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Effective use of peer teaching and self-reflection for the pedagogical training of graduate teaching assistants in engineering

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ABSTRACT

The use of the graduate teaching assistant (GTA) to support the teaching activities of higher education institutions has been growing over the years and it is now a well-established practice. Conventionally training sessions, consisting usually of workshops, remain general and overemphasise policies, not providing sufficient preparation for in-service teaching. This study proposes to overcome these shortcomings by introducing a new methodology that is based on the use of peer teaching and self-reflection and that is both continuous and discipline-specific. The analysis of the feedback, collected from GTAs' teaching practical engineering sessions during a full academic year, shows that by engaging with the training, each GTA developed their reflective practice and their student-centred teaching. Interestingly, results also show that some GTA underwent a regression phase during the second semester. It is expected that only a training method that continuously supports their pedagogical development can lead these GTAs towards a recovery phase.

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GTA training; microteaching; self-reflection; feedback; engineering

Introduction

The teaching role of Graduate Teaching Assistants (GTAs) in higher education has significantly increased over the years (Muzaka 2009). Research-led universities have responded to the growing demand for teaching staff (due to the rising number of enrolled students) by relying increasingly on GTAs to support undergraduate teaching. GTAs' involvement has reached the point that, in some instances, particularly in science, technology, engineering, and mathematics (STEM) subjects, it represents a large proportion of the teaching staff in most of the introductory courses and laboratory sessions (Gardner and Jones 2011; Sundberg, Armstrong, and Wischusen 2005). Arguably, GTAs now play a crucial role in educating the next generation of STEM graduates (O'neal et al. 2007).

The decision for employing GTAs instead of full-time staff who specialise in teaching is based on financial and strategic considerations; GTAs are relatively inexpensive to hire and offer unique flexibility (Chadha 2013). Yet, only a handful of each new GTA cohort have prior teaching experience or have received any pedagogical training (Shannon, Twale, and Moore 1998; Schussler et al. 2015). Many institutions offer explicit pedagogical training before GTAs begin teaching to support the certain, varied, but implicit, experiential training that GTAs receive in the classroom (Addy and

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Blanchard 2010). However, the success of such training receives mixed reviews, and the perception remains that GTAs are often insufficiently prepared (DeChenne et al. 2012b).

The authors believe that the main causes that allowed research-led institutions to overlook GTAs' training were two-fold. First, there was the belief that pedagogical skills are an inevitable acquisition, osmotically absorbed by undergraduate students during their degree (Latulippe 2007). In addition, a heuristic approach has been often deemed as sufficient standard for teaching training (Gunn 2007). This is in stark contrast with the pressure towards teaching professionalisation experienced in the past two decades (DeChenne et al. 2012b). In the authors' experience, ineffective GTAs can severely impact the student experience and provide themselves with an unrealistic view of their capabilities. GTA training is often only provided as an initial enabler with little follow-up support.

Literature review

In most research-led universities, the pool of GTAs is formed by PhD students. They are research students, yet they teach. The duality of their role is not a simple juxtaposition of research goals and teaching duties. We could say that they are both researchers and teachers but are fully, neither. This duality creates a struggle to balance personal time, which can expose GTAs to high levels of stress (Chadha 2013; Park and Ramos 2002; Park 2004). Most GTAs are encouraged by their supervisors to focus more on research rather than teaching (Smith 2001), thus pressuring GTAs to prioritise the development of their research identity at the expense of their teaching one (Buerkel-Rothfuss and Gray 1990). The authors agree with the literature, when it states that GTAs' perceived disengagement towards pedagogical training is connected to their lack of ownership of the teaching and learning process (Park and Ramos 2002).

It should be noted that many GTAs will teach as soon as they complete their degrees. It is therefore often assumed by employers that the higher (research) degree has somehow prepared them for being effective teachers; however, the literature suggests that GTAs' experiences do not align with all the roles they will perform as academics (Svyantek, Kajfez, and McNair 2015). The authors' experience confirms what has been known for several years that as a result of an ineffective, or at times non-existent, pedagogical training, the GTA's teaching identity can only mirror their past experience as a student. Untested personal beliefs can be in clear contrast with current practices for undergraduate teaching (Kagan 1992). For example, new international GTAs are more familiar with the pedagogical approaches of their home countries (which in some instances are didactic and teacher led) as opposed to the student-centred methodology now well-established in the UK (Menges and Rando 1989).

GTA training methods

EXPLICIT GTA training often consists of a university- or department-wide workshop with highly generalised content (Gardner and Jones 2011) usually overemphasising policies and, only in some instances, addressing pedagogical techniques (Shannon, Twale, and Moore 1998; French and Russell 2002). Follow-up activities from these workshops (e.g. mentoring, in-class observation), when existent, are usually poorly supported (Schussler et al. 2015; Rushin et al. 1997). The authors believe that such training leaves GTAs with a false perception of their 'readiness' for in-service teaching, despite the limited development of their actual pedagogical skills (Chiu and Corrigan 2019), which can only be attained through self-reflection and peer-discussion. It could be argued that a more comprehensive way to support GTAs should provide, in addition to an initial workshop, continuous and discipline-specific training (Chiu and Corrigan 2019; Deacon, Hajek, and Schulz 2017). The authors believe that an effective strategy should support GTA self-reflection by integrating a repeating cycle of teach-critique-reteach (Calonge et al. 2013) and timely feedback (Wiggins 2012).

