HOW DOES A TEACHING ASSISTANT'S DEFINITION OF SUCCESS RELATE TO HOW THEY PERFORM THEIR ROLES IN TUTORIALS FOR INTRODUCTORY PHYSICS COURSES AT THE RIJKSUNIVERSITEIT GRONINGEN?

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INTRODUCTION

At universities across the world, the tutorial system has a central role in modern physics pedagogy and the use of teaching assistants (TAs) to run tutorials is well-established (Lewis & Lewis, 2005, p. 3; Park, 2004; Wagener, 1991). However, if a TA's definition of success affects how tutorials are held then the TAs implicitly have an important part to pay in upholding or undermining faculty or university educational goals. To address this issue, we must understand the factors influencing how TAs teach. These factors affect the TAs definition of success, which is related to the 'apprenticeship of observation', where student teachers (as TAs arguably are) do not recognise that the years spent observing their previous teachers during their own education only exposed them to the visible parts of a teacher’s role, and is responsible for preconceived ideas about how to teach that are very hard to change (Lortie, 1975/2002).

Until relatively recently most TAs were post-graduates, valued for their essential role as mentor in undergraduate research as well as teaching, which not only spreads the faculty workload but provided the TAs opportunities to develop a deeper understanding of their research (Feldon et al., 2011; Good, Marshman, Singh, & Yerushalmi, 2020). However, graduate TAs (GTAs) are subject to the same tension between their teaching and research responsibilities as their own research mentors and faculty staff, and so it has become quite common to see a rise in the use of undergraduate TAs (UTAs) (Weidert, Wendorf, Gurung, & Filz, 2012).

Undergraduate TAs are current undergraduate students who have previously completed the same course, even as recently as one semester previously. How graduate and undergraduate TAs are selected is a university or faculty decision, as is the need for their training. There is no regulatory control concerning training, minimum levels of experience, or suitability. For GTAs, the teaching element may be a formal part of their research, whereas UTAs are not required to teach as part of their degree. Both the GTA and UTA positions are paid roles.

The initial drive to use TAs may have been borne out of cost-cutting but subsequent research has shown that the influence of TAs has many benefits. One benefit is that UTAs are highly motivated, in part because of self-selection, and that motivation and energy is infectious (Rives & Jabker, 1976). In addition, the TAs also develop more comfortable and close relationships with their student peers, creating a more relaxed environment where students feel more able to ask questions and engage with the material more effectively. Lastly, the UTAs also have valuable insight into the course, as they have recently completed the same course at the same faculty and therefore have a unique perspective of the expectations and outcomes (Dickson, 2011; Reges, 2003; Roberts, Lilly, & Rollins, 1995; Stang & Roll, 2014).

The use of TAs benefits not just the students, but also the TAs themselves (Baxter Magolda & Rogers, 1987; Harper, May, & Oliver, 2002; Hendrickson, Schalk, McGinnis, Smith, & Harring, 2009; Weidert et al., 2012). There a wide body of research into how to improve the effectiveness and utility of TAs (Tanner & Allen, 2006; Tien, Roth, & Kampmeier, 2002; Wagener, 1991; White & Kolber, 1978), but there is very little existing research into how those enactments affects TAs’ effectiveness and utility in helping students learn.

Thus, this research addresses the question: How does a teaching assistant's definition of success relate to how they perform their roles in tutorials for introductory physics courses at the Rijksuniversiteit Groningen (RUG)?

LITERATURE REVIEW

The literature review develops a baseline set of prior research that frames the research within a context. The literature was selected primarily by keyword searches relate to TAs (e.g., GTA, TA, UTA Teaching assistant, physics instruction and enactment including synonyms and related word and phrases (e.g. alignment of beliefs and practices, teaching orientation, values). To keep the research current, the main focus was on peer-reviewed and published articles from 2000. However, earlier articles dating back to the 1970s were also used where the conclusions had direct relevance to this research. The research was conducted using SmartCat, the library search engine at RUG. Where possible the articles were limited to issues related to physics courses.

ROLE OF TEACHING ASSISTANTS

There is a rich body of research concerning the role of TAs; one study that has a direct read-across to this study concerns first year introductory physics courses. The University of Colorado Boulder (CUB) utilises a system of undergraduate learning assistant (LAs) alongside GTAs (Gray, 2013). In this context LAs are a form of UTAs, whose role is to facilitate discussions among groups of students in a variety of classroom settings that encourage active engagement. The LA program is formalised, with weekly preparation groups and mandatory training. The tutorials have around 28 students, one GTA and 2 LAs and attendance counts towards the final grade. The tutorials are guided through the use of validated research worksheets.

In Gray (2013), the LAs understand their role is " *to facilitate students' construction of knowledge*" (p. 84), to help the students develop a deeper understanding that goes beyond just getting the answers, in contrast to teaching which the LAs see as *"is giving students information"* (p. 84). Gray (2013) presents an encompassing summary of the experiences of undergraduate LAs at CUB and recognises that there is an important missing aspect in their research:

> "*Do LAs who did not have an LA when they were a student in the class develop different views of teaching and learning than the views presented here….. because they did not have the opportunity to experience that element when they were students?*" (Gray, 2013, p. 199)

A further study by (Chini & Al-Rawi, 2013) explores how physics-based GTAs align their own beliefs about teaching and their classroom practices in an algebra-based physics laboratory in large research university, with a traditional teaching method and less engagement with independent thinking. In this study, five GTAs were first video-recorded teaching Newton's Second Law and then interviewed about these teaching sessions; student evaluations of the course were also taken into consideration. The GTAs all believed the session helped students to '*enhance their understanding' (p. 2)* and to show the relationship between physics and the real world.

Similarly, all GTAs in Chini and Al-Rawi's (2013) study understood their role to include *"answering students questions and explaining how those concepts related to the tutorial'* (p. 2) but they were split, whether this help should be limited to answering the questions that were asked, or by recognising when help was needed. This was demonstrated by their preparations: some focussed on ways to explain or brainstorm interesting questions while others focussed on knowing the material thoroughly.

Chini and Al-Rawi (2013) described the GTAs on whether they supported or opposed curricula goals to enhance independent learning, which required the students to organise the data presentations and work out derivations and analysis questions in groups. The GTAs were categorised as student-centred if the emphasis was on students performing the behaviours (and thereby supporting the course goals of independent learning), instructor-centred if the GTA performed the behaviours (so not supporting course goals), and shared if the GTA lead the behaviour but required student involvement, or sometimes performed the behaviour and sometimes required students to perform it. This revealed that there was very poor alignment between TAs statements, their practices and student evaluations: most marked was the inversion between TAs whose statements supported student -centred learning, and those who supported instructor-centred. Invariably their teaching styles revealed the opposite behaviours, a finding that indicates the research question in this study has a valid premise.

Winstone and Moore (2017) studied how GTAs 'flex' between student and teacher. This study addressed the question of GTAs being neither student and not teacher, which required them to adopt different identities at different times. (Winstone & Moore) clearly articulated their research was driven by a lack of previous research into how this liminal position affected their teaching abilities as opposed to their research activities. This study identified one particular area that underpins this research: GTAs were not confident of their 'teacher' identity in terms of meeting the student expectations as a knowledgeable person, concisely expressed as *"…someone who's pretending to be a lecturer for an hour"* (p. 496).

In Winstone and Moore (2017) was not examined further as the focus was one how to develop GTAs into academic professionals but it serves to further spotlight the general lack of research in whether TAs can separate their inherent preconceptions and assumptions as required in a teaching environment.

Lastly, another aspect of the role of TAs is illustrated by Ornek, Robinson, and Haugan (2008) which identifies some reasons why students might find physics difficult and concluded that that students and TAs have almost the same perceptions about the factors which make physics difficult: too much theory, too many formulas and too many laws and rules, whereas faculty members believe the problem is that physics is not interesting to students. The only area where TAs and faculty members hold the same views, in opposition to the students, is that physics requires a good mathematics background. Ornek et al. (2008) recognises that faculty member and students should understand the others' views and identifies TAs as a bridge between the two groups:

> *"It may be because TAs still remember what it is like to be new to the subject. Students and faculty members think differently in terms of difficulties which students have in physics."*
>
> (Ornek et al., 2008, p. 34)

ENACTMENT EFFECTS

In educational pedagogy, the enactment effect is where a person believes they know how to teach after years of watching their elementary and secondary teachers. A relevant study that is specifically related to enactment effects in physics is Madsen, McKagan, and Sayre (2015), who used the Colorado Learning Attitudes about Science Survey (CLASS) and the Maryland Physics Expectations Survey (MPEX) to consider how physics instruction impact students' beliefs, when physics undergraduates gain expert-like beliefs, and lastly how these beliefs impact their learning of physics. Madsen et al. (2015) found that Physics majors' beliefs remain relatively unchanged over the course of their physics studies and those who major in physics have more expert-like beliefs than other majors, demonstrated by the experiences of non-physics majors who take calculus-based courses:

> *"We expect students would better understand the discipline of physics and how to learn physics after completing a physics course. Instead, their beliefs become less expert-like and students leave their course believing that physics is, for example, about memorizing facts, plugging numbers into equations, and not relevant to their life" (Madsen et al., 2015, p. 16)*

Madsen et al. (2015) further asserts that these physics belief are developed and fixed during high school and suggests strategies to address this, and these are all in areas where TAs operate: tutorials to refine and reconcile intuitive ideas, reflection activities and peer instruction. After all a tutorial TA who does not believe that intuition from everyday experience can be a useful foundation for building physics knowledge may disregard students' common-sense ideas, negating the intention of the tutorial design.

