TRANSFORMING THE PREPARATION OF PHYSICS GRADUATE TEACHING ASSISTANTS

A Dissertation
Presented to
The Academic Faculty

By

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In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Physics

Georgia Institute of Technology

May 2020

TRANSFORMING THE PREPARATION OF PHYSICS GRADUATE TEACHING ASSISTANTS

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I survived cancer. I can survive grad school.

ACKNOWLEDGEMENTS

First of all, I would like to give a million thanks to my thesis advisor, Mike Schatz. Thank you for welcoming me into the Physics Education Research (PER) Group when I started at Georgia Tech and helping me make a smooth career transition from astrophysics to physics education. Thank you for helping me focus my work and successfully turn a teaching assignment into a thesis topic. Thank you for your enthusiasm! I could hardly imagine having a more enthusiastic advisor. Thank you for all the comments, suggestions, guidance, and criticism that have all helped in refining my project, making it the best it can possibly be. And thank you so much for your kindness and understanding when my health issues prevented me from making faster progress.

Another million thanks go to Carol Subiño Sullivan. Thank you for being a fantastic mentor, thank you for introducing me to the field of educational development, thank you for all the conversations and discussions over the years that helped me improve both the content/structure of the course and the research aspect of my work, and thank you for all the emotional support you've given me when things got rough.

Yet another million thanks are directed to Ed Greco. Thank you for being a great TA supervisor, thank you for all the help in developing and improving the M&I-specific content of the class, thank you for all the super valuable and helpful comments and suggestions about research and about the class, during group meetings or during any one of the thousands of times I stopped by your office to ask a quick question which then resulted in talking for 30 minutes or more.

And I also want to thank Flavio Fenton and David Ballantyne for agreeing to be in my thesis committee, and for the valuable discussions and constructive criticism that have helped improve this dissertation.

I want to thank the various friends and colleagues who have helped me in one way or another in the time I've been working on this project: Elaine Rhoades, Danielle Skinner, Benjamín Loewe, and Logan Kageorge, who have helped me at one time or another (or in the case of Elaine, for several years in a row!) with doing Classroom Observations and/or facilitating the Lab Simulation. Andrea Welsh, who came to the Orientation one year to talk with the GTAs about issues concerning LGBT+ students and later helped me with ideas and suggestions for developing the OK/NOT-OK game. Kimberly Short, Mia Bovill, and Vanessa Hernández, who, along with Elaine and Andrea, have always been there to chat when I needed someone to talk to. Martin Jarrio and Eric Murray, with whom I had several conversations that helped me develop the content specific to the GTAs for the Traditional intro classes. Curtis Balusek, who gave me a crash-course on IPLS GTA duties when I suddenly found myself with an unexpected IPLS GTA in my class. Kate Williams and Felicia Turner, from the Center for Teaching and Learning, who have helped me with coordination and logistics for the Orientation for several years. Scott Douglas and Erika Cowan, former and current members, respectively, of the PER Group, who have given me valuable comments and feedback on my work during group meetings. Joan Espar Masip, who was an undergrad at the Universitat Politècnica de Catalunya, and for whom I was research supervisor when he spent a semester at Georgia Tech, working on data analysis of student evaluations. Kevin Carter and Stephanie Niebuhr, who helped me with data collection for student evaluations, demographics, and other logistics things relating to each year's incoming first-year grad students who would take my GTA preparation class. Jordan Gerton, from the University of Utah, who has, with Mike and I, ran a National TA Workshop roughly every other year since 2014, and who has given me lots of encouragement and suggestions for improving my research. Ken Heller, Melanie Cooper, Marilyne Stains, Jackie Chini, and Justin Carmel, who have been facilitators in the workshops and from whom I have learned a lot about TA training. Much thanks to everyone mentioned here for the help and support you've given me over the years.

A big thank you to all 152 grad students who have participated in the Physics GTA Preparation class, from 2013 to 2019, both to those of you who agreed to participate in this study and also to those of you who elected not to. Your comments and suggestions have helped me tremendously in improving the content of the class year after year.

The last two years have been pretty tough, since my health wasn't really cooperating with me. I'm now past the worst of it, and this would not have been possible without the wonderful team of doctors, nurses, and other medical personnel who helped me defeat breast cancer: Dr Adrienne Zertuche, who first discovered the lump, and although she thought it was nothing because of my age, she still sent me to a specialist to have it checked out just in case; Dr William Barber, my breast surgeon, who did a wonderful job getting the cancer out of me while minimizing scarring and other side-effects; Dr Adam Nowlan, who blasted me with 60.4 Gy of radiation over a period of two months, to ensure the cancer would not come back (all that radiation and I didn't even develop superpowers, sigh); Dr Perry Ballard and Dr Samantha Shams, who have continued monitoring my health with hormone therapy to prevent a recurrence; Arrington Leitch, the patient navigator at the Piedmont Cancer Institute, who helped me so much during those terrifying first few weeks after the diagnosis; Lauren McDermott and Jennifer Munn, who are Dr Barber's physician's assistant and oncology nurse, respectively, who were so kind and understanding whenever I bombarded them with a million questions; Gwen Forbes-Kirby and Jennifer Bayer, with whom I did what seemed like endless rounds of physical therapy and occupational therapy, who were both always so upbeat and encouraging, never letting me give up; Lauren Garvey, who coordinated the PINK program, and Jasmin Theard, Joel Hardwick, and Noah Robins, who taught the PINK classes, who believed in me and helped me slowly regain my energy and strength; Tori Thompson, whose counseling has helped me cope not just with cancer, but also with the stress of grad school; María Burkle, who's not a part of my cancer team but instead is a friend and fellow survivor who provided me with much emotional support; and Angélica Pérez, a long-time friend whose research is on radiation oncology and whose words of wisdom helped calm down my nerves. Thank you all so much, I quite literally owe my life to you all. And although this isn't related to cancer, I also want to acknowledge the help I've received from my neurologists, Dr Charles MacNeill and Dr Robert Gilbert, who have kept my migraines under control, the first via nerve-blocks and the second with a new medication that was only recently FDA approved and that works like a miracle.