Impact of reflection on a teacher confidence

A student-centred teaching environment fosters students' proactive engagement, which generally translates, in its simplest form, in students asking frequent more challenging questions. Teaching in such settings requires increased confidence, flexibility, and resilience. In particular, for new teachers, self-confidence appears as a key influence in the use of teaching strategies that actively involved the students (Sadler 2013).

Reflective practice can be used to overcome a perceived crisis in confidence arising from mistakes made due to an over-reliance on a working model that revolves exclusively around the application of knowledge. As such this working model does not allow for failures or mistakes whereas the reflective process uses these as an important part of the process of problem solving. The act of looking back, evaluating, and thinking about teaching experiences and behaviours allows teachers to analyse and work through challenges and helps them to identify new approaches to trial (Braun and Crumpler 2004). This suggests there may be a link between reflection and teacher confidence as they build resilience by seeing challenging teaching experiences, and the inevitable mistakes, as opportunities for growth.

Several studies support the hypothesis that reflection promotes and develops confidence. For example, some remark that teacher developers should encourage dialogue and reflection in relation to the self-confidence and content knowledge of new teachers (Sadler 2013), and that GTAs feel reassured of their teaching capabilities as a result of using reflection to evaluate their practice (Chadha 2015). Similarly, self and collective reflection is identified as one of the top factors to boost self-efficacy- the teachers' beliefs to be able to effectively teach students a specific subject (Deacon, Hajek, and Schulz 2017; Dechenne and Enochs 2010)- alongside with other factors including leading sessions, observing colleagues teach and co-teaching sessions (Naidoo and Naidoo 2021). The same study also concludes that a strategy based on cycles of action-reflection can increase self-efficacy.

Context

The policy towards GTA training at the authors' Institution (The University of Sheffield) fits within the general traits highlighted above in most instances. The institutional learning and teaching strategy (University of Sheffield 2016) states that the university values 'staff providing them with the environment, resources and time to be able to develop and innovate as teachers within the context of their discipline'. As part of their Excellence in Practice, Sheffield University further commits 'to help staff develop their teaching both as individuals and as part of teaching teams', introducing a recognition scheme (LTPRS) and a training program (PGCert). The latter is not open to students so GTAs, despite being hired to teach, are not eligible.

Sheffield Teaching Assistant (usually referred to as STA) workshops are the current institutional pedagogic training dedicated to GTAs which, unlike the findings of many university-wide programs mentioned above, centres around pedagogic techniques and reflection over policy. Unfortunately, departments do not always support GTAs' attendance, or pay for the time GTAs spend in those training sessions. In addition, as these workshops are offered to GTAs across the whole University, these sessions use general pedagogical techniques and learning theory as their primary focus, encouraging participants to reflect on how it might work in their context but remaining holistic in approach and as a result leaving the responsibility of any discipline-specific or activity-specific training to departments. In the authors' experience, within the Faculty of Engineering, the reality speaks of a situation where discipline-specific GTA training, when available, is usually idiosyncratically and independently developed and offered by the same academics who employ the GTAs.

Multidisciplinary Engineering Education (MEE) is a specialist department at University of Sheffield which is dedicated to delivering practical teaching for all students in the Faculty of engineering using large, shared laboratories and workshops (Garrard and Beck 2018). MEE is the largest employer of

GTAs in the faculty with more than 200 GTAs employed each year across 13 laboratories. Standard GTA training in MEE starts with an induction workshop focused on policies and, briefly, on teaching skills. It also includes online training about *Supporting our Students*, and a workshop on *Implicit Bias*. Highly recommended, but not mandatory, STA workshops include *Assessment and Feedback* as well as *Laboratory Demonstrating*. In addition, for each lab activity, a specific training session is provided, however, its consistency and quality may vary as different academics employ different training strategies. What separates MEE from other departments in the Faculty of Engineering is the expectation of GTAs engaging with the training and also the level of support MEE offers to GTAs. In fact, MEE introduced the concept of a minimum threshold level of pedagogical training to become employable. In addition, recognising the importance of professional development, and to promote engagement with their training, MEE pays GTAs for the time they spend attending both workshops and the activity-specific trainings. Even with these improvements, at present, the GTA training presents a significant limitation for the individual learning process of GTAs. This is because, the training remains compartmentalised as workshops, and activity-specific sessions are disjointed from one another and do not provide a clear path for GTAs to grow as teachers.

Research statement

This research stems from the realisation that GTAs are the primary teaching force in MEE but are the least trained to do it, which is in stark contrast, institutionally, with the learning and teaching strategy and, nationally, with the Teaching Excellence Framework (TEF). This study reports on strategies to overcome these shortcomings by introducing a novel GTA training, based on peer-teaching and self-reflection, that is both continuous and discipline-specific. The effectiveness of the proposed GTA training method is assessed by answering the research question, 'To what extent does the continuous GTA training cycle support the development of GTA's teaching skills and reflective practice?'