This is also a large amount of research covering the development of expert-like behaviours, specifically relating to physics R. M. Goertzen, R. E. Scherr, and A. Elby (2010) proposes a different perspective on how teachers can best assist learners based on a physics GTA with clear and strongly held beliefs about how students learn physics. The focus on the TAs beliefs and the investigation into the clarity of his thought process behind his actions is the main interest here:

> "*People do what they do because it makes sense to them based on their past experiences… Novice instructors existing beliefs and prior experiences (are) the essential material from which expert conceptions of teaching are constructed" (R. M. Goertzen et al., 2010, p. 3)*.

R. M. Goertzen et al. (2010) introduces the idea of framing: what to do in a situation based on understanding of the nature of the situation, asserting that that *" students and TAs naturally use information from their prior experiences at school to inform their framing of present course activities" (p. 3)*. For example, if students and TAs prior experiences have emphasised rote learning then activities to promote intuitive sense making may be misinterpreted. This effect is illustrated through a case study of a GTA who consistently demonstrated behaviours inconsistent with faculty goals, for example equating "*assisting students with giving them information" (p. 4)* and thereby "*failing to elicit student ideas"(p. 5)*. On closer study, it is shown that the TA believed that the conceptual focus of the tutorials was not giving the students sufficient instruction on developing key skills was driving his demonstrations of how to solve quantitative problems by clearly answering questions:

> *"I don't think it's the math that's holding them back. It's the translation of intuitive ideas into algebra" (R. M. Goertzen et al., 2010, p. 7)*.

The GTA had strong memories from high school where teachers marked his work as incorrect because his (correct) answers were not in the expected form. He also assumes that because he would be ready for direct instruction to get '*unstuck*' after struggling with a problem so would his students and that they would be equally frustrated if, after asking for help, they were only given hints and tips.

Further research into developing advanced problem-solving capabilities in physics exposed tangential enactment effects. Problem solving is well-studied field (Heller & Hollabaugh, 1992; Van Heuvelen, 1991; Yerushalmi, Henderson, Heller, Heller, & Kuo, 2007) that aims to quantify the differences between experts such as physics faculty and TAs, and novices like physics students and then to identify strategies to make the novices solve problems in a 'expert like' way. Lin, Henderson, Mamudi, Singh, and Yerushalmi (2013) concluded that the influence of former education experiences on the TA hindered in the goal of helping students develop an expert-like problem-solving approach because of discrepancies between their beliefs and their practices. Like Madsen et al. (2015), this study concluded that this was likely due to conflicts with values established during their own education.

SUCCESS

Many studies have attempted to measure the relationship between attitudes about science and student achievement (Marina, Tetyana, Andrea, & Anna, 2011) but in this study the focus on success is not about quantifying if the TAs or their students were successful but rather more related to trying to tease out TAs beliefs through their actions.

In order to understand what success means it is useful to understand what a TA might understand as the purpose of physics education. Volkmann and Zgagacz (2004) documented a GTA delivering a inquiry-based physics for the first time and how this led to a change in her orientation to teaching, where orientation is "*general patterns of thought and behaviour relating to science teaching and learning*" (p. 2). Of interest to this research is in her perspective on why she studied physics: *"Its beautiful how all subjects in physics are tied together, but nobody put it that way, nobody pointed out patterns, shortcuts, similarities etc. I usually learned by myself how the topic tied to what I already knew*" (p. 6) related to her thoughts on what is teaching and what is learning: *"teaching consisted of information delivery and learning resulted from the individual's native talent and hard work…class time was for teaching not learning"* (p. 6). Referencing Magnusson, Krajacik, and Borko (1999) the GTA's orientation was determined as "*didactic and academic rigour*" (p. 9), where didactic means to tell, show, explain and question students to verify knowledge, and academic rigour verifies concepts, shows links and represents science as a body of knowledge, focusing on students ’ learning. In this context) success is indicated by the students acquiring the *"correct scientifically accepted facts"* (p. 10). The GTA felt that the assessment process *"should reward students that worked hard and made sense of physics and penalise students if they did not have the native intelligence to understand physics".* (p. 11).

This attitude to success was substantiated by Kind (2016) which examined the orientations and beliefs about science in pre-service teachers and discovered that the same didactic academic rigour orientation was dominant, not just in physics but all STEM subjects.

This prior research establishes a firm framework that underpins this research exploring whether the TAs own background in learning physics and their own underlying assumptions about the nature and purpose of physics, informs the delivery of tutorials for introductory physics.

METHODS

This section describes how this study was designed and conducted. The following sections present the research design, the population and disciplinary context, an overview of the participants, the data collection techniques, and the analysis methods.

RESEARCH DESIGN

The purpose of this study was to examine whether how TAs teach tutorials for introductory physics courses is shaped by their pre-existing beliefs about the purpose of studying physics. To address this, the study employs both qualitative and quantitative research methodologies, and follows a staged process as presented in Figure 1.

The first step was to identify the study population, consisting of UTAs and GTAs from the Faculty of Science and Engineering (FSE) and from University College Groningen (UCG), which are the two faculties offering physics courses. The scope was limited to introductory physics courses as these are taught by both faculties.

For convenience, the term TAs will be used to represent both GTAs and UTAs.

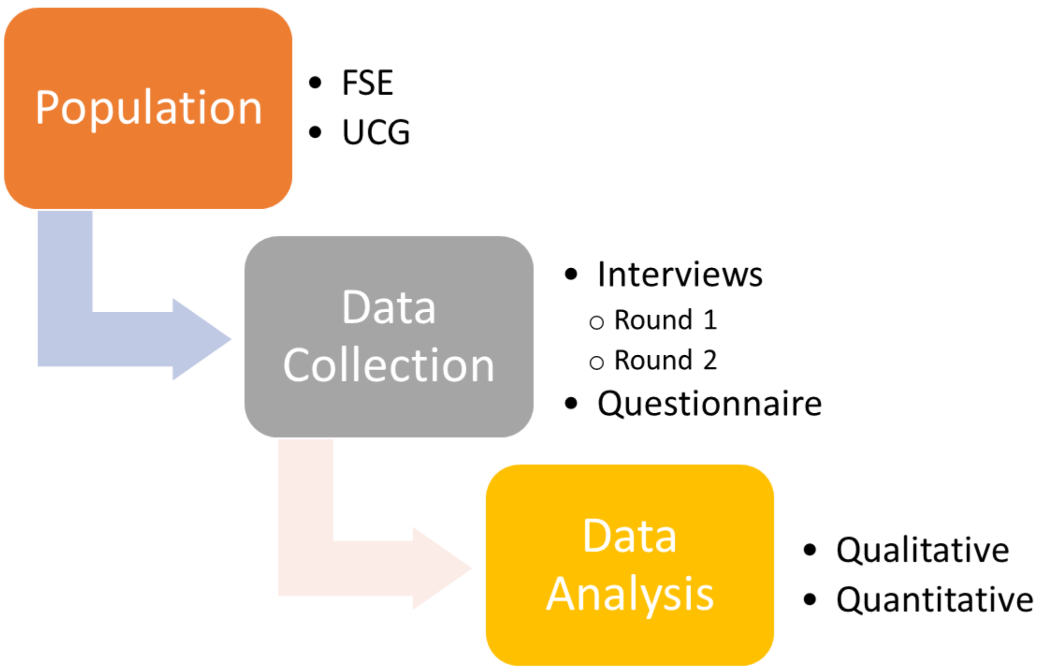


FIGURE 1: RESEARCH DESIGN OVERVIEW

The second step was to identify both qualitative and quantitative data that could be collected for this study. Qualitative research is largely exploratory, designed to draw out underlying motivations, opinions, and perspectives of the participants, using a variety of methods such as focus groups, individual interviews, and observations. The sample size is typically small. In this study, semi-structured interviews were used to elicit information from the TAs on the major themes - how they viewed success, how they learned the content and how they taught it, and how they learnt physics, expressed in their own words. This allows the research to identify and assess both common and divergent strands of thought and opinions among the TAs. As these interviews were conducted either face to face or via video conferencing, this technique also allowed for interesting or unexpected responses from the TAs to be probed further and gave personal insight into the TAs.

This approach is in line with current practice and use of qualitative data (Bogdan & Biklen, 1997; Hammarberg, Kirkman, & de Lacey, 2016; Patton, 1990; Teherani, Martimianakis, Stenfors-Hayes, Wadhwa, & Varpio, 2015).

Quantitative research, on the other hand, is used to quantify issues by generating numerical or statistical data It is used to quantify defined variables, such as *'How many?'*, *'How much?'* or *'How often?'* . Quantitative data collection methods are generally more structured than qualitative data collection method, and typical methods include surveys, online polls and questionnaires. Again, this in in line with current practice. (Babbie, 2016; Muijs, 2011). In this study questionnaires were developed to provide some statistical insights on the population of TAs at the RUG, as well as to have a wider variety of answers. The interviews on the other hand were to have a deeper answer to questions.

The combination of both qualitative and quantitative data to address different aspects of the research question incorporates the strengths of both, and is an accepted technique, generally referred to as 'mixed methods' research (Bryman, 2006; Onwuegbuzie & Leech, 2005) and is the research approach adopted for this study.