Some people may think that a pet is just an animal, but to me a pet is part of the family. And I definitely want to acknowledge all the help our cat Ditto has given me over the years. Ditto is an adorably round and squishy British shorthair mix, and she's also known as Her Royal Roundness, Madame Ditto Squishington, Grand Duchess of Wigglebottom. She somehow always knows when I'm feeling down or when I have a migraine. Soon enough, she's next to me giving me cuddles and purring at me to make me feel better. Thank you, Ditto, for all the emotional support you've given me. And although they are no longer with us, I also want to acknowledge our two older kitties, Jeremy (1999-2010) and Sampson (1999-2016), who also provided me with lots of chirps and meows over the years.

My parents, Ana Muñoz and Noé Alicea, who have always been there for me and supported me in everything I've done, and even came to live with us for five months while I was undergoing cancer treatment. Mami, Papi, les tengo que dar muchísimas gracias por todo el amor y apoyo que ustedes me han dado toda la vida. Gracias por creer en mí, gracias por siempre estar orgullosos de mis triunfos, gracias por siempre consolarme cuando algo salía mal. Gracias por venir a cuidarme cuando estaba en tratamiento para el cáncer, por toda la ayuda que nos dieron durante esos cinco meses, haciendo los quehaceres de la casa y llevándome a radiación todos los días. Los quiero mucho mucho mucho.

And finally, I want to give the biggest thanks of all to my husband, John Wise. Thank you for your love and your support. Thank you for your patience and your understanding. Thank you for always being there for me, thank you for believing in me, thank you for encouraging me to never give up. Without you, this second go-around through grad school would have been much more difficult, and without you I definitely would not have been able to get through cancer and all that came with it. Thank you. I love you and I look forward to getting even more gray hairs and wrinkles alongside you for many years to come.

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SUMMARY

Graduate Teaching Assistants (GTAs) are key partners in the education of undergraduate students. In large-enrollment intro physics classes, students spend roughly half of their in-class hours in labs and recitations under the supervision of GTAs. Since GTAs can have a large impact on their students' learning, it is important to provide them with appropriate preparation for teaching. But GTAs are also students themselves – they have many demands on their time, and not all of them want to become professors after grad school. Therefore, it is crucial that GTA preparation not be a burden but rather be fully integrated into their professional development.

The School of Physics at Georgia Tech has been offering a GTA prep course for first-year Ph.D. students since 2013. The majority of these first-time GTAs have no prior teaching experience but consider teaching to be an important part of their professional development as physicists. Through a cycle of implementation and revision, and guided by the 3P Framework we developed (Pedagogy, Physics, Professional Development), the course has evolved into a robust and comprehensive professional development program that is well-received by physics graduate students.

We assessed the effectiveness of the course with a combination of surveys, pre/post tests, and student evaluations. We found that GTAs feel better prepared for teaching after going through the Orientation. GTAs consider most useful the course activities in which they can practice and get feedback on their teaching ("Microteaching", "Lab Simulation") and the lessons in which we discuss the pedagogical content knowledge necessary to teach intro physics labs and recitations ("Teaching Physics"). GTAs who participate in the GTA prep course adopt more learner-centered teaching approaches and increase their pedagogical knowledge. They also receive higher end-of-semester student evaluations than GTAs whose first teaching experience predated the establishment of the GTA prep course.

CHAPTER 1
INTRODUCTION AND MOTIVATION

Graduate Teaching Assistants (GTAs) are essential partners in the education of introductory physics students. In a large-enrollment intro physics class, students spend nearly as much in-class contact time with GTAs as they do with faculty [1]. GTAs typically teach labs or problem-solving sessions (also called “recitations” or “discussions”) to a smaller group of students than faculty do in the lecture (e.g., 20-30 students in a lab/recitation but 100+ in a lecture [2]), which means students can get more individualized attention from GTAs than they can from faculty. A typical GTA teaches two or more labs/recitations each semester, so it is likely that many more students interact in a one-on-one manner with GTAs than they do with faculty. A consequence of this is that for many undergrads, GTAs could be the first and/or only impression they ever get of what it means to be a physicist, and students’ attitudes about physics could end up depending more on the GTAs than on the professors [3, 4]. This alone is reason enough to emphasize the importance of providing GTAs with adequate preparation to support their roles as educators, but teaching is not the only thing GTAs do. GTAs are students themselves and there are many demands on their time, such as going to class, doing homework, studying for exams, doing research, attending meetings [4, 5], and occasionally to eat and sleep and take a shower. Therefore it is crucial that GTA preparation not be perceived as a burden but instead be fully interwoven and integrated into the graduate students’ professional development. This dissertation aims to describe such an effort in the School of Physics at the Georgia Institute of Technology, where we have created a GTA preparation course that fully integrates pedagogy, physics, and professional development, that is well-received by the GTAs and that has had a measurable positive impact on their self-efficacy and approaches to teaching.