Method

Administration and participation

The proposed training was trialled over a full academic year for all the 20 activities (13 in Autumn and 7 in Spring semester) taking place in the Structures Laboratory in MEE. Of the GTAs employed by MEE, only the 15 working in the Structures laboratory received this training. However, in line with Institutional ethical regulations, this research only analyses the feedback received from the 12 GTAs who consented to use their information.

It should be noted that the GTAs working in the Structures laboratory were identified not only for their engineering skills but also considering inclusivity and diversity. As a result, the participating GTAs account for differences in gender, age, and nationality. In addition, with regards to GTAs teaching experience, three categories (or combinations thereof) can be identified. These are teaching experience before their PhD (typically from abroad), new GTAs, and prior GTA experience.

Intervention: a new training model

The proposed training explicitly introduces an element of continuity in the learning journey of GTAs. This is obtained by not isolating the training, and, more specifically, by incorporating it inside a cycle of training (blue), teaching (red), and feedback (yellow) (Figure 1(a)), after which, the GTAs resume their journey and train for the next activity.

The teaching context

While logically sitting in the middle of the aforementioned cycle, it is beneficial to introduce the teaching activities upfront to provide better context to this method.

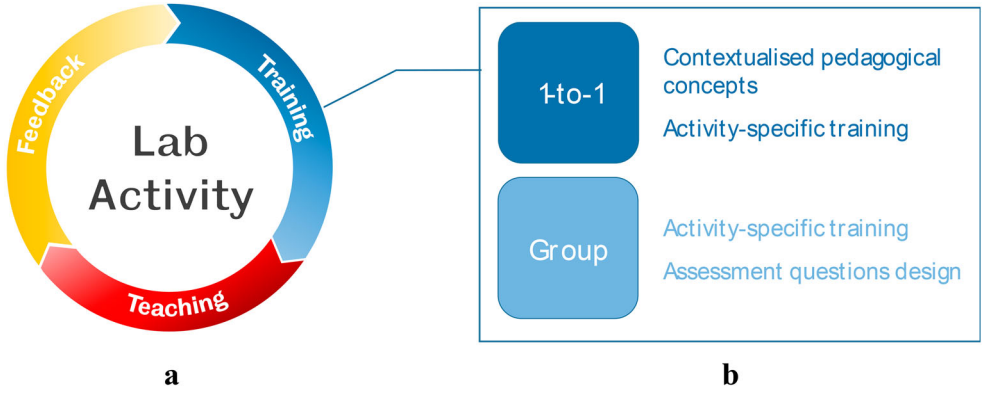

Figure 1. Schematic of the continuous GTA training cycle (a) and breakdown of the teaching activities during each training session (b).

The activities in the Structures laboratory encompass a range of practical experiments related to solid mechanics, structural analysis, and material characterisation and they are offered to undergraduate students primarily from Mechanical, Civil and Structural, Aerospace, and General engineering.

Each activity is split into a series of identical sessions whose number depends on the capacity of the lab (typically 40 students for a session) and the number of students the activity is offered to. For example, 5 'identical' sessions will be offered to a cohort of 200 first-year students, to ensure that all students can attend one. In a typical session, students are split into 10 groups of 4 and work on identical equipment. To ensure that sufficient support is provided to students throughout the session, GTAs are employed. The student to GTA ratio ranges between 10 and 20 depending on how challenging the activity is (typically, for a 40 student session, 3 GTAs are employed). An academic assigns GTAs to sessions of the same activity balancing two factors. On one hand, giving as many GTAs as possible the opportunity to learn and teach one activity, and on the other, ensuring that, when possible, each GTA engages with at least two teaching sessions of the same activity. This is because teaching multiple consecutive sessions based on the same activity to different students but from the same cohort is expected to provide an opportunity for self-reflection and development. In fact, using reflection-in-action (Schon 1984), where the reflection happens at the same time as the action is happening, GTAs can adjust their teaching based on how they performed during earlier sessions, rather than having to wait for the next year with a new cohort. It will be noted that in most engineering departments, round-robin teaching is employed whereby one GTA might demonstrate a single experiment to a large number of groups of students over a complete academic year. This allows them to become experts in delivering that one activity, but does not provide variety, reflection, peer support or to appreciate the generality of their teaching experiences.

The training process

In the approach described here, for each experimental activity, this GTA training consists of two sessions: an initial individual 1-to-1 session approximately two-hours long, followed by a group session (Group) of the same length, as shown in Figure 1(b). In the 1-to-1 session, the academic trains one of the GTAs (a different one for each activity), who, will subsequently lead the Group session, teaching all the other GTAs the activity, with the academic not present.

At the beginning of the semester, the academic allocates each GTA to at least a single 1-to-1 session. This is done randomly with the only additional consideration that GTAs with no prior

teaching experience in the Structures laboratory are given the possibility to settle in the new environment and are invited to their 1-to-1 training only after attending a few Group training sessions.

During the 1-to-1 session (Figure 1(b)), along with the activity-specific practical training, the GTA also receives some pedagogical training. The intents are two-fold but entwined. First, keeping in mind the aforementioned aim of continuity, this training tries to bridge the contextual gap with the institutional workshops by reshaping their general content to one more contextualised to engineering laboratory session. The second aim is to shift the GTA's perception of the teaching process from a simplistic form of content delivery to a now well-established student-centred approach. More specifically, the initial 1-to-1 session includes a contextualisation of the three domains of Bloom's Taxonomy and that of Constructive Alignment (Biggs 1996) to laboratory settings and strategies to define effective learning outcomes. In addition, previously established reflective questions (i.e. what they would: stop doing, continue doing and start doing) are introduced as a self-reflection technique to identify, as part of their teaching practice, areas of strength/weakness. Finally, the appropriate questioning methods (i.e. broad and targeted questions) to use during a lab session is discussed.