POPULATION AND DISCIPLINARY CONTEXT

The Rijksuniversiteit Groningen (RUG) is a public research university in the city of Groningen in the Netherlands. The university was founded in 1614 and is the second-oldest university in the Netherlands. It has eleven faculties, nine graduate schools, 27 research centres and institutes, and more than 175 degree programmes. Currently, there are over 30,000 students from more than 120 countries.

Within RUG, there are two faculties that provide instruction in introductory physics courses: Faculty of Science and Engineering (FSE) and University College Groningen (UCG). FSE is a broad science and engineering faculty, with over 6500 students, 700 TAs and 14 undergraduate courses, including physics which is divided into 4 separate tracks. By contrast, UCG is a liberal arts and science college offering small-scale, individual and interactive learning and typically has around 300 students in total, following a single Liberal Arts and Science course that offers several specialisations including a physics major. At UCG there are typically around 10 TAs.

The RUG encourages a student-centred approach to teaching, combining traditional large-scale lectures with smaller interactive tutorial groups, led by TAs, known as student assistants. In these tutorial groups, the students are expected to think along with the TA and other students, to encourage the development of conceptual knowledge and critical thinking skills. The RUG prioritises interactive and deep learning over passive and superficial memorization of facts, and currently has over 700 student assistants to lead these interactive and smaller-scale tutorials. This approach is adopted at both FSE and UCG, but are enacted in very different learning environment: FSE uses a traditional large lecture / smaller tutorial combination and UCG has small groups, around 6 to 10 students for both lectures and tutorials and encourages project based and independent learning..

The TAs are selected on a variety of criteria, which varies between lecturer and faculty. Generally, an active willingness to act as TAs takes priority, while previous high attainment on the same course is often required. The TAs are paid hourly, with semester long contracts, and some TAs lead more than one course. Whilst many are postgraduates, there are also many second- or third-year undergraduates. Training is offered at the RUG but is not mandatory, and many TAs have not been offered any formal training before or after commencing the role.

Specifically, this study looks at TAs who lead the introductory physics tutorials for first year undergraduates. These tutorials are part of the mandatory courses undergraduate students majoring in physics and includes the following courses: electricity and magnetism, programming in python, linear algebra, calculus, mechanics and relativity and physics lab. Given the wide variety of available tracks within both FSE and UCG, these are the only courses taken by all students at both faculties, and therefore provide the maximum commonality of experience.

The introductory physics courses are generally in one or two 10-week long blocks. At both FSE and UCG, each course generally has two 2-hour long lectures a week supplemented by two 2-hour long tutorials. At both FSE and UCG, a single TA leads the tutorials. At FSE, this tutorial size may range from between 10-40 students whereas at UCG the tutorial size is generally closer to 5 to 10 students.

At both FSE and UCG, the TAs are free to lead tutorials in the format they choose. At the FSE, this takes the form of leading the students to work through the assigned tutorial questions in a classroom setting. The students generally work in pairs or small groups and are encouraged to freely discuss the topics and to question the TA. At UCG, the TAs are provided with structured notes summarising the topic, the questions to be worked through, and any other useful information. An example is included at **Error! Reference source not found.** .

The number of physics TAs at FSE greatly outnumbers those at UCG although there is some useful overlap as some of the TAs at UCG completed their undergraduate studies at FSE, and as the learning environment is quite different in these faculties, these TAs have experienced learning and teaching physics in very different environments. Many TAs also take more than one course, and often do the same course for many years in a row. Often the more experienced TAs will also then also become a TA at UCG.

The study uses the TAs in two ways. The qualitative interviews focus on 3 TAs that were volunteered from each faculty whereas the questionnaire was distributed to all TAs from the UCG and a simple random sample from the FSE.

It is worth noting here that although the RUG is in the Netherlands, all physics courses are taught in English and the TAs come from a variety of nationalities.

PARTICIPANTS

Seven TAs participated in the interviews and have been allocated a pseudonym. An overview of the experience of each TA is given in Table 1. An equal number of TAs were chosen from each faculty as well as one TA who teaches at both faculties.

TABLE 1 INTERVIEW PARTICIPANTS

Pseudonym	Faculty	Courses	Level
Lars	FSE	15	GTA
Daan	FSE	6	GTA
Coen	FSE	3	UTA
Tom	UCG	3	UTA
Jeroen	UCG	2	UTA
Erik	FSE/UCG	3	GTA
Lily	UCG	1	UTA

DATA COLLECTION

The data collection was divided into three distinct phases: the first phase was based on a separate research project, in which the interviews were conducted by another person, for related research purposes with specific questions to address this research. These interviews were limited to TAs from FSE. These interviews were audio-recorded and transcribed, and as these initial responses were analysed, the research question matured. Consequently, a second phase of interviews with participants from UCG, as well as one TA who taught at both faculties were undertaken, to provide wider variety of answer but in less depth.

The initial interviews were conducted face-to face but COVID 19 restriction prevented this for the second phase in which two performed via video conferencing and two face to face.

The interview questions developed from the first phase of the data collection are shown in **Error! Reference source not found.**.

Questions 16 and 17 refer to supplementary tutorial information. These questions were also used in the second phase of the interviews, with the exception of questions 16 and 17.

