support for GTAs in their teaching role; such as dedicated meeting times with academic staff, common rooms and the provision of feedback and feed-forward on their role and the curriculum on which they teach. Formal recognition and departmental integration hold obvious benefits to the GTA, however, the benefit for the institute and the undergraduate students is also clear; skilled, trained and reflective GTAs will enhance the learning experience for all students as they learn in the laboratory.

Learning in the laboratory; what is it and who influences it?

Johnstone and Al-Shuaili (2001) describe the key aspects of learning in the undergraduate laboratory as the ability to plan an experiment, to execute the experiment with appropriate manipulative skill, and finally observe, record, interpret and communicate the data generated during lab work. At the most basic level those tasked with 'teaching' laboratory skills will influence all aspects of laboratory learning. This is particularly true for first year undergraduate students, as they transition from second level to higher education. Some of these students may not have had access to a laboratory during their second level education and, as such, require guidance during the development of their fundamental laboratory-based skills. It can be very beneficial for apprentice scientists to observe and discuss how a skilled scientist, the GTA, carries out their laboratory work. Learning here can be a mixture of behaviorist style learning, where the undergraduate student replicates the actions of the skilled GTA, and also cognitive, as the GTA talks through their thought process as they, for example, set up an experiment. Central to this process is a natural working relationship; where the apprentice is willing to learn, the skilled GTA is willing to pass on their knowledge and the "*principles of natural conversation*" exist between novice and 'expert' (Moore et al., 2008). In the correct environment, the undergraduate can quickly reach a level of basic competency allowing a more autonomous learning curve to be taken.

The style of laboratory can also not only affect the learning experienced by the undergraduate, but also affect the teaching delivered by the GTA. Traditional laboratories are considered those that follow an expository style, otherwise known as 'recipe' or 'cook-book' labs. Undergraduate students in these laboratories follow a pre-determined method to achieve a pre-determined outcome and typically communicate these findings in a standard lab report (Dunne & Ryan, 2011). The depth of undergraduate learning here is questionable; however, there are advantages to running this style of lab, particularly with large first year cohorts. On an economic level, it is much cheaper to prepare the undergraduate teaching lab with multiple repeats of the same equipment and consumables; technical preparation time can be reduced and the process optimized. Logistically, for the 'novice academic practitioner' expository labs can be easier to run as the results are more predictable and the undergraduate assessment and feedback procedures can be streamlined through years of optimisation. These advantages pale in comparison to the major pedagogical disadvantages to implementing 'verification' type lab work. Students gain limited exposure to key elements of scientific lab work such as experimental design, problem solving, critical thinking and creativity (McDonnell et al., 2007). These are the very skills the GTAs have developed during their own postgraduate research; however, expository style undergraduate labs can reduce the GTAs ability to pass on the skills they have acquired. A style of laboratory that promotes and celebrates the core skills of the research scientist would promote deeper undergraduate learning and also demonstrates that the greatest teaching resource in the undergraduate lab then becomes the lab based researcher, the GTA.

GTAs are critical research orientated laboratory teaching

The integration of research and research-like activities should be central to undergraduate learning. Neary and Winn (2009), through the 'students as producer' philosophy have suggested the positive effect on student learning through the inclusion of real-life, complex and unstructured research-like activities at the core of the undergraduate curriculum. In this approach to learning, undergraduate students are encouraged to develop their understanding by carrying out research, or research-like, activities. This aligns to the GTA and how they develop understanding of their research topic; through research. Aligning how GTAs research and how undergraduate students learn by carrying out research-like activities would be beneficial to both cohorts. Integrating research-like activities into the undergraduate laboratory can develop skills that prepare students and GTAs for life-long learning and enhance their future employability. An obvious example here would be the teaching experience gained by the GTA; particularly important if the GTA intends to enter into an academic career. Exposure to contemporary pedagogy will enhance future academic perspectives and potentially introduce novel teaching methods into other institutes (Partridge, et al., 2013). Furthermore, life-long skills such as communication, time management and enhanced self-confidence are attributes that the GTA can use in their own research and their future career (McCready & Vecsey, 2013).

Although a potential symbiotic relationship could be forged, it is crucial that the undergraduate research activities are aligned to the curriculum and are authentic as possible in order to enhance the student learning experience (Schuck & Kearney, 2008). The type of research carried out by the undergraduate, and facilitated by he GTA should be tailored. This 'research tailoring' can vary from research led, wherein the student assists in current research and is thus GTA centred; to research based, where the student is central to the process and undertakes research and enquiry, and is GTA facilitated (Healy & Jenkins, 2009). A subtle blend of this research spectrum would provide appropriate structure and support for undergraduate students; simultaneously allowing undergraduate students to develop as autonomous learners and maximising the positive influence of the GTA.

This blend can be achieved by introducing structured and facilitated research-like and research-based laboratory learning. Inquiry-, discovery- and problem-based labs are some of the more popular alternatives to the traditional, expository lab that encourage undergraduates to develop their core skills as apprentice research scientists and are suitable to all undergraduate years (Buck, et al., 2008, Domin, 2007). The GTA can add value to these laboratory teaching environments; drawing on their own research experience to support and guide the undergraduate students. Sandi-Urena and co-workers (2011) examined the affect of GTA work in an intellectually stimulating teaching environment, as is often found in research-like teaching laboratories. In their study, Sandi-Urena and colleagues observed how, in the correct teaching environment, GTAs developed their metacognitive skills, their epistemological perspective and their affective engagement, echoing Herrington and Nakhleh's (2003) previous work. Development in each of these areas was seen to be beneficial to the GTA in their own research. For example, development of their epistemological perspective allows the GTA to become more reflective in their own learning and research. Oftentimes this development stems from an internal conflict surrounding the GTAs own understanding of 'knowledge'. Through reflection, the GTA forms their own epistemological outlook and this directly influences their own research and life-long learning. This epistemological transformation can take place through other life experiences; however, it is accelerated through reflection of their dipolar research/teaching experience (i.e. their personal research and assisting apprentice scientists in their research; Sandi-Urena et al., 2011).