It should be noted that since there are more activities than GTAs, five GTAs received the 1-to-1 training twice in the same academic year. The aim of the pedagogical training of the second 1-to-1 session was agreed with the GTAs and focused on how to deal with challenges which may arise with students and also the GTA's experience of teaching both students and their peers.

Peer teaching sessions (also known as peer assisted learning) provide an opportunity for new teachers to practice designing and delivering teaching sessions to their peers in a safe space and before they teach it to their students. Peer teaching is an indispensable component for the success of the proposed cyclic training. The Group session is intended to offer an opportunity to the lead GTAs to practice the techniques, theoretically learned in the 1-to-1 session, by teaching other GTAs that, having limited prior knowledge on the lab activity (i.e. learning outcomes and procedure), play the role of students.

The GTAs experience teaching through a student's eyes when they are taught by their peers. They become more invested in the experience than they may otherwise have been as they will subsequently teach the session to students and therefore need to be sure they have understood the content. In this environment, observing GTAs are more likely to pose questions whenever anything is unclear, alerting the lead GTA to where their teaching method is less successful (Cressey, Boud, and Docherty 2006). The experiences of the Lead and observing GTAs can then be used as a starting point for reflection as seen in the reflection-on-action in (Munby 1989) and more recently in the action-reflection cycle in (Naidoo and Naidoo 2021).

If the design of the initial part of each Group training is session specific and the responsibility of the Lead GTA, the last part is consistent for all Group training session and is used to align the assessment of the teaching with the learning outcomes. During this stage, GTAs collegially design targeted questions that allow them to assess the learning outcomes based on the teaching activity that they have just completed (Figure 1(b)). Having GTAs developing the assessment with a sufficient level of autonomy aims to motivate them (Kajfez and Matusovich 2017), while fostering a sense of ownership of the teaching process. In addition, having GTAs working collaboratively towards the assessment questions, mitigates the risk of having different GTAs assessing different students non-homogenously.

The feedback process

Feedback is the final, crucial, step to complete the envisioned cycle of GTA training as shown in Figure 1(a). The purpose of feedback is two-fold. From a GTA's perspective, having to provide feedback in a structured way represents an essential opportunity to foster self-reflection. From a teacher's perspective, the same feedback can be used to monitor GTAs' progression and consequently assess the validity of the training. The idea is that originally implicit knowledge, through a process of self-

reflection and sharing, can become explicit (Kusano et al. 2014, June). That is, if the personal reflection of a GTA becomes more concerned with pedagogical considerations, it will demonstrate an increase in their awareness and perception of the value of pedagogy as part of their approach to the sessions. Consequently, the scaffolding for a successful teacher has been put in place and the training can be considered effective.

Data collection

GTA feedback was collected with a personal online survey distributed after all the sessions of a given lab activity were completed. Before deploying the survey, its validity was reviewed by an additional member of the Academic Professional Development team with knowledge of survey design.

The survey is divided into two parts, prompting GTAs to reflect on their training and teaching separately (Figure 2). Each part starts with a question on a Likert scale about the overall success of the session whose answer spans from strongly disagree (1) to strongly agree (5). All remaining questions are open-ended so that GTAs can write their responses with no word constraint.

	Autumn Semester	Spring Semester
GTA Training Feedback	A0. Was the training provided for this session sufficient for you to confidently engage with students? (Likert scale)	S0. Was the training provided for this session sufficient for you to confidently engage with students? (Likert scale)
	A1. Explain below the reason for your selection	*S1. Provide evidence for your selection
	A2. As you received your training, what was the "muddiest point" you faced? Why?	*S2. As you received your training, what were the highlights? Provide evidence to support your answer.
	A3. What do you think could be improved about your training? Why?	*S3. As you received your training, what was the "muddiest point"? Provide evidence to support your answer.
		S4. What do you think could be improved about your training? Why?
Teaching Feedback	A4. Were the sessions you taught successful?	*S5. In your opinion, to what extent did students meet the learning outcomes?
	A5. Explain below the reason for your selection	*S6. Provide evidence for your selection
	A6. What were the highlights (things that went well)?	*S7. When were the students most engaged? Provide evidence to support it.
	A7. What were the challenges you faced?	*S8. What showed you that the use of final group discussion was (not) effective?
	A8. What do you think you need to work in/address for next time?	*S9. What were you most proud of about your teaching and what was the biggest pedagogical challenge you faced? Provide evidence to support it.
		S10. What do you think you need to work in/address about your teaching for next time?

Figure 2. Feedback form questions employed during Autumn (left) and Spring (right) semesters for GTAs to reflect on their training (blue) and teaching (red). An asterisk (*) denotes questions that changed in the Spring semester.

These questions, asking GTAs to identify the highlights and challenges faced in the session and the improvement deemed necessary, were designed in conjunction with the aforementioned self-reflection technique introduced in the 1-to-1 training, in order to provide structure to the GTAs self-reflection.