There is little available information about GTA training in the Georgia Tech School of

Physics before 2010. From what we can find, it seems that back then preparation for new GTAs consisted of a one or two day orientation at the start of the semester to discuss GTA duties and responsibilities, Institute policies, and grading, followed by weekly meetings with the lab/recitation coordinators to talk about "next week's lab/recitation." Efforts to provide more preparation to first-time GTAs increased sometime after 2010. Although no formal preparation program existed at that time, new GTAs started receiving more training than before. For example, in Fall 2012[1] the preparation of new GTAs consisted of four elements:

- *New TA Orientation (NTAO)*. This was an Institute-wide four-hour meeting before the start of the semester which mostly covered important policies (e.g., FERPA[2]) and a brief handful of pedagogical topics.
- *Meetings with the Intro Physics GTA Supervisors*. Also before the start of the semester, new GTAs met the coordinators for the Introductory Physics courses to go over topics such as proctoring, grading, and general GTA duties and responsibilities.
- *Weekly lab/recitation meetings*. Every Friday afternoon, the GTAs met with their respective GTA Supervisor and/or Head TA[3] to discuss the content of the following week's lab or recitation and, in the case of labs, set up any necessary equipment.
- *Pedagogy Seminars*. New GTAs were required to attend four pedagogy seminars run by the Center for Teaching and Learning (CTL) in the first two months of the semester.

There were several problems with this piecewise approach to GTA training. First and foremost was the complete disconnect between pedagogy and physics content. The GTAs learned a few basics of pedagogy in very general contexts, with little to no connection to

[1] The author of this dissertation went through this training, as that was her first year at Georgia Tech.

[2] Family Educational Rights and Privacy Act, `https://www2.ed.gov/policy/gen/guid/fpco/ferpa/index.html`

[3] The Head TA is an experienced GTA who has taught the class before.

physics in general nor to the specific physics content they would be teaching. At the same time, the physics content training focused almost exclusively on troubleshooting equipment, with conceptual understanding only covered on a need-to-know basis and with zero pedagogical backing. Another problem was the lack of pedagogical reinforcement – whatever little pedagogy GTAs learned during the NTAO would never again be revisited during the semester. Theoretically, the CTL seminars should have provided such reinforcement, but in practice this was not the case. GTAs were quite vocally unhappy about the scheduling of these seminars[4] and many appeared to strongly resent being taught how to teach by someone who was not a "physics person." The pedagogy training was thus essentially outsourced, leaving GTAs with the impression that pedagogical knowledge was not relevant or important to their actual teaching duties.

In addition to these problems, the absence of a coherent and unified GTA training program meant a lack of mentoring and career development opportunities, resulting in many unmotivated GTAs who seemed to think about teaching as a burden they must get through in order to get paid instead of as an essential aspect of their development as physicists.

Around the same time that this was happening in the School of Physics, the Center for Teaching and Learning had been preparing and piloting a "Super TA" program to integrate GTA preparation into the academic units while still coordinating it from a central entity [6, 7]. The School of Physics soon joined this effort, and Fall 2013 saw the pilot implementation of the "Physics GTA Preparation" course, co-taught by the author of this dissertation and another experienced physics GTA. Teaching the class allowed us to gauge the relative success of each lesson. Informal observations like the level of engagement from the GTAs gave us an idea of which lessons they found interesting and which ones they did not. More concrete data came from reflection assignments, where GTAs elaborated on which course topics and activities had the most impact on them. In general, GTAs preferred material that was practical and directly applicable to their teaching and disliked heavily theoretical

[4] Let it be noted that mandatory seminars at 6pm on Fridays do not make for very happy GTAs.

topics or topics that did not appear relevant to their professional careers. The main work of this dissertation was born from these observations, driven by the need to improve GTA preparation and the desire to provide our graduate students with professional development opportunities that would be useful to their future careers as physicists.

It is important to note that graduate students themselves find value in teaching as part of their professional development, even if they do not explicitly state it. In Spring 2016, we conducted a survey of all then-current graduate students in the School of Physics to ask for their thoughts on teaching and GTA training. At that time, the graduate student population amounted to 129 full-time grad students, and 59 of them responded to the survey – a 46% response rate. In terms of GTAs who had participated in the GTA prep course versus GTAs who predated the course, the groups were split roughly 60/40, with 34 respondents who had participated (58%) and 25 who had not (42%). One of the items in the survey stated:

> Being a GTA has helped me improve my skills in...

The statement was followed by a list of physics skills and transferable skills, and for each of them the respondents would indicate their agreement on a five-point Likert-type scale, from strongly disagree (1) to strongly agree (5). Figure 1.1 shows the results, for physics skills on the top panel and for transferable skills on the bottom panel. The results are reported in aggregate, since there was little to no difference in how the two groups (GTAs who participated in the course and GTAs who predated it) responded.

The majority of respondents agreed or strongly agreed that being a GTA improved their skills in explaining physics concepts and ideas (93%), facilitating physics problem-solving (86%), and mastering the fundamental principles of physics (56%). Clearly our GTAs agree with the old aphorism about not really understanding something until you can teach it well, or at the very least, the act of teaching helped them enhance that understanding.