FIGURE 2: INTERVIEW PROTOCOL

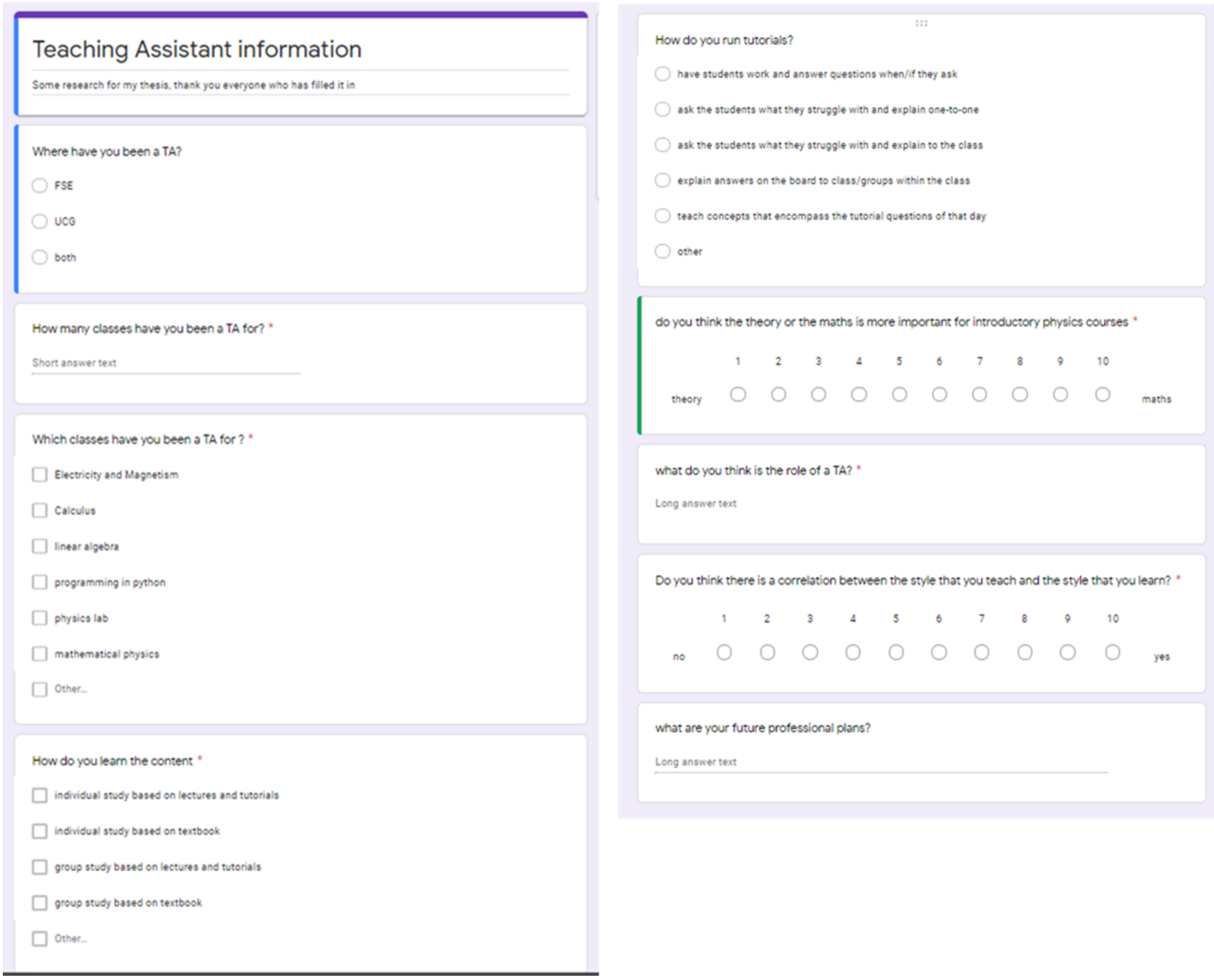
TA Interview Protocol

1. How many courses have you been a TA for? What subject(s) did you TA for and where were you in your program at that/those time(s)?
2. How would you describe your role as a TA for this course? Did your role differ for other courses?
3. Based on what you've observed in your tutorials so far, what have you noticed/stands out to you about how your students work in tutorials (e.g., group vs. individual, level of math, gender, language)?
4. What are your thoughts about group work vs. individual work for learning E&M? Do you think transforming tutorials into group work would be possible?
5. How would you describe what you do on a typical non-exam day in your tutorial? What about first days? What about on exam day? What about day after the exam?
6. How do you gauge the students' progress on a tutorial problem?
7. Would you do the same things if your section had more/less students? What do you think is the maximum number of students a TA could/should handle for E&M? Do you have thoughts about a minimum number of students?
8. What do you think affects student attendance in tutorials? What are your thoughts about keeping track of the attendance?
9. Do you know any/some/most/all of your students by name? Will you eventually (intentional or not)? What are the pros/cons of that?
10. How do you prep for tutorials right now (and about how much time do you spend prepping)? Do you collaborate with other TAs? How does your prep this year compare to your prep in previous years?
11. What kinds of challenges or barriers have you encountered as a TA (e.g., grading exams, other TAs not pulling their weight)? How do you address those challenges/barriers? Do you anticipate encountering additional other barriers? Why or why not?
12. What kinds of supports would you like to see happen (e.g., same room, collective prep, more chalkboard, demos) that would help TA instruction for E&M? What are your thoughts about a co-TA model?
13. What do you do when same/different questions are asked by lots of students? When there are no questions? Why?
14. What do you think about the tutorial problems that have been assigned to the students (e.g., helpful in learning E&M, too easy/hard, too few/many…depends on topic)?
15. What do you think students should do (lecture, tutorials, HW, work with others, practice problems, etc.) to be successful in E&M? Why do you think that (is it based on how you/your friends/observations of students learned physics)? What counts as successful? How do you think students learn E&M?
16. This [tutorial] is something that was developed by another university using Griffiths to teach E&M. Take a minute to read through this. What are your initial thoughts about this tutorial? Do you think this would be helpful to students? Would it be helpful to do as a group, individually, both, or neither? How easy/difficult do you think it would be for TAs to implement them in tutorials?
17. Are there other thoughts about tutorials that you think I should know about but didn't ask?

This study focused on the TAs responses to questions 1-8, 10, 13-15 and 17 as the other questions relate to a larger project involving the data collected from the first phase. However, all the responses were considered and used if relevant. The TAs were self-selected for these interviews and therefore the data is classified as non-probabilistic sampling, which is regarded as appropriate for qualitative research (Muijs, 2011; Teherani et al., 2015) as it is not about a large population but instead trying to develop a deeper understanding of this small population of TAs involved in introductory physics courses.

The third phase of data collection invited all TAs teaching introductory physics courses at both FSE and UCG to participate in an online questionnaire. Random sampling in this way is considered probability sampling in order to make statistical inferences about the data and the population. The questionnaire is shown in Figure 3.

FIGURE 3: QUESTIONNAIRE DETAILS



Teaching Assistant information

Some research for my thesis, thank you everyone who has filled it in

Where have you been a TA?
- FSE
- UCG
- both

How many classes have you been a TA for? *

Short answer text

Which classes have you been a TA for ? *
- Electricity and Magnetism
- Calculus
- linear algebra
- programming in python
- physics lab
- mathematical physics
- Other...

How do you learn the content *
- individual study based on lectures and tutorials
- individual study based on textbook
- group study based on lectures and tutorials
- group study based on textbook
- Other...

How do you run tutorials?
- have students work and answer questions when/if they ask
- ask the students what they struggle with and explain one-to-one
- ask the students what they struggle with and explain to the class
- explain answers on the board to class/groups within the class
- teach concepts that encompass the tutorial questions of that day
- other

do you think the theory or the maths is more important for introductory physics courses *

theory 1 2 3 4 5 6 7 8 9 10 maths

what do you think is the role of a TA? *

Long answer text

Do you think there is a correlation between the style that you teach and the style that you learn? *

no 1 2 3 4 5 6 7 8 9 10 yes

what are your future professional plans?

Long answer text

VERIFICATION AND RIGOUR

To provide a reasonable amount of rigour in line with established practice (Morse, Barrett, Mayan, Olson, & Spiers, 2002) verification activities were built into this study to ensure both reliability and validity of the data:

- Methodological coherence in this study is shown by consistency between the research question, the method, the data and the analytical procedures. This is demonstrated by the introduction of a second set of interviews and modification of the question as themes arose. This shows that the interdependence of qualitative research was understood and addressed.
- Sampling sufficiency requires that participants should best represent the research topic, and this addressed by using only TAs who have taught introductory physics courses at both faculties
- The data was collected and analysed concurrently to allow adaptation of the question and iterations of the data collection.
- The research question grew organically from the themes arising from the data and was not used as a rigid framework to constrain the data collection and analysis.

Lastly an additional form of verification was used in the form of member checks by blinding the responses and having a sample of five people, unrelated to the study, code a sample of quotations based on the major themes. A sample of 5 people, 2 of which study at the RUG and 3 who are outside of education, were asked to categorize some sample quotes by the specific TAs and this was compared to the coding in this study.

		Member Check					
	Study Coding	1	2	3	4	5	Agreement
Lars	F	F	F	F	F	F	100%
Coen	T	T	T	T	T	F	80%
Daan	T	T	T	T	T	T	100%
Jeroen	T	T	T	T	T	T	100%
Lily	T	T	T	T	T	F	80%
Tom	F	F	F	F	F	F	100%
EriK	F	F	F	F	F	F	80%

F	Facilitator
T	Teacher

		Member Check					
	Study Coding	1	2	3	4	5	Agreement
Lars	E	E	E	E	E	E	100%
Coen	E	E	E	E	E	E	100%
Daan	E	E	E	E	E	E	100%
Jeroen	L	L	L	L	L	L	100%
Lily	L	L	L	L	L	L	80%
Tom	L	L	L	L	L	L	100%
Eric	L	L	L	L	E	L	80%

E	Exams
L	Learning

		Member Check					
	Study Coding	1	2	3	4	5	Agreement
Lars	+	-	+	+	+	+	80%
Coen	+	+	+	+	+	+	100%
Daan	+	+	+	+	+	+	100%
Jeroen	-	-	-	-	-	-	100%
Lily	-	-	-	-	-	-	100%
Tom	-	-	-	-	-	-	100%
Eric	+	+	-	+	+	+	80%

+	Positive
-	Negative

Figure 4 Validation of coding through member checks

As shown in **Figure 4** the majority have agreed with coding; Lars, Coen, Daan, Jeroen, Lily and Tom all have 100% consistency with my own coding, and Lily and Erik have an 80% consistency with my coding, which represents 1 person coding differently.. This validates the categorisation process.

Taken as a whole these verification activities confirm the coding and analysis is as accurate as reasonably possible and eliminated sources of potential bias.

Data Analysis

In this study, content analysis was used to identify patterns in the responses from the TAs. Responses to interview questions that addressed the role of TAs, what activities were carried out during tutorials, what constituted success for students and methods of learning physics were selected to reflect the focus of the research question.

The audio recording of each TA interview was transcribed into text and used as the primary source. By reading and re-reading these texts, it was possible to identify sections of the texts that addressed one or more aspects of the research question, defined as the 'themes':

- The role of a TA
- How success in introductory physics courses is measured
- Evidence of enactment effects
- Teaching Style

The texts were physically annotated with the theme and then the excerpts within each theme was further coded using emergent codes arising from the material rather than as pre-determined questions. This approach is broadly in line with established content analysis techniques (Bengtsson, 2016; Bennett, Barrett, & Helmich, 2019).

After several iteration and re-reading of the texts the codes were refined to a small group to closely reflect the research questions. These are shown in Table 2. These definitions of these codes have been chosen to force binary coding decisions which, when taken together, address the research questions

TABLE 2: THEMES AND CODES USED FOR CONTENT ANALYSIS

Theme	Code	Definition
Role of TA	Teacher	Provides information aligned with curriculum, the 'what'
	Facilitator	Enhance understanding of concepts, provides missing or additional information, the 'why'
Teaching Style	Didactic	Tells, shows, explains and questions students to verify knowledge; presents content knowledge
	Other	Not mentioned or other technique
How success is measured	Exam	Quantitative: Passing exams is the main success criteria
	Learning	Qualitative: Conceptual learning is valued above exam success
Enactment effects	Positive	References own prior experiences, such as 'how I did it', 'that's how to learn physics' etc when describing tutorials
	Neutral	No references made to own experiences / follows lecturer's guidelines or instruction

The quantitative aspect of the content analysis was through word frequency analysis: scanning the interview transcripts for the words most commonly used by respondents (after filtering out words such as I, me, we and fillers such as ok yeah, uhm, hmm, yep as well as the word student, as this occurred very frequently as a general noun rather than being associated with a specific point). The results were presented as word clouds.

After the themes and codes were established, a generalised model which concentrates on the points of similarity between the TAs opinion, and case studies which attempt to elucidate each TAs own experience.

RESULTS

The interviews for each respondent were summarised into individual case studies so that the coding could be applied. These are shown in Annex A. The interview responses were categorised and then assigned into two groups based on the first part of the research question: the role of the TA, mapped to the teaching style (didactic or other) as shown in Table 3..