It should be noted that the language used in the questionnaire was updated between the Autumn and Spring semesters. Such modifications, marked with an asterisk (*) in Figure 2, were deemed necessary after a preliminary analysis of the GTAs' feedback (more considerations about this will be discussed below).

Data analysis

The analysis of the data collected with the aforementioned feedback forms consisted of a combination of quantitative and qualitative approaches.

Quantitative analysis included the study of the results from the two Likert scale questions, both individually and in comparison to one another. In addition, the written production of each GTA was measured in terms number of produced words, while the timeliness of the feedback was measured by observing the time passed between the last teaching session and the submission of the relative feedback form.

The qualitative analysis hinged on an open thematic analysis that allowed for an inductive examination of the collected data. Each feedback was reviewed and codes emerged from the answers to the open-ended questions of the survey. The identified codes were 'competence', 'procedural', 'teaching performance', 'questioning', 'learning outcomes', 'engagement', and 'feedback'. The qualitative analysis allowed the authors to dig deeper to seek an answer to the research question.

Results and discussion

The main question this research tries to answer is whether the new protocol for training GTAs was successful. That is: if the training was effective in building GTA self-confidence, to support their self-reflection, and to develop their student-centred teaching skills. Three strategies were adopted: first, by looking at how GTAs perceived their training, then by comparing this with their assessment of the teaching, and finally, by analysing GTAs' feedback – looking for common themes.

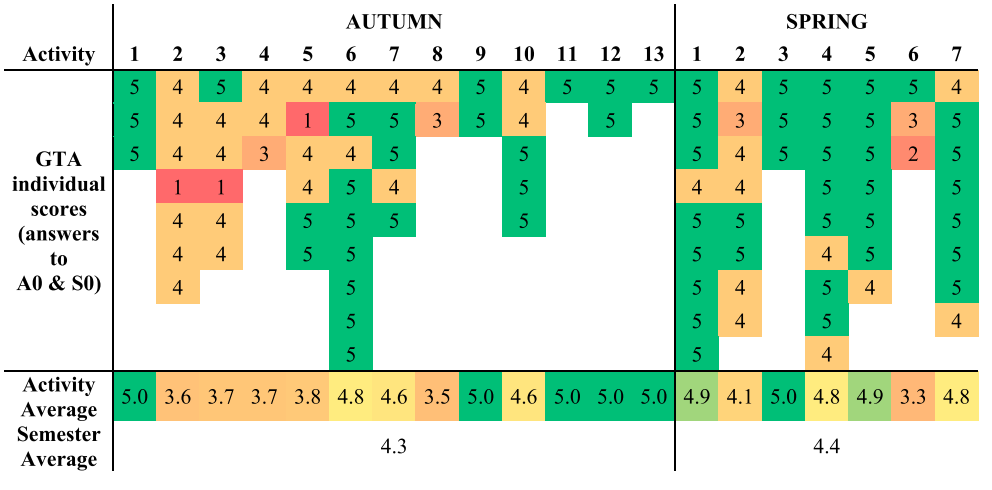

Figure 3. GTAs' individual assessment regarding if the training received built their confidence in engaging with students (i.e., answers to questions A0 and S0 of the Feedback form, with 1 indicating strong disagreement and 5 strong agreement)

GTA view of training effectiveness

When reflecting on the training session, GTAs were asked to assess their confidence in engaging with students based on the received training (questions A0 and S0 in Figure 2). The GTAs individual scores are shown in Figure 3 and suggest an overwhelming success of the training method with a staggering 90% of GTAs agreeing (4) or strongly agreeing (5) that the training sufficiently built their confidence ('*The individual session was really helpful and provided enough confidence to engage with the students*'). A closer look at the numbers highlights some other interesting aspects of the results of this survey.

No training activity was marked, on average, lower than 3.3 with an average of 4.3 in the Autumn Semester and 4.4 in the Spring one. In particular, the authors noticed that almost all trainings marked below average (i.e. all but one) were provided for newly introduced activities. Training for a new activity is challenging because of the lack of previous experience to build upon. This is true both for teachers and GTAs. As a teacher, this translates in the inability to fully support the GTA's learning. As there is limited anticipation of when and what their 'muddiest point'- most difficult or confusing part of a lesson (Brookfield 2015)- could be, no specific preparation can be made ahead of time. As a GTA new to the activity, this pressures them to obtain all 'knowledge' that needs to be learned within the few hours of the training session, exacerbating the stress they are under. If GTAs perceive that they did not achieve a sufficient level of self-recognised competence, they would get demotivated (Kajfez and Matusovich 2017). This, in turn, directly impacts their predisposition towards the training session, putting them at a lower level of the affective domain. This can be seen for example when some technical problems, which are almost unavoidable during training for a new lab activity, disrupt their learning. One of the GTA's comments ('*The beams were initially too long, meaning that the solutions did not work – highly confusing!*') clearly portraits the situation where the GTA, as a result of a technical problem, focuses only on the lack of a correct solution rather than on the learning outcomes achievable with the designed teaching activity.