A majority or plurality also agreed or strongly agreed that being a GTA helped improve their skills in public speaking and oral communication (75%), evaluating and providing feedback (52%), and organization and planning (49%). Although these numbers are lower

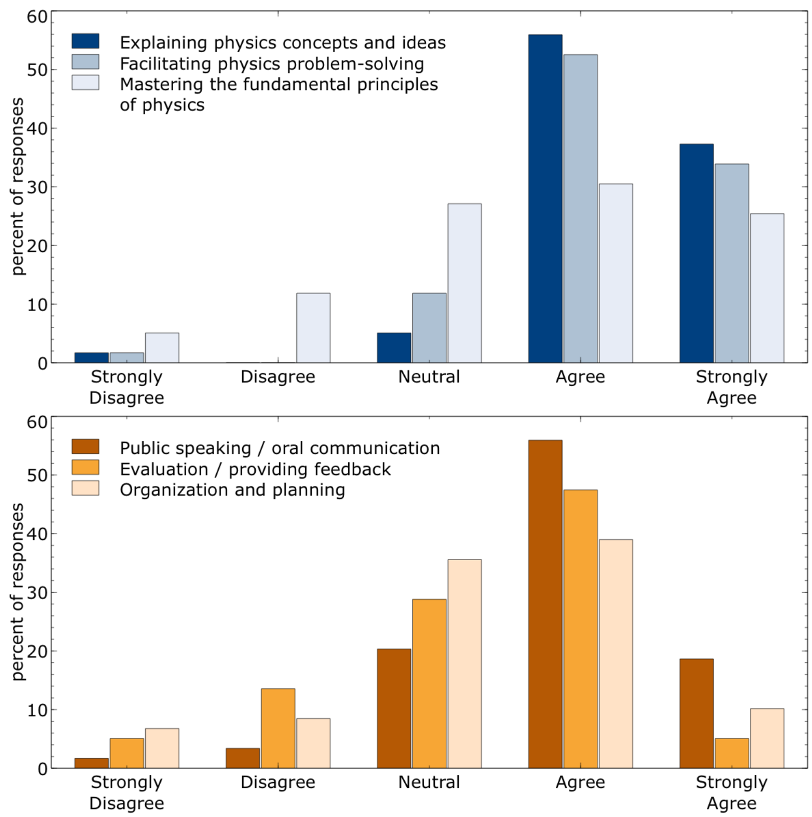

Figure 1.1: According to a Spring 2016 survey of then-current graduate students in the School of Physics, our GTAs find that teaching helps them improve their physics skills (top panel, shades of blue) and their transferable skills (bottom panel, shades of orange).

than the numbers for physics skills, it does not necessarily mean that more GTAs *disagreed* with them. The difference lies in the "neutral" and "strongly agree" options – GTAs selected "strongly agree" more often for physics skills than transferable skills, and they selected "neutral" more often for transferable skills than physics skills. This can be clearly seen in Figure 1.1.

Taken together, the mean ($\pm$ standard deviation) rating for physics skills was 4.01 ± 0.37 and the mean rating for transferable skills was 3.53 ± 0.29. Although the mean rating for physics skills was higher than the mean rating for transferable skills, this difference is not statistically significant (paired t-test, $t = 3.009$, $p = 0.095$). Regardless, the main takeaway that we can get from these results is that GTAs in the School of Physics benefit from their teaching experience, in terms of honing both their physics skills and their transferable

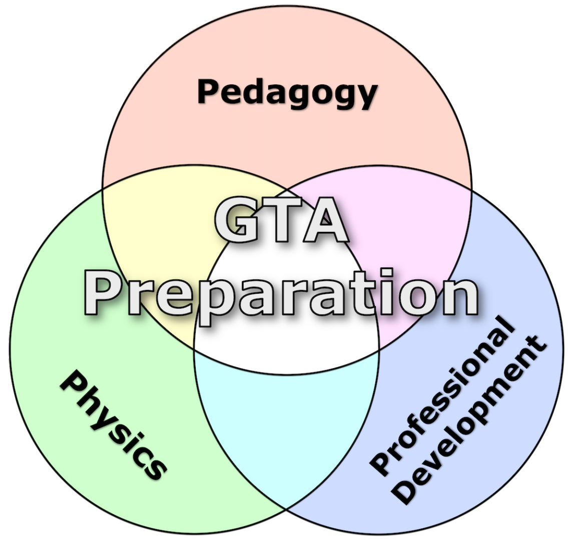

Figure 1.2: Illustration of the 3P Framework, and how the integration of Pedagogy, Physics, and Professional Development leads to a comprehensive GTA Preparation program.

professional skills. As such, teaching is an important part of these students' professional development, and providing them with comprehensive teaching preparation can only have positive effects on their development in the path to becoming professional physicists.

In order to make curricular improvements to the Physics GTA Preparation course we developed a framework for the integration of Pedagogy, Physics, and Professional Development that we are calling the **3P Framework**. This framework posits that in order to have a comprehensive program for GTA preparation that is useful and valuable for GTAs in the classroom and beyond there must be full integration between pedagogical knowledge, physics content, and professional development strategies. Pedagogy alone is not enough, because GTAs are novice instructors who need guidance in how to apply pedagogical knowledge to their physics teaching assignments. Physics alone is not enough, because just knowing the content does not guarantee skills in how to teach it. And professional development is crucial for motivation, so GTAs will see that teaching can help them achieve their professional goals even if they lie outside of academia. A key feature of the 3P Framework is that the intersections of the three P's are just as important as the three P's themselves – hence the Venn diagram visualization in Figure 1.2.