TABLE 3 ROLE OF THE TA VS TEACHING STYLE

	Group 1 Teacher			Group 2 Facilitator		
Didactic	Lily Coen Daan	UCG FSE FSE	UTA UTA GTA	Lars	FSE	GTA
Other	Jeroen	UCG	UTA	Tom Erik	UCG FSE/UCG	UTA GTA

With respect to role of the TA, the responses were sorted into two groups. Group 1 defined the role as TEACHER, someone who provides information aligned with curriculum, the 'what'. Some quotes typifying this are shown below:

Lily: *"I would help them with their computer practical, which they were assigned by the teacher."*

Coen: *"my goal was kind of to try and help them solve the assignments, not to completely show them, like a mini lecture on how to do it"*

Group two believe the role of TA is a FACILITATOR who enhances understanding of concepts, provides missing or additional information, the 'why' and this is illustrated by some typical responses:

Lars: *"I see myself as a guide to, make sure that people have fun and progress during the making of the exercises. Of course, that means that sometimes you have to do a bit more than just give answers or give hints towards answers"*

Erik: *"Where you want to try to get people to understand what they're actually supposed to do with the material, and what it needs"*

The teaching style was primarily determined by use of a didactic academic rigour style as defined in (Magnusson et al., 1999) . The didactic academic rigour is characterised by use of words like "tell", "explain" or "show", or the assumption of an essential level of knowledge and is shown by:

Daan: *"once I graded a number of the exercises, then I tend to write down all the common mistakes that I find and then I treat them at the start of the tutorial on the black board. "*

Coen: *" the first year has been kind of that test to show if this is really this study for you … but I don't think that's a bad thing because …that's kind of my idea for it that it, it works kind of as a threshold… then you should definitely be able to pass the first year. That should not be a problem for you. If you want to get into real physics"*

The OTHER category covers a variety of different techniques such as this typical quote:

Tom: *"one student can explain to another student who has a similar mindset, a way of doing it that you didn't think about or that you don't grasp. And in that way, it can help them in a way that you wouldn't be able to."*

The next result shows the correlation between the TEACHER and FACILITATOR group and their views on success. This is shown in Table 4**Error! Reference source not found.**.

TABLE 4 WHAT CONSTITUTES SUCCESS

	Group 1 Teacher			Group 2 Facilitator		
Exam	Coen Daan	FSE FSE	UTA GTA	Lars	FSE	GTA
Learning	Jeroen Lily	UCG UCG	UTA UTA	Tom Erik	UCG FSE/UCG	UTA GTA

In the same way, with respect to what constitutes success, the responses were sorted into two groups: Exam, which focusses on quantitative results and LEARNING, where qualitative learning is valued above exam success. The quotes below are examples coded as exam:

Lars: *" So if you know the previous exam you can and make the current exam, if you understand like 50% of the material and have done enough exams, then you're going to nearly ace the new exam. "*

Daan: *" because E&M you can in principle do just by following Maxwell's laws and then just writing it out in a mathematical way without actually knowing what's, going on. "*

Coen: *" if you want to be successful for this course, you would just go through the homework assignments and make sure that you know the derivations of them."*

Group two believe the measure of success is related to learning, as illustrated by some typical responses:

Tom: *" I honestly think that the most important thing is getting that Eureka moment. Like, even if you suck at actually just calculating stuff in your head or whatever, if you can understand and grasp the concepts behind it, to understand how say integration works and how it relates to differentiation and how all of these things, um, sort of function together. If you can like sort of start plotting in your mind these abstract graphs or whatever. I think that is the important thing."*

Jeroen: *" success is a very personal thing. So there can be students who really struggle with mathematics for whom getting a six and a half is amazing. Um, so like the success of a student depends on every individual student and how difficult they find this particular course"*

Erik *"It can be really important to structure 'what is part of what', because in physics you can get so overloaded with a bunch of equations or that kind of thing, which you don't even need…. to be able to reproduce every single derivation. You don't need to memorize a formula if you understand where it comes from"*

The texts were further assessed for any obvious enactment effects, indicating they were *'teaching as they had been taught*' and or underlying assumptions about physics. This was graded positive or neutral , where positive means the TAs referenced their own prior experiences, such as 'how I did it', 'that's how to learn physics' etc when describing tutorials and neutral means no references made to own experiences, or the TA followed lecturer's guidelines or instruction.. These results are shown in Table 5

TABLE 5 ENACTMENT EFFECTS

	Group 1 Teacher			Group 2 Facilitator		
Positive	Coen Daan	FSE FSE	UTA GTA	Lars Erik	FSE FSE/UCG	GTA GTA
Neutral	Jeroen Lily	UCG UCG	UTA UTA	Tom	UCG	UTA

Enactment effects can to some extent be shown in the following quotes although it is accepted that this can only touch on the surface of this complex subject.

Erik: *" I like to teach the course in the way that I would have wanted it to be taught to me , or how I think it's best to teach based on how I learned it.."*

Lars: *" based with what I see myself doing during tutorials, what I have done"*

Daan *" And then I try to explain based on my experience from last year or when I did it my myself, what the points of attention should be "*

.

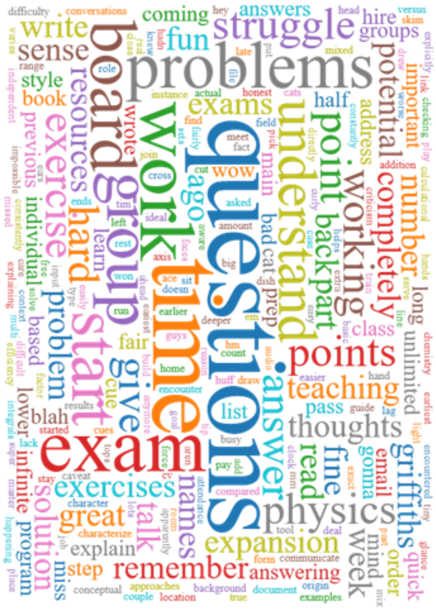
Daan *"And that's something that I try to tell them from the start, because if someone would have told me that when I started doing physics, it will make a lot more sense"*

It is important to note that neutral does not mean the TA did not experience enactment effects, but just reflects that in this study they were not mentioned and therefore there are no sample quote for this category.

Word Frequency Analysis

The word frequency was calculated using an online application 'Word Cloud Generator' which provides both a list of word frequency counts and a visual representation in the form of a word cloud. The bigger and bolder the word appears, the more often it is mentioned within the TA interview transcript and the more important it is to the TA. These are shown in Table 6.

TABLE 6 WORD CLOUDS

<table>
<tr><th>Lars</th><th>TOP THREE WORDS</th></tr>
<tr><td>
</td><td>

- Questions
- Time
- Exams

Lars most frequent words are directly related to the coding of didactic and exam oriented. These words were only just the top three, nearly as important to Lars were *'group'* and '*understand*' and this points to his coding as a facilitator.</td></tr>
<tr><th>Daan</th><th>TOP THREE WORDS</th></tr>
<tr><td>
</td><td>

- Time
- Work
- Question & Exam

Daan's most frequent words relate to ensuring the students work hard and pass exams, succinctly illustrating his coding of teacher, didactic, exam oriented.</td></tr>
<tr><th>Coen</th><th>TOP THREE WORDS</th></tr>
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<tr>
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- QUESTIONS
- TIME
- ASSIGNMENTS

Rather like Daan, the major themes through Coen's interviews demonstrate his major concerns with ensuring the students complete their assignments and illustrate his coding of teacher, didactic, exam.</td>
</tr>
<tr>
<th>TOM</th>
<th>TOP THREE WORDS</th>
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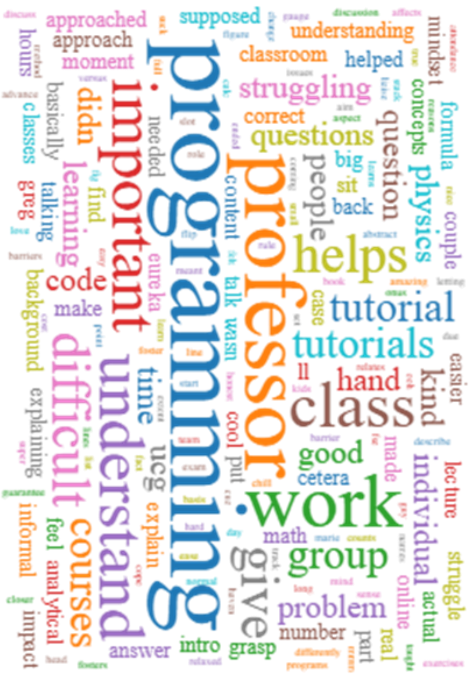
<td>
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<td>

- PROGRAMMING
- PROFESSOR
- UNDERSTAND & IMPORTANT

Tom shows a broader focus on the aims of the course rather than meeting a specific goal, consistent with a coding of facilitator, other and learning</td>
</tr>
</table>

<table>
<tr><th>JEROEN</th><th>TOP THREE WORDS</th></tr>
<tr><td>
</td>
<td>COURSES
TUTORIALS
GOOD & GROUP
Jeroen is was coded as teacher, learning and other, which is many ways is reflected in his word cloud. The top 10 words occurred with almost the same frequency and there is very little to between them. Jeroen was difficult to code between teacher and facilitator and I think this balance is shown in his word cloud. </td></tr>
<tr><th>ERIK</th><th>TOP THREE WORDS</th></tr>
<tr><td>
</td>
<td>WORK
PHYSICS
QUESTIONS & UNDERSTAND
Erik is another TA who was coded as Facilitator, other and learning. In the interviews he had very strong views about the important and value in understanding the concepts over reproducing the and this is illustrated in his word cloud. </td></tr>
</table>

<table>
<tr><th>Lily</th><th>TOP THREE WORDS</th></tr>
<tr><td>
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- GOOD
- CLASS
- TUTORIALS & WORK

Lily was coded as teacher, didactic because she is concerned with making sure the students attended lectures, worked hard and contributed to the tutorials for their own benefit. She believed learning was more important that exam success, so was coded as learning but overall Lily's word cloud is extremely balanced with hardly any change in the frequency of the top 10 words which also included questions, teacher, time mandatory and attendance. This also could be because Lily was much more succinct in her responses.
</td></tr>
</table>

Questionnaire Results

The questionnaire became less relevant as the research question matured but there are still a few valuable answers that can contribute to the conclusions. They were relatively few responses which also makes these results less statistically significant.