Another way to study the effectiveness of the training is to compare, for each session, 'how confident were the GTAs in engaging with the teaching activity' (i.e. after training but before teaching) with 'how successful the GTAs perceived the teaching session to be' (i.e. after teaching). Information on the latter was gathered using the GTAs' individual scores to the two Likert scale questions of the feedback form (questions A4 and S5 in Figure 2). Results are presented in Figure 4. In both semesters, the large majority of GTAs (75%) rated equally their 'confidence after training' (Figure

	AUTUMN													SPRING						
Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
GTA individual scores (answers to A4 & S5	4	5	4	4	5	5	4	4	5	4	5	5	5	4	4	5	5	5	5	4
	4	4	4	4	1	5	3	4	5	5		5		5	3	4	5	5	4	5
	5	4	4	5	5	4	5			5				4	4	4	5	5	3	5
		1	1		3	5	4			5				4	4		5	5		5
		4	4		5	5	5			5				5	5		5	5		5
		4			5	5								5	5		4	5		4
		5				5								5	4		4	4		4
						5								4	4		4			4
						5								4			4			
Activity Average	4.3	3.9	3.4	4.3	4.0	4.9	4.2	4.0	5.0	4.8	5.0	5.0	5.0	4.4	4.1	4.3	4.6	4.9	4.0	4.5
Semester Average	4.3													4.5						

Figure 4. GTAs' individual assessment regarding if the teaching session was successful/students met learning outcomes (i.e., answers to questions A4 and S5 of the Feedback form, with 1 indicating strong disagreement and 5 strong agreement).

3) and their 'teaching successes' (Figure 4). This means that the remaining 25% of GTAs did not remain 'neutral' and that, based on their confidence level, they either 'over-performed' or 'under-performed' during teaching. In Autumn, the majority of non-neutral GTAs (60%) rated teaching success higher than their confidence level before teaching. Conversely, in Spring, more than 80% of non-neutral GTAs reported a teaching success lower than their initial confidence.

It should be noted that GTAs both regularly completed their Group training (activity-specific) and taught students throughout the Autumn semester. However, all GTAs only completed their 1-to-1 (pedagogical) training by activity 3 in Spring. Since much teacher learning occurs on the job (Sykes, Bird, and Kennedy 2010) and anxiety tends to drop as a result of gained teaching experience (Reeves et al. 2018), the authors expected that less experienced GTAs (Autumn) would feel less confident for in-service teaching than in Spring. However, this was not backed by the aforementioned results (i.e. GTAs underperformed in Spring). A trend more closely representing these findings is based on the shock theory reported in the literature (Chiu and Corrigan 2019). Here GTAs' self-efficacy – the teachers' beliefs to be able to effectively teach students a specific subject (Deacon, Hajek, and Schulz 2017; Dechenne and Enochs 2010) – after initially increasing during the 'honeymoon' phase crashes during the 'shock' phase only to then increase again in the 'recovery' and 'resolution' phases. Another interpretation from the literature comes from (Kruger and Dunning 1999), suggesting that GTAs' '*incompetence robs them of the metacognitive ability to realize it*'. While offering different interpretations, both studies support the thesis that GTAs will undergo a phase of perceived underperformance when they realise that they are not as ready as they thought they were. This outcome stresses, even more, the importance of continuous training for GTAs to overcome their 'recovery' phase. The element of continuity is central to the proposed training, which also offers them support and guidance. The former as peer-support, by having GTAs teach each other, and the latter by providing them with a tool for structured self-reflection.

Perceived pedagogical changes

The 1-to-1 training session is the first step of the cyclic GTA training method considered in this research. During the 1-to-1 sessions, GTAs receive pedagogical training contextualised to lab activities, the effectiveness of which is assessed by analysing the answers to the open ended questions of the surveys submitted by GTAs, looking for signs (if any) of improvement in their student–centred teaching and reflective practice.

The pedagogical training explicitly appeared only once as supporting evidence that the training was successful (or otherwise) in building confidence. The minimal reference to the training is a first sign that GTA reflective practice is still not well articulated. With deeper analysis, the impact of the teaching training could be extracted from some of the submitted comments. For example, if throughout the year ambiguous ('*more knowledgeable trainer would be better*') and often not usable ('*everything was clear*') comments were received, in Spring, once all GTAs had their 1-to-1 training, more pedagogical considerations started to appear. In particular, some of the comments addressed the principles of constructive alignment ('*the questions were well linked to the learning outcomes*'), diversity ('*critical questions can be used to address learning outcomes to the different group of students with different mode*'), and communication ('*the teacher was clear in his communication*') and they included, on top of a personal point of view, also the students' perspective ('*Being very visual makes the session really engaging from a student point of view*'). These comments show a gradual shift of the reflection towards more mature pedagogical considerations highlighting aspects typical of student-centred teaching. This increased reflectiveness is also consistent with the 'stages of concern model for TA development', which conceptualises a seven-stage pathway from teacher- to student-centred teaching (Ferzli et al. 2012).

These results seem to confirm the value of the pedagogical training after only one iteration of this continuous training methodology. As found in the literature (Mutambuki and Schwartz 2018),

prompting GTAs to reflect is helpful in identifying areas of difficulty. GTAs could use reflection, in conjunction with their peers and more senior colleagues, to formulate a gap analysis on their higher-level skills. For example, (Kusano et al. 2014, June) reports that GTAs, through a process of reflection and sharing can make their knowledge more explicit. As they start realising what they know (and consequently what they yet do not know), additional interventions could be targeted at addressing such gaps to further reinforce their teaching ability. These reflections will enable each GTA to be more responsible for and able to direct their learning into the future.