Under the 3P Framework, our GTA preparation course has evolved from "pedagogy and logistics with a few physics sprinkles" into a robust and comprehensive professional development program that is well-received by the GTAs, is considered useful for their first teaching assignment, and that highlights the ways in which teaching can help them hone their transferable professional skills.

1.1 Terminology

The Physics GTA Preparation course is listed as "CETL 8000 PH1" in the Georgia Tech Course Catalog. It is a one-credit, pass/fail course required for first-time GTAs in the School of Physics. Throughout this work, we refer to it interchangeably as "GTA prep," "GTA preparation," and "GTA-PD" (where PD stands for "professional development"). We use "class," "course," and "program" interchangeably as well. We generally avoid using the term "training" when we refer to our integrated approach, since that term can be perceived to have negative connotations [8], though we do use the term when appropriate in the literature review and elsewhere when referring to "basic" non-integrated GTA preparation.

The GTA-PD class meetings are structured in two parts: the *Orientation* and the *Follow-Up Meetings*. The Orientation comprises roughly 3/4 of the total contact hours of the class and happens before the semester begins. The Follow-Up Meetings happen every 2-3 weeks during the semester. In the class materials reproduced in the Appendices, the Orientation and Follow-Up Meetings are referred to as "JumpStart" and "Check-In Meetings," respectively. These terms can be considered local jargon and are not used in the dissertation.

In addition to class meetings, the GTA prep class also includes out-of-class work and activities such as classroom observations, workload surveys, and mentoring meetings. These are collectively referred to as "Activities" in the present work.

The students enrolled in the GTA prep class are all first-year Ph.D. students in the School of Physics. They are referred to in this dissertation as "students," "graduate students," "GTAs," and "participants" interchangeably.

1.2 Institutional Context

Our study focuses on first-time GTAs and it takes place in the School of Physics at the Georgia Institute of Technology, an R1 Institution according to the Carnegie Classification of Institutions of Higher Education [9] and among the top 20% of physics Ph.D.-granting institutions in terms of graduate enrollment [10]. The graduate student population in the School has varied between 120 and 135 graduate students per academic year in the last five years, and on any given semester roughly 50 of them are employed as GTAs.

The Introductory Physics classes are required courses for a large majority of Georgia Tech's undergraduate students, a majority of whom are engineering majors. These classes are PHYS 2211 (Introductory Physics 1 – Mechanics) and PHYS 2212 (Introductory Physics 2 – Electricity and Magnetism). About 1800 undergrads take these classes on any given semester. The classes have six contact hours per week between undergrads and instructors: three hours per week of lecture with a faculty member and three hours per week of labs and recitations with a GTA. On any given semester, between nine and thirteen faculty members are assigned to teach the Introductory Physics lectures and a bit more than half of all the GTAs in the School are assigned to teach two or more of the approximately 70 lab and recitation sections for these classes. And of these, the majority are first-time GTAs (who are also first-year Ph.D. students).

The Introductory Physics classes come in three "flavors" [11, 12]: (1) Traditional, (2) Matter & Interactions (M&I), and (3) Intro Physics for Living Systems (IPLS). Traditional and M&I differ on the textbook used and the style of labs and recitations, with Traditional classes having 2-hour labs and 1-hour recitations, and M&I classes having a combined 3-hour lab+recitation (which are typically referred to as just "labs"). The IPLS classes also have a combined 3-hour lab+recitation, and the curriculum is designed to have more relevance to students whose majors are in the biological sciences.

GTAs assigned to the Introductory Physics classes teach either three labs (Traditional), or four to six recitations (Traditional), or two lab+recitation sections (M&I, IPLS). Each lab and recitation section has an enrollment of around 20-30 students, so a first-time GTA in our School is in charge of anywhere from 40 to 180 undergraduate students, depending on their specific GTA assignment.

In addition to teaching labs and recitations, all GTAs for the Introductory Physics classes are responsible for proctoring and grading exams. Exams differ depending on the "flavor" of the class, which usually results in different time commitment depending on what type of exam a GTA is grading. Traditional Recitation GTAs also grade their students' recitation worksheets, and Traditional Lab GTAs grade their students' online lab reports. GTAs for the Introductory Physics classes are not required to host office hours, but they are given the opportunity to do so if they wish. In the past, GTAs were required to staff the Help Center, a drop-in tutoring service for intro physics. This requirement was dropped in recent years, with undergraduate TAs (UTAs) now assigned to the Help Center instead.

GTAs assigned to upper-division or graduate courses typically grade homework and exams, host office hours, and occasionally guest lecture. However, these are nearly always experienced GTAs, and as such are not the target population of this study.

1.3 Research Questions

The Physics GTA Preparation course is by now an established, stable, and long-running professional development program for first-time GTAs in the School of Physics. Assessing the effectiveness of the program is crucial for its continued success. There are many different aspects of the program that can be assessed, but in this dissertation we focus on three aspects by asking the following research questions:

RQ1 What elements of a formal GTA preparation program do GTAs perceive as the most useful or beneficial for their professional development?