Role of TA?

This was one of the main research questions and has a free text entry so this serves as a good control for the interview section Essentially only 1 or arguably 2 responses would be coded FACILITATOR and the remaining e responses would be coded as TEACHER **if** based solely on these responses. This aligns very well with the interview coding.

- To help understand the material and the reasons why either the solution works, or how the physical phenomenon work. The 'Why' or 'where does it really come from' is important for me to emphasis on in my tutorials.
- to support the teacher in any way the teacher needs as well as helping the students to understand concepts and help in practicing questions
- To facilitate learning in a group setting and to help the students to understand the concepts of physics
- to answer questions from the students
- Teach to the students how to apply the theory that they learned in the lectures.
- To help the student understand the material with the tutorials and be as approachable as possible for questions.
- Students could learn more, but it is not a sufficient way for all students.
- To help wherever they can, explain concepts and help work out problems with students
- to help the students with any problems that come up that they can't go to see the teacher about- we are just there as support. however, in many physics courses we often have to teach concepts as well
- To help students 1 to 1 to grasp concepts they're struggling with. To educate in a manner that is easier to relate to, and more informal. To liaise between the professor and individuals/the class.
- As TA, I am supposed to be an approachable support for the students, in addition to relieving some of the teacher's workload. Of course, my explanations should be clear, but I have little responsibility in the way in which students are taught
- The role of a TA is to guide in the learning process, breaking the material into chunks and pointing out common mistakes.
- Explain how to apply the theory to the provided problem sets
- To do our best to make students understand the content
- To give individual support to complement course-wide lectures by the professor. (Teaching Assistant)

Where have you been a TA?

This question unsurprisingly showed far more TAs ate FSE over than UCG. Given the relative sizes of the faculties this is entirely to be expected It was known at the design phases that the TA selection was slightly skewed, but this was deliberate to keep the faculty split even. If the percentages shown in were used in the interviews there would have been 4 FSE, 2 UCG and 2 both FSE/UCG so this aligns well to the chosen TAs. See Table 5

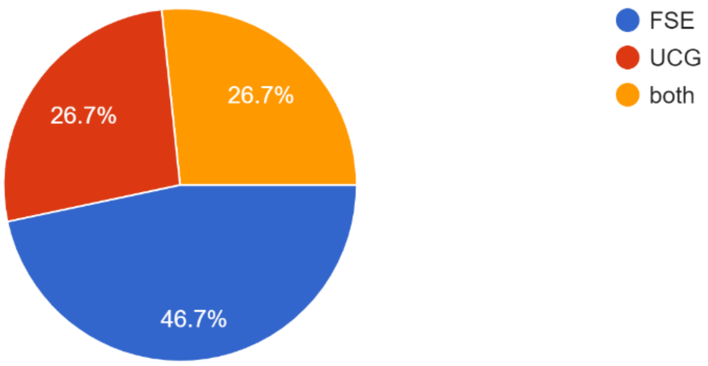

FIGURE 5 FSE / UCG TAS

HOW MANY CLASSES HAVE YOU BEEN A TA FOR?

Most TAs who responded have only been a TA for 1 year, although there is a core of TAs who have run over 6 courses as shown in Figure 6. These most TAs run courses at both UCG and FSE. The remaining respondents were equally between FSE and UCG.

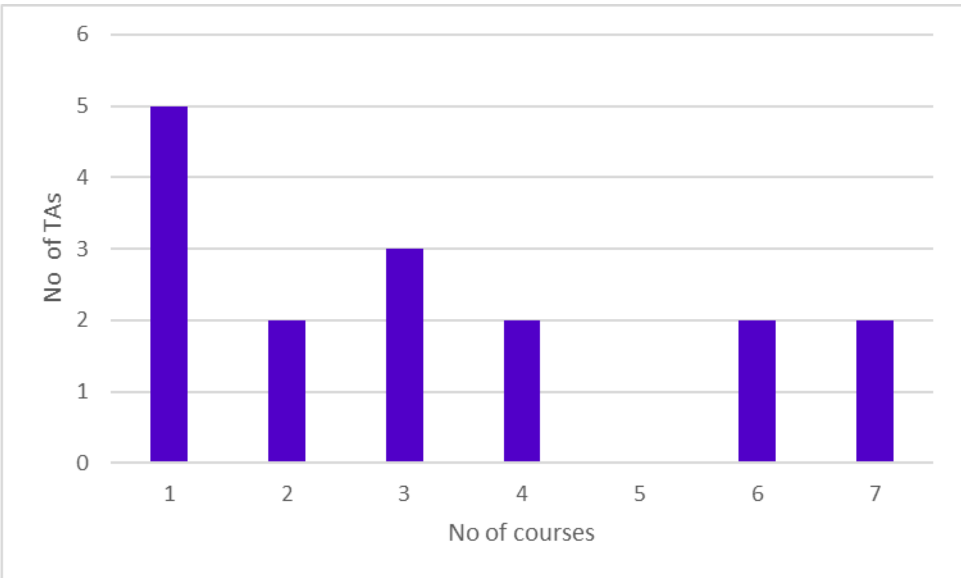

FIGURE 6 NUMBER OF COURSES

HOW DO YOU RUN TUTORIALS?

The majority of respondents taught courses in a manner that could be considered didactical. 1 TA indicated more conceptual teaching. This was the most experienced TA, who taught at both FSE and UCG, and who was hoping to become university. These results align with our findings in the interviews. See Figure 7

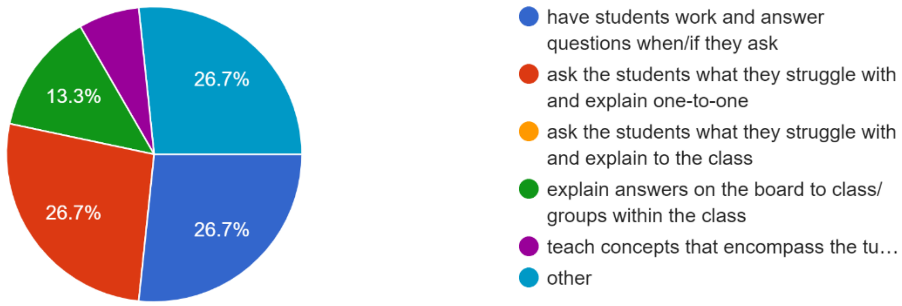

FIGURE 7 TEACHING STYLE

THEORY OR CONCEPT?

This question probed the importance of theory/concepts over maths and is supporting evidence towards learning style. This shows a substantial number of TAs feel both are important. See Figure 8. This aligns with the teaching styles shown above

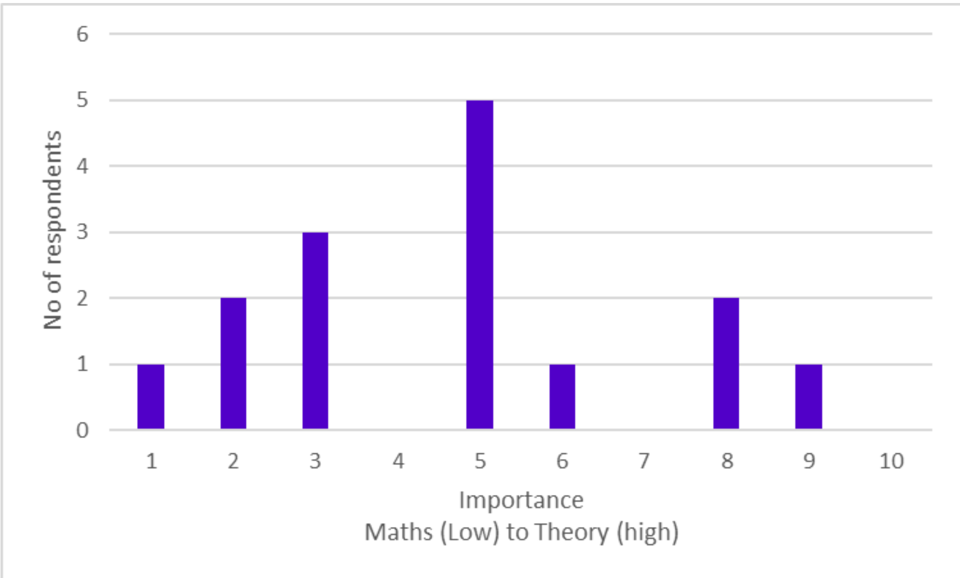

FIGURE 8 RELATIVE IMPORTANCE OR MATHS AND THEORY

DISCUSSION AND CONCLUSIONS

At the onset of this study, there was an expectation that outcome might align with previous research showing that TAs would *'teach as they had been taught'* as well as being unwilling to align their teaching practices with their stated beliefs as indicated on previous studies (Friedrichsen, Driel, & Abell, 2011; R. Goertzen et al., 2010; Kind, 2016).