GTA engagement with feedback

Completion of the feedback form was an integral part of the GTA training as it was envisioned as a necessary step to promote self-reflection. In this section, the authors take stock of how the GTAs fared when engaging with it.

Considering that all GTAs are from engineering and the majority are international students, a limited writing output was expected. Nonetheless, in Autumn, the production was minimal with an average of only 100 words per form (14 words per question) which indicates a marginal articulation of their thoughts. This warranted a revaluation of the feedback form. In Spring, the authors introduced a new form, based on the same key points of the previous one (i.e. highlights, challenges, required improvements), but with a more structured scaffolding for the GTA's self-reflection. The quality of the submissions had clearly improved as the word count doubled to 200 per form and the scope of the reflection deepened.

One of the key features of effective feedback is timeliness (Wiggins 2012). In Autumn, about 45% of GTAs submitted their feedback within 3 days of the last teaching session, which rose to 80% after 2 weeks. Conversely, in Spring, submissions came in quite late, as the same target of 45% of GTAs was only reached after 2 weeks. It should be noted that while less timely feedback was provided in Spring, the completion rate increased and reached almost 100%.

One possible interpretation of this is that GTAs are engaged with the teaching and feedback process but not effectively enough. In other words, while the feedback was not quick enough to effectively redirect other GTAs' teaching performance (i.e. before starting a new cycle of the training), the GTAs consistently engaged with self-reflection.

It should also be noted that throughout the year less than 5% of GTAs disagreed (2) or strongly disagreed (1) that their training was effective. The authors believe this result to be unrealistic, even when accounting for the fact that some GTAs had previously taught some of these lab sessions. A plausible explanation for this comes from the literature (Young and Bippus 2008), suggesting that a social desirability effect could skew the answers of the survey when asking GTAs to assess their own training. This arises from the GTAs intention not to disappoint the trainer, leading them to report that the training was effective. For example, the same GTA supported a mark 5 for a training saying that '*the experiment was easy both to understand and to deliver to students*', only to then state, as the 'muddiest point', that '*the learning outcomes and the discussion questions were not clear and understandable for both GTAs and students*'. The latter is clearly incongruous with the GTA's assessment of the training session.

Future training should include more effective strategies to collect more candid feedback (using an anonymous form). While recognising that for the proposed training this incongruity was probably due to the unsuitable format, the authors also believe that this may represent a symptom of a deeper and wider issue; the GTAs did not know how to provide constructive feedback. Future pedagogical training (1-to-1 session) should support GTAs to value the power of learning strategies for providing/receiving effective feedback. This is in line with existing programs to support GTA teaching in Science (Gardner and Jones 2011) and more specifically in laboratory settings (Lang, Randles, and Jeffery 2020).

How can we help GTAs to understand their role?

By looking across all the comments some interesting considerations can be made on the perceived role of a GTA. Some GTAs do not recognise themselves as teachers and thus unintentionally reject some responsibilities and expectations that derive from this role. For example, a GTA suggested that '*more critical thinking questions should be provided*' deferring to the academic for the design of such questions, without realising that they would themselves benefit from engaging with that process. Similarly, another GTA pointed out that discussing the assessment questions among GTAs was useful to build confidence, but this should not exclude a final check with the academic. While seeking approval from the figure recognised as the authority may be related to their cultural background, this need shows that this GTA did not feel sufficiently empowered to 'own' their teaching. In both instances, the GTAs behaviour may stem from a low perception of autonomy, which translates into a lower engagement with the teaching and exacerbates their dependence on the academic (Winters and Matusovich 2011, June). Finally, some GTAs suggested that '*all questions should be discussed until all GTAs fully understand*'. While possible in principle, this is practically unfeasible because of the tight timetable the lab activities are forced to work around. It also highlights the underpinning belief that training stops when the session is completed, whereas good practice would have teachers gauge their preparedness and, if necessary, practice more. An example of the latter is provided by one of the experienced GTA that stated that '*Usually I do lots of search on internet after training sessions about background information needed for each lab*'. The need to '*fully understand*' may also indicate that GTAs believe that the students learn at a lower than expected level of Bloom's Taxonomy. In other words, GTAs might think that students require concrete answers. Consequently, they seek such answers during training in order to be able to provide them to students during teaching. Also in the literature (Gardner and Jones 2011; Volkmann and Zgagacz 2004) there are examples of this, with GTAs that shy away from inquiry-based teaching and tend to give students the 'correct' answer, as inquiry could lead to a 'viable' explanation rather than correct information. However, this often clashes with the expectations academics have of GTAs. Generally, academics would prefer GTAs to admit to student that they do not know an answer, but that they will show students how to logically find it out. This approach in fact would better support students' learning while also showing that there are many ways of getting the required information.