Adopting a new, holistic, approach to learning in the laboratory
Teaching undergraduates in a research-like environment is beneficial to the development of essential GTA research skills (Feldon, et al., 2011). Simultaneously, the undergraduate apprentice research scientist profits from the inclusion of research-like activities in the undergraduate curriculum and engagement with the GTA. If the benefits of research like activities are clear for both undergraduate students and GTAs, then should this method of teaching laboratory skills (and theoretical content) be expanded to cover the entire curriculum? Healy and Jenkins (2009) put forward a convincing argument, using case-studies to provide evidence, for the inclusion of research and inquiry in all aspects of every undergraduate curriculum, not just STEM. The scope and the depth of the research carried out can be tailored to suit the level of undergraduate student, however, the exposure to this approach to learning should be absolute, from first year through to graduation and beyond.

If the undergraduate students and the GTAs adopt this mantra, there remain only faculty members to embrace this pedagogical paradigm. In many research centred higher-level institutes undergraduate teaching is the responsibility of GTAs; however, often times the course, curriculum and method of delivery are pre-determined by tenured staff. Integrating pedagogical-based research into the faculty portfolio is one way to square the circle of 'publish or perish' and the requirements of the undergraduate student and GTA. Furthering this concept of research-based and research-informed teaching Ramsden and Moses (1992; p.273) describe how research and teaching can be harmonious and compatible partners; "*Scholars who are energetically occupied in creating or reinterpreting the knowledge of their subjects will be competent lecturers: teaching based solely on the research of others is dull and fails to inspire students*". By embracing a research-based teaching laboratory undergraduate students can become a valuable addition to the research world, the GTA can teach and inspire in a stimulating and rewarding environment and the lecturer can align their teaching and research portfolios.

Recommendations for Practice

Training and support. The provision of the correct training before the GTA teaches and support during their teaching duties is paramount. For example, Boman (2013) observed GTAs that were provided with suitable training significantly increased their self-efficiency and teaching effectiveness. Furthermore, those that participated in the training cited an improvement in their public speaking skills. Luft and colleagues (2004) noted the importance training and support specialisation provided to the GTA. For those involved in science teaching the inclusion of appropriate educational research and the process of teaching science was crucial.

Fostering a community of practice. The provision of a suitable training and support system could lead to the development of a 'community of practice' (CoP) amongst GTAs. This eclectic community would allow pedagogical idea transfer and cross-pollination between different stems of wet-lab teaching. Communities of practice are observed in other areas of academia and the development of a GTA CoP would provide additional social and pedagogical support (Hiebert et al., 2002).

Less is more. In terms of introducing a research driven undergraduate laboratory that can enhance undergraduate student learning and centralise the GTA, large scale curriculum remodelling is not required. Hughes and Ellefson (2013) observed that appropriate GTA training in inquiry based learning and minimal curriculum change resulted in improved GTA teaching, undergraduate perception and module scores in an undergraduate biology laboratory.

Involve and inform the undergraduate students. The majority of GTA teaching takes place in early undergraduate laboratories, as is traditionally the case (Park and Ramos, 2002). Early year undergraduate students are transitioning from dependant (second level) to independent (third level) learners. Many students take time to adapt to taking responsibility for their learning, and introducing research centred laboratory learning can add additional stress. Informing the students of third level education expectations, their role in their learning and involving them in laboratory design can aid in their adoption of this teaching approach.

Blurred lines. The distinction between 'teaching' and 'research' should be reduced in order to fully integrate research-driven learning in the laboratory. The interaction between the GTA and the undergraduate should be fluid and 'peer'-like, with the boundary between GTA mentoring and undergraduate research-driven learning becoming blurred (González, 2001).

Near Peer Mentoring. Many GTAs are doctoral research students who, along with carrying out limited teaching duties, are full time research students. These GTAs are often closer in age and background to the undergraduate students than the tenured academic. In this sense the GTA is a 'near-peer' to the undergraduate student. Near-peer teaching has been shown to be a powerful pedagogical approach with undergraduate peers, separated by one or two years, working effectively together to promote learning (Campolo et al., 2013). Adopting this approach across the undergraduate/graduate divide could further enhance the laboratory learning environment.

Academic adoption and facilitation. Ultimately academic adoption will veto any change in wet laboratory teaching. Luft and colleagues (2004) suggested that academic staff be encouraged to engage with, and mentor, GTAs. GTAs should be included in the development of the laboratories and integrated into the teaching community. At another level, academic staff must fully adopt this new centralised role of the GTA if research driven undergraduate laboratories are to succeed.

Conclusions

The role of the lab based GTA is critical in many higher-level institutions; however, they are often thought of as the 'forgotten tribe', or worse, casual 'slave labour' (McCready & Vecsey, 2013). The GTA should, instead, be celebrated as being a 'distinctive tribe' at the interface of student, researcher and teacher (McKiggan-Fee, et al., 2013). This unique position should be harnessed in laboratory teaching as, if utilised correctly, the benefits extend beyond the undergraduate student. However, to achieve this the GTA must be suitably equipped with the skills required to enhance the learning experience of the undergraduate, they must teach in a stimulating and research orientated environment, and they must be supported by their mentoring academic and institute.

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