RQ2 What effect does a formal GTA preparation program have on graduate students' teaching self-efficacy and attitudes about teaching?

RQ3 Does a formal GTA preparation program have an effect on graduate students' teaching effectiveness, as determined by end-of-semester student evaluations?

Due to the large amounts and variety of data we have collected over the years, additional program assessment is planned for future work (Section 5.2).

1.4 Significance of the Study

The last two decades have seen substantial research on the preparation of GTAs. Chapter 2 presents a review of the relevant literature, including a summary of the most important results from GTA preparation initiatives, and what we have identified to be the principles for best practices in GTA preparation. And as the reader will see in that chapter, the vast majority of research on GTA preparation has focused on its present effect on GTAs and its impact on GTAs as future faculty. However, a large portion of physics graduate students do not go on to become physics faculty (see Section 2.7). An inevitable question arises from this – what do grad students who do not become faculty get out of GTA preparation?

Aside from its immediate effect of improving GTAs' teaching skills, GTA preparation can be used as a springboard for broader professional development. The 3P Framework that we have developed to improve our GTA preparation course ensures that professional development becomes an essential component of the GTAs' preparation for teaching. We have found that providing GTAs with opportunities to identify and hone their transferable skills can help motivate them – and a motivated GTA is a GTA who wants to do a good job and cares about the learning environment of their students. We want to make sure our GTAs are motivated, even if they plan on never setting foot inside a classroom after they graduate. Although no "one-size-fits-all" approach exists for GTA preparation [13], we propose that GTA preparation programs integrate broader professional development with pedagogy and discipline-specific pedagogical content knowledge. The 3P Framework can be a guiding principle for effective GTA-PD that can then be tailored to fit with the specific needs of the institutional context.

1.5 Theoretical Framework and Research Methodology

In this section we describe the theoretical frameworks and methodologies used when designing and developing the GTA preparation class and the processes of data collection and analysis for program assessment. We close the section by discussing the limitations of the study.

1.5.1 Course Design

The pilot semester of the Physics GTA Preparation course (Fall 2013) followed the course design described by Utschig, Carnasciali, and Subiño Sullivan [6] and Gormally, Subiño Sullivan, and Szeinbaum [7]. The initial design was informed in part by process education, an educational philosophy that focuses on the development of broad, transferable learning skills [14]. The main structure of the class – the Orientation and the Follow-Up Meetings – has remained unchanged, but its content and focus have evolved. Changes to the curriculum have been grounded in the principles of instructional design [15]. The overarching goal of the course is to produce GTAs who are motivated and effective teachers, which is achieved with the following course learning objectives for the GTAs:

- Developing and applying learner-centered teaching practices to create a valuable, student-centered, learning experience
- Explaining physics concepts, addressing students' preconceptions, and facilitating problem solving
- Applying teaching principles to giving and receiving feedback to revise and improve their teaching practice

- Managing classroom dynamics and developing efficient ways of grading students' work
- Reflecting on their professional identity and identifying transferable skills utilized in teaching that are useful for their future careers as professional physicists

The course activities are created with constructivism [16, 17] and active learning [18, 19] in mind, so GTAs learn how to teach in the same way that they are expected to teach [20]. The course experience as a whole can be framed within situated learning theory, an approach based on constructivist epistemology in which learners construct new knowledge by connecting prior experience to active participation within a community of practice [21, 22, 23, 24]. The community of practice emerges organically; all the GTAs in the class share the experience of teaching at Georgia Tech for the first time (and of being first-year Ph.D. students taking the core graduate physics courses), and participation in this class gives them a sense of everyone being "in it together" [25].

1.5.2 Curriculum Development

The Physics GTA Preparation course has been offered every Fall semester since 2013. Development of the curriculum follows a yearly cycle of implementation and revision (Figure 1.3):

- The class is offered in the Fall semester to all first-year Ph.D. students who are concurrently enrolled in a Graduate Teaching Assistantship. The author of this dissertation is the curriculum designer/developer and course instructor. A colleague distributes informed consent forms to the students at the start of the second class meeting, and keeps them until the semester is over. Various program and GTA assessments are carried out throughout the semester when the class is in session.
- After the class is over, in the following Spring semester we compile the assessments and collect the signed informed consent forms. Through a combination of looking at

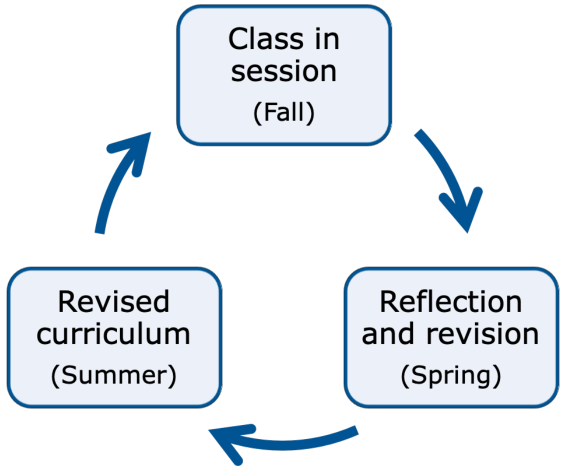

Figure 1.3: Cycle of implementation and revision of the Physics GTA Preparation class. Figure adapted from [26].

the GTAs' responses to some of the assessments – particularly those that deal with curricular matters – and self-reflection on part of the course instructor, changes and revisions are planned for the following iteration of the class.

- The revised curriculum (e.g., class materials, slides, activities) is crafted during the Summer term. At the end of Summer, the revised curriculum is implemented and the cycle begins anew.

This process can be contextualized in the light of two similar theoretical frameworks: *Design Research* and *Action Research*. Design Research (DR) investigates how people function in a real learning environment by designing experiments with successive refinement based on data [27, 28, 29]. Action Research (AR) is a recursive, reflexive, dialectical technique used to iteratively revise plans and implementations of educational reforms [30, 31, 32]. These two frameworks share many epistemological, ontological, and methodological underpinnings, and have a common meta-paradigm – pragmatism [33]. In terms of both DR and AR, feedback from the GTAs is crucial for the cycle of revision and implementation [34, 35].

1.5.3 Data Collection

Our study has approval from the Georgia Tech Institutional Review Board (IRB), protocol number H12281. Every semester (starting in 2014) we secured informed consent from the students in the class. The signed consent forms were kept by a colleague in the Center for Teaching and Learning, and the course instructor did not see them until after final grades were submitted. For assessments that are not anonymous (e.g., pre/post tests), we only analyzed data from students who signed informed consent. Data from anonymous assessments were analyzed in their entirety. End-of-semester student evaluations of teaching do not fall under the category of human subjects research for IRB purposes and therefore we did not collect informed consent for that specific analysis.

Program and GTA assessments are performed at various points during the semester when the class is in session. Chronologically:

- *Entry Survey (GTA Assessment).* The Entry Survey is an online questionnaire, delivered via the Qualtrics platform, administered in late Summer to all incoming first-year Ph.D. students who will work as GTAs in their first semester. This survey is not anonymous, and it is used to determine the initial conditions of our first-time GTAs.

- *Pre/Post Tests (GTA Assessment).* We use two pre/post tests to assess the changes in GTAs' approaches to teaching and pedagogical knowledge. The pre-tests are administered on paper just before the first class meeting of the Orientation. The post-tests are administered on paper during the last Follow-Up Meeting of the semester. The pre/post tests are not anonymous.

- *Microteaching (GTA Assessment).* This is a brief, supervised, practice teaching exercise for novice teachers to receive substantial feedback on their performance [36]. Every GTA receives feedback from the course instructor and their peers, and they later write an essay reflecting on the received feedback and their plans for improvement. Qualitative data from Microteaching is not included in this dissertation but will be analyzed as future work.

- *Lab Simulation (GTA Assessment).* Similar to Microteaching, but in a laboratory setting. Every GTA gets an opportunity to roleplay facilitating a lab and receives feedback from the course instructor or her assistants. At the end of the activity, GTAs answer a series of questions on their thoughts about teaching in lab. Qualitative data from the Lab Simulation is not included in this dissertation but will be analyzed as future work.

- *Orientation Survey (Program Assessment).* The Orientation Survey is a series of five-point Likert-type statements that ask students to rate the usefulness of the topics and activities of the Orientation. This is administered on paper during the last class meeting of the Orientation, and it is anonymous.

- *Midterm Evaluations (Program and GTA Assessments).* Halfway through the semester, GTAs are asked to complete a Midterm Evaluation [37] for the GTA prep course and the course instructor. This is administered on paper during one of the Follow-Up Meetings and it is anonymous. The GTAs are then instructed to write their own Midterm Evaluations to collect feedback from their undergrad students. The GTAs then write a report summarizing the feedback and detailing their plans for improvement. Data from the Midterm Evaluations is not included in this dissertation but will be analyzed as future work.

- *Individual Classroom Observations (GTA Assessment).* The course instructor and/or her assistants observe the GTAs while teaching and provide them with feedback. In the first few years of the course, GTAs were only observed once per semester, but currently each GTA is observed twice in their first semester of teaching. Observations are video recorded if the GTA allows it. We created a custom-made observation rubric for providing feedback to the GTAs. Data from the classroom observations is not included in this dissertation but will be analyzed as future work.

- *Final Survey (Program Assessment).* During the last Follow-Up Meeting of the semester, GTAs are presented with the Final Survey. This paper assessment includes two quantitative Likert-type questions asking the GTAs to rate how interesting and how useful they found the course modules, and several open-response questions. The Final Survey is an anonymous assessment.

- *Thoughts about GTA Experience (GTA Assessment).* This is an anonymous four-question assessment administered on paper during the last Follow-Up class meeting of the semester that asks for the GTAs' thoughts about their first teaching experience. Data from this assessment is not included in this dissertation but will be analyzed as future work.

- *Final Reflection Essay (Program Assessment).* This is the final assignment of the semester, in which GTAs describe in detail their thoughts on what aspects of the course they think had the most impact on them. Data from this assessment is not included in this dissertation but will be analyzed as future work.

- *End-of-Semester Student Evaluations (Program Assessment).* The Georgia Tech Office of Academic Effectiveness conducts end-of-semester teaching evaluations for all instructors in the Institute. We collected all available end-of-semester evaluation data for GTAs in the School of Physics who had their first teaching experience before GTA-PD came into effect (2011-2012), and for GTAs who participated in the first three years of GTA-PD (2013-2015). We are currently in the process of acquiring data from 2016 onward.

Figure 1.4 shows a schematic of the timeline of assessments, indicating which are GTA assessments and which are Program assessments.

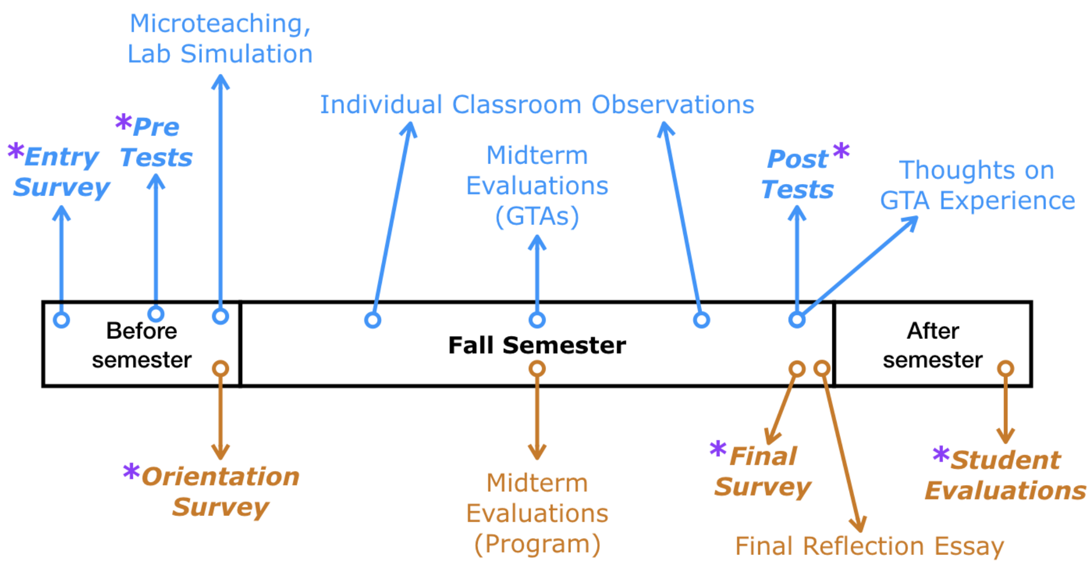

Figure 1.4: Timeline of assessment for the GTA preparation course – before, during, and after the Fall semester. Items in blue (above the rectangles) are GTA assessments, and items in orange (below the rectangles) are program assessments. Items in ***bold italics*** and with a purple asterisk (*) are the assessments analyzed and discussed in this dissertation.

In this dissertation we only analyze and discuss a portion of the plentiful amounts of data we have gathered:

- To determine the initial conditions of first-time GTAs we use the Entry Survey (Section 4.1).
- To determine the GTAs' perceived usefulness of the course we use the Orientation Survey (Section 4.2.1) and Final Survey (Section 4.2.2). These help us answer RQ1.
- To determine the changes in GTAs' attitudes about teaching and pedagogical knowledge, we use the Pre/Post Tests (Section 4.3). These help us answer RQ2.
- To (indirectly) determine the effects of GTA-PD on the GTAs' teaching effectiveness, we use the End-of-Semester Student Evaluations (Section 4.4). This helps us answer RQ3.

The data that are not discussed in this dissertation will not be discarded or forgotten, but rather they will be analyzed in future work, as part of a larger effort to characterize the professional development of GTAs in the School of Physics.

The data collected follow a mixed methods approach [38] since we have both qualitative and quantitative data. Our method of program assessment loosely follows a modified Kirkpatrick Model [39, 40]. In the Kirkpatrick Model there are four levels of evaluation: Reaction, Learning, Behavior, and Results. In the Reaction level we have the Orientation Survey and Final Survey, which give us the GTAs' thoughts about the program. In the Learning level we have the Pre/Post tests, which tell us how much the GTAs learned in the class (although one of the pre/post tests could be argued to represent the Behavior level). In the present work we do not go into detail about the Behavior level, although we do have data on it (classroom observations). For the Results level we would need to know what eventual effect GTA preparation has on the undergrads' intro physics learning outcomes. This, however, is very difficult to achieve, since there are many confounding variables to keep track of (e.g., the professor teaching the lecture, the undergrads' incoming GPA and major, whether they have taken the class before or not, the time of day their lab/recitation takes place, etc). We will therefore not explore the last level directly, but rather we will use end-of-semester student evaluations of teaching as a proxy for determining the GTAs' effectiveness as teachers. We should note that others have highlighted the importance of investigating student learning outcomes as a result of GTA preparation [41], but little such work has been done [e.g., 42], likely for the reasons listed above.

1.5.4 Data Analysis

We performed several statistical tests when analyzing our data. We used IBM SPSS Statistics, RStudio, and SciPy in our data analysis process, and all statistical tests were two-tailed and performed at the $\alpha = 0.05$ significance level.

A large portion of our data involves five-point Likert-type items. Likert-type data can be considered as ordinal or as interval data [43] depending on how traditionalist you want to be, and there does not appear to be a consensus on whether or not it is appropriate to use parametric statistics in their analysis [e.g., 44, 45, 46, 47, 48, 49]. Although certain parametric tests are robust against deviations from normality [50, 51], the majority of our data are highly skewed. Therefore, to err on the side of caution we have decided to use non-parametric tests in the majority of our analyses, in spite of the loss of statistical power:

- Kolmogorov-Smirnov test [52] when comparing the shapes of two distributions