It was therefore not unexpected to see that the outcome of the categorisation of TAs into TEACHER or FACILITATOR was relatively evenly split: 3 of the 7 TAs were coded as facilitators. 2 of them taught at UCG and this probably reflects the different faculty education goals and teaching methods, as UCG favours a more problem-based approach and places less store on exams than FSE. The other TA coded as FACILITATOR was Lars, the most experienced TA, who teaches only at FSE.

What was less expected is the number of TAs who felt that qualitative conceptual leaning was more important than quantitative exam success. Generally, most TAs who defined success as passing exams also described their roles as teachers, but that was not reflected here which showed learning as success definition was broadly spread across both teacher and facilitator.

The previous research showed that teachers who self-described themselves as facilitators (or similar terminology) often in fact acted as didactic teachers. Out study did not show this with such certainty: Tom and Erik showed consistent behaviour between their beliefs and their actions as facilitators as did Daan and Coen, who ran tutorials aligned to their teacher coding. The inconsistent behaviour tended to fall on extremes of experience. The least experienced TAs (Lily and Jeroen) both coded as teachers but believed learning was the success criteria. This almost certainly reflects the different faculty approaches as Lily and Jeroen are both UCG UTAs, and UCG professes a *"experiential education, encouraging students to put their existing knowledge and experience to work, pulling in new knowledge when and where it is needed the most. Passive and superficial learning focused on memorising facts have no place in experiential learning."* (RUG, 2020). Given this it is hardly surprising the UCG TAs demonstrated this behaviour.

Lars on the other hand is the most experienced TA and teaches at FSE. Lars also coded contradictorily with a didactical style, but this comes from his acknowledgement of the competing tensions for a student between learning and passing exams: *" I trust that everybody here wants to understand electricity and magnetism. But I would also like for you to just pass the exam*."

The hardest area of the research question to address is that of enactment effects. This showed a split along faculty lines, with the FSE TAs all showed strong evidence of *'teaching as they were taught'*. This was not so obvious for the UCG TAs but this in no way means the TAs are not affected. It is more likely to arise from the different teaching methods: the UCG TAs often have specific worksheets that mandate the content of each tutorial and so have less need to develop their own tutorial content and delivery style as the FSE TAs do. In addition, Lily and Jeroen's views on the role of the TA and exam success might also indicates enactment effects so in a modest way the study supported the plentiful research on enactment effects.

So, can this research categorically address the research question " how does a teaching assistant's definition of success relate to how they perform their roles in tutorials for introductory physics courses at the Rijksuniversiteit Groningen?" The answer is that the TAs are more likely to be TEACHERS although some TAs were more or equally interested in advanced conceptual learning and were coded as FACILTATORS. There is no common ground on what constitutes success, as this seems to be driven by a combination of differences between faculties and the TAs own personal beliefs and so it is clear that the TAs own definition of success does affect how tutorials are taught. None of this is surprising as the TAs do not generally set faculty strategy, curricula, or educational goals.

This would not be problematical if the TAs were professionally trained or guided by the faculties: just because the TAS act as teacher or facilitators does not necessarily imply that is what the faculties wanted or desired.

Several TAs mentioned training, and this is certainly an area that could be addressed by both faculties as this would allow the TAs to understand their roles more clearly as well as how to implement the faculty strategy. The TAs are free to run the tutorials as they please and there does not seem to be a common experience from the student's perspectives. Given that such a large part of the students' education is developed through tutorials it may be pertinent to ask why these tutorials are taught by untrained TAs without any over-arching guiding focus.

Also mentioned by several TAs mentioned increased student participation, to get more involved in the tutorials and discussions and while this is hard for the TAs to consistently implement, the faculties could perhaps look at ways of encouraging the students to get more involved. Perhaps this would go hand in hand with more training and consistent approach of content and purpose so that the students more readily appreciated what the tutorial system can provide.

In summary, this research has determined that the experiences of TAs and their own beliefs does affect how success is defined and so answers the research question.

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ANNEX A

INDIVIDUAL CASE STUDIES

LARS

ROLE OF TA: CODED FACILITATOR

Lars is a postgraduate student at FSE and has been TA for around 15 different courses over several years. All the courses have been at FSE. TA1 describe as the role of TA as:

> *" I see myself as a guide to make sure that people have fun and progress during the making of the exercises…of course that means that sometimes you have to do a bit more than just give answers*".

During explanations of how Lars conducts the tutorials first describes walking around, answering questions and giving tips but later expands this to explaining concepts to the whole class on the blackboard one on-one or through group work and discussions. As a student Lars relates a very mixed experiences in lectures and tutorials, which is used as the basis for the tutorial style:

> "*I never understand things the first time so I want to keep things light because of knowing that feeling very well. … it's based on my own experience, never understand things when I see them done on the board. And then I do have to do it myself. So preventing that kind of fooling yourself has been one of the pillars of how I approached my tutorials. I tried to do as little on the board as possible because people should feel out solving a problem for selves*."

TEACHING STYLE: CODED DIDACTIC

Lars refers to researching additional material outside the curriculum and developing his own complex reasonings for the student to understand the material as well as encouraging the students *"read the book and thinks about things on your own or talk about things with your fellow students and teachers. Maybe even supplementing it with the things that you can find online".* However, he also stressed the importance of passing exams and teaching weaker students.

WHAT IS SUCCESS: CODED EXAM

Lars believes TA have a specific task to support weaker students, to pass the course,

> *" weaker students, um, they like having things done on the board, but when they start doing it their selves, they don't, uh, they don't get it ….You are as a tutorial assistant, not for the stronger students, but for the weaker specifically. Stronger students will get it no matter what"*

Lars acknowledges a tension relating to the relative importance of understanding concepts and passing exams:

> *" I trust that everybody here wants to understand electricity and magnetism. But I would also like for you to just pass the exam* "

And for other students who want to understand the concepts more deeply Lars suggests useful self-study techniques:

ENACTMENT EFFECTS: CODED POSITIVE

Lars is clear that he teaches as he learnt, "*it's based on my own experience, never understand things when I see them done on the board. And then I do have to do it myself*". Lars also chooses to not attend any taught courses and believes that " *it's good to struggle with hard problems… But that's fine because then, you know, they still have spent two hours struggling with the physics, which is how you learn physics".*

Daan

Role of TA: Coded teacher

Daan is a postgraduate student at FSE and has been TA for around 5 different courses over several years. All the courses have been at FSE. Daan see the role of a TA as:

> "*your goal or your aim should be to… clarify stuff that was not really completely clear from the lecture. So that's what I, what I always start with. And secondly, well basically just help them to kind of get a right set of tools with which they can actually solve the problem"*

Teaching style: Coded didactic

Daan often refers to asking students questions and monitoring their progress. He starts every lecture by running through questions on the board and acknowledges that this can turn into a full solution.

> *"But I think guiding them in doing the problem just turn a bit more into showing them how to do one problem and then letting them do the other problems themselves"*

After grading exams he provides feedback to the whole group: " *I tend to write down all the common mistakes that I find and then I treat them at the start of the tutorial on the black board*. "

What is success: Coded exams

Daan believes tutorials are generally focused on enabling the weaker students to pass the course - *"optimal preparation for that exam"*

Enactment effects: Coded positive

Daan conducts tutorials based on his own experiences: "*people especially in the first years they sometimes struggle with notation. I also had that when I was coming from high school" and "And then I try to explain based on my experience from last year or when I did it my myself, what the points of attention should be."*

Coen

Role of TA: Coded teacher

Coen is an undergraduate student at FSE and has been TA for 3 different courses over two years. All the courses have been at FSE. Coen see the role of a TA as fluid and open to interpretation but interprets his way a a teacher.:

> *" I think that really differs per person, everyone does it in their own way, but my goal was kind of to try and help them solve the assignments, not to completely show them, like a mini lecture on how to do it. I'd like them to work on the assignments and then I can support them with it"*

Coen was extremely hard to code as his statement are often very contradictory. For example, despite " *I'd like them to work on the assignments* " is contrasted with his descriptions of the tutorials giving *" the bigger picture, the understanding of the physical situation that's going on"* and his efforts to go beyond the curriculum *"students should know how to solve the questions" with " But rather I tried to implement to, to compliment with more of an understanding behind what you're doing"*

Teaching style: Coded didactic

It was extremely hard to code Coen because he shows a number of didactic style responses, such as discussing problems and solving questions at the blackboard based on his own notes and the course textbook:

> *"So in my notes I tried to refer a lot to the examples and the equations in the book as well. And then try to use them and then show, okay, now we do this and now we do that. So it's really like I can really easily copy it when someone asks me"*

On the other hand, Coen professes to value conceptual understanding

> *" But whenever I try to derive something, whenever I try to explain something, I really try to explain, okay, what, what's physically going on… it's things like those that I think the book misses on, which for me personally is why I have my own way of studying to cross more of these kinds of ideas and which is why I really enjoy talking to other people about it"*

> *" I would give them, again, less of the mathematics and more of what's physically going on. and then I do refer to a few equations and then I qualitatively explain the equations"*

and is very dismissive of tutorials taught in a didactic style and what can be gained from them:

> *" I can already imagine people preferring to skip those tutorials. Right. Because for me, there's no difference between working in the canteen and working in the tutorial except that it's way more quiet with me and they can ask questions"*

Coen notices his students barely ask him questions so uses tutorials as an opportunity to do other work:" *I do have to admit I'm slightly being a bit of a cheeky one, I'm doing part of the assignments during the tutorial because nobody asks me questions anyway*", so it is hard to see an implementation of a conceptual teaching style.

What is success: Coded exams

Coen is conflicted again, understanding that it is perfectly acceptable to pass exams without conceptual

> *" because especially for this course, the assignments, the exam questions really look like, they're really similar to the homework assignments, the tutorial assignments. So you can kind of copy your homework on the exam. if you want to be successful for this course, you would just go through the homework assignments and make sure that you know the derivations of them."*

Coen values conceptual learning about quantitative understanding, particularly to provide the students with something beyond the lectures, the assignments, and the textbooks and that students need more than *"a few mathematical tricks"* and values discussion but:

> *"But the one thing that sticks out from my group is that they never ask questions. Personally, don't take me wrong, but I find it a bit of a boring group because one of the things I like the most about giving tutorials is to discuss the material. They do at least discuss amongst each other, at least some of them. They sometimes also work on different courses at the same time and then they discuss about that….. I try to look around a bit as well. Sometimes maybe listen a bit to conversations that are going on.*

ENACTMENT EFFECTS: CODED POSITIVE

Coen is somewhat of an enigma who on the whole didn't study but also doesn't seem to mind if his students study and in this was he is perpetuating his own experience, and certainly his strongly held beliefs:

> *"Personally I grasped ideas way easier. So my way of studying personally is not so much working on assignments, but rather trying to get the idea behind them and then improvise on the exam ….Like I get slightly less good grades because I'm not doing the assignments. I'm not copying the assignments, but I do feel, personally, I don't want to be annoying about that one, but I do feel personally that I have on average a way better understanding of the physics on what we're doing rather than the mathematics"*

Coen also believes that there is threshold ability level in physics

> *" the first year has been kind of that test to show if this is really this study for you … but I don't think that's a bad thing because …that's kind of my idea for it that it, it works kind of as a threshold… then you should definitely be able to pass the first year. That should not be a problem for you. If you want to get into real physics* "

Tom

Role of TA: Coded facilitator

Tom is an undergraduate student at UCG and student who is taking courses at both UCG and FSE and has been a TA for the same course three times. While Tom saw the role of a TA was to help get to the students to a clear understanding of the why:

> *"And personally I've always found that it sort of comes with, sort of bit of a Eureka moment where you're like, 'okay, now I understand. I get the concept where this relates to this', you know. Um, and for that I think it's very difficult if you haven't got that in class, I think it's very difficult for you to sit there and stare at the paper in front of you at home and then suddenly have that Eureka moment."*

Tom also suggested a benefit of TAs not mentioned by any other TA*:*

> *"a good TA to some extent also has to compliment the professor. And that way, sort of the professor should choose a TA, that will help to fortify the weaker aspects of their own learning or their course"*

and went on to make a comparison:

> *" because there were so many students that needed help, [lecturer 1] just basically needed a second hand. Meanwhile, [lecturer 2] thinks like a lot more like a programmer… And needed someone who was able to translate programming into the language of a normal human being"*

Teaching style: Coded other

During tutorials, Tom would circulate around the class and give individual attention to students. There was no formal teaching to the class or explaining concepts on a blackboard and Tom was very focussed on conceptual understanding and group discussions "*group work is vital*", which also opened up the chance for all students' contributions to add value:

> *"one student can explain to another student who has a similar mindset, a way of doing it that you didn't think about or that you don't grasp. And in that way, it can help them in a way that you wouldn't be able to."*

What is success: Coded LEARNING

Tom felt that the success was defined by understanding over exams:

> "*I honestly think that the most important thing is getting that Eureka moment. Like, even if you suck at actually just calculating stuff in your head or whatever, if you can understand and grasp the concepts behind it, to understand how say integration works and how it relates to differentiation and how all of these things sort of function together…. that is the important thing……As opposed to just memorizing lines of code or whatever*"

Enactment effects: Coded Neutral

Jeroen

Role of TA: coded TEACHER

Jeroen is an undergraduate student at UCG and student who is taking courses at both UCG and FSE and is a TA at UCG for two courses. Jeroen summarises the role of a TA as:

> *"Mostly as a support for the teacher, I guess. … well if there's a classroom to teach in, just walking around and helping the…like the teacher is usually there as well…but not always so sometimes I did it alone. Basically just me helping students get through their worksheets basically".*

Teaching style: coded OTHER

Jeroen was provided with prepared worksheets from the lecturer and conducted the tutorials by proactively approaching students to discuss the worksheets:

> *" if you actively ask them how they're doing, they'll usually also tell you whether they have problems. So they might not raise their hands if they have an issue. But if you ask them if they have an issue, then they do tell you".*

TA5 also mentioned a wider role to play in physics education:

> *". in mathematics you're basically only teaching math, right? Yeah. And you're trying to help someone understand how to do math. Whereas in physics you're both trying to teach someone to understand mathematics as well as helping them understand the physics*

what is success: Coded LEARNING

Jeroen believed that the tutorials are for all students providing they take the initiative to get involved. Jeroen also noted that recognising that students benefit in a variety of ways:

> *" either different ways to study that or different ways or different speeds at which they understand these things, right…. success is a very personal thing. So there can be students who really struggle with mathematics for whom getting a six and a half is amazing".*

He went on to describe his own personal experience "*for me being successful in calculus courses meant getting A+. Being successful in physics courses from FSE meant putting in, like, as much as I could to understand the topic and to have a comfortable relationship with the physics,"*

enactment effects: Coded NEUTRAL

Erik

Role of TA: coded FACILITATOR

Erik is a postgraduate student at FSE who a TA for 3 different courses over a number of years at both FSE and UCG. Erik has grading responsibility and articulates the role of TA as:

> *"they are supposed to help the students understand the material… to try to get people to understand what they're actually supposed to do with the material, and what it needs… the extra push to understanding the 'why', I think is what a TA can help with a lot. Understanding and structure arising from the material"*

Erik is clear that his own student experiences drives his tutorial style:

> *.As an example, it was really the case for physics lab 1, I had a TA that's had a method of teaching that didn't work for me. So I specifically wanted to TA that course to teach it in a way that would've worked for me and that's how I approach teaching*"

Teaching style: coded OTHER

Erik accepts that people work and learn in different ways, and that any student can get stuck on an issue:

> *"I can take an hour to explain something that might be really trivial to other people but maybe not to that person…. I'd say don't be shy because every single question that you get an answer for, every problem that you face and you get an answer for, it is going to help you in your curriculum, no matter if you think that the question is stupid because they're not - Because in the end if you learn from it, it's not a stupid question"*

What is success: Coded LEARNING

Erik encourages the students to complete the tutorial assignments and participate in group discussions, asserting that a good way to learn is a combination:

> "*I found is that when I or other people really go through their derivations or reading chapters, that's really an individual thing. But when it comes to trying to understand the material or working together on homework then that's when like discussion in a group really is super helpful in understanding of concepts and solving problems, to understand how to solve certain problems"*

Erik accepts that people work and learn in different ways, and that any student can get stuck on an issue:

> *"I can take an hour to explain something that might be really trivial to other people but maybe not to that person…. I'd say don't be shy because every single question that you get an answer for, every problem that you face and you get an answer for, it is going to help you in your curriculum, no matter if you think that the question is stupid because they're not - Because in the end if you learn from it, it's not a stupid question"*

Enactment effects: Coded POSITIVE

Erik coded positive on his on his strong views about how to teach as de

> " *I like to teach the course in the way that I would have wanted it to be taught to me , or how I think it's best to teach based on how I learned it."*

LILY

ROLE OF TA: CODED TEACHER

Lily is a UCG undergraduate student who is taking courses at both UCG and FSE and is a TA at UCG. Lily is the least experienced of the TA covered in this study. For Lily the role of the TA is clear and bounded:

> *" I would help them with their computer practical's, which were assigned by the teacher".*

TEACHING STYLE: CODED DIDACTIC

Lily works hard to support the teacher and to ensure the student receive the help they need. She prepares diligently to ensure she can address all the student's questions. In Lily's tutorials, worksheet are produced by the lecturer and Lily guides the students through the worksheets:

> *"I reviewed the notes before class, so I would go through all the exercises beforehand"*

WHAT IS SUCCESS: CODED LEARNING

TA7 believes that a combination approach, balancing individual and group work and taking advantage of the support offered all students:

> *" show up to class and show up to tutorials because these teachers .....are there for you. I think that's something that students really need to take advantage of"*

As a student taking courses at FSE, Lily also comments on the differences between tutorials in the two faculties:

> *"I think tutorials style at UCG are different than the tutorials style at Zernike., and you can definitely see that tutorials at Zernike are less interesting for students to attend, maybe because they're not as helpful a lot of the time. "*

ENACTMENT EFFECTS: CODED NEUTRAL