It appears that, for some GTAs, either the full potential of the role they are offered is unclear or they are unwilling or not sufficiently motivated to fully embrace it. This perceived disengagement towards pedagogical development may stem from the lack of support of their supervisors to develop their teacher identity (Buerkel-Rothfuss and Gray 1990) or it may be the result of exploiting this opportunity simply to secure financial support (Park 2004). Actually, being a GTA should be appreciated as the foundation of a career as a teacher in higher education. The authors believe that this is only possible by empowering GTAs, for example by building a community of learners and involving them in more aspects of the teaching process. All actions should be concerted to build a sense of ownership of their L&T process.

Limitations and future work

A key limitation of the present research was the absence of a control group of GTAs who did not participate in training. Without a control group, it is unclear to what extent GTAs who did not participate in training showed similar improvements in outcomes. In addition, no demographical information on the GTAs participating in the research was collected. For example, the lack of information on their educational background prevented to investigate how this factor might influence their perceptions of and engagement with the training.

Another limitation of the proposed training methodology is that formal feedback only takes place after the last teaching session of each lab activity (Figure 1). Retrospectively, the authors believe that

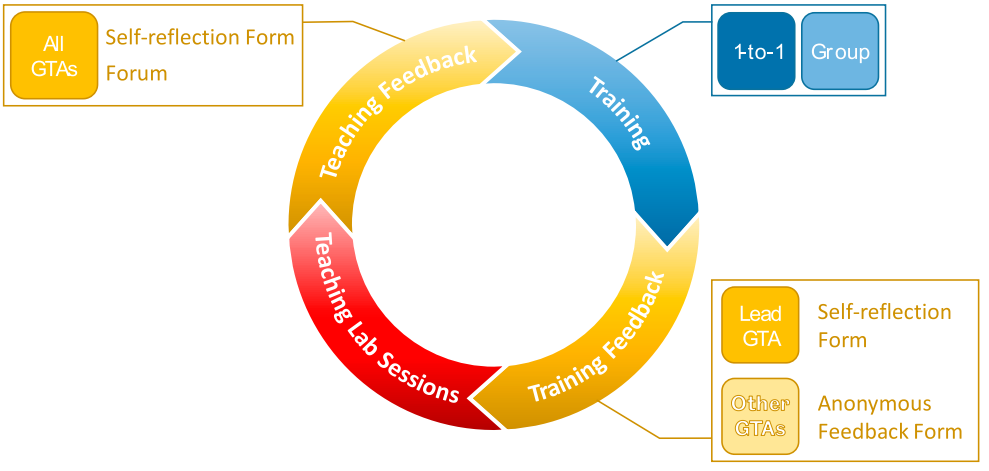

Figure 5. Schematic of the revised GTA training cycle in light of the outcomes of this research.

a more effective strategy would have included some timely feedback for the GTA leading the Group training session.

Moving forward, and incorporating these limitations, the proposed method will be further developed. A possible future GTA training cycle is presented in Figure 5, with changes to the feedback stages and their format. In particular, time for feedback should be allocated right after the Group training session itself. Also, for the teaching sessions a regular forum could be held to collect and discuss feedback.

The pedagogical component of the training is envisioned to become GTA-specific, targeting required areas of need to further promote their teaching profile development. Throughout their training, GTAs should be empowered to build a sense of ownership of their teaching. This could be translated into employing more experienced GTAs in leading a teaching session, developing new teaching material, or even taking over some of the lab activity completely. This latter would show that they are ready to take on a teaching post and could be affirmed via accreditation and membership of teaching organisations.

GTAs' confidence level will be further investigated by studying GTAs teaching self-efficacy using a well-established instrument introduced by Volkmann and Zgagacz (DeChenne et al. 2012a). In addition, to better assess progression of their development of students-centred teaching and reflective practices the use of the 'stages of concern model for TA development' (Ferzli et al. 2012) will be explored. Finally, GTAs will be asked to reflect on their training after a semester or even a year to consider how (or if) the new conception of pedagogical approaches has impacted their teaching in the long term. This could be done with a series of interviews or using focus groups.

Conclusions

This study presents a training method for Graduate Teaching Assistants (GTAs) teaching in engineering laboratories. The proposed training was based on session-specific content, contextualised pedagogical material, and self-reflection. In addition, by exploiting peer teaching, it offered a series of recurring individual and group training sessions where GTAs could practice before engaging with in-service teaching. The feedback collected from the GTAs over a full academic year was analysed. The main outcomes are summarised below.

- Both the direct (self-assessed GTA confidence level) and the indirect (supporting evidence) methods used to study the effectiveness of the proposed methodology show encouraging

results. In particular, the confidence level after training was scored highly by GTAs and, as a result of their self-reflection, a shift towards more pedagogically oriented comments was observed, improving from the Autumn to the Spring semester.
- The collected comments highlighted the struggle of GTAs with the format selected for the feedback. In particular, the written feedback was minimal and often not sufficiently articulated, it was often submitted too late to be effective at redirecting their practice. In some instances, self-assessments were skewed because of a social desirability effect.
- The perception of their role as teachers is inconsistent among GTAs. There are a few GTAs eager to develop their teaching profile, but the majority seem disengaged towards pedagogical training.
- Some GTAs underwent a 'shock phase' (i.e. teaching success lower than their initial confidence level) during the second semester. Only a training method that is continuous in its nature can support these GTAs to enter a 'recovery phase' to exploit their gains in confidence and capability.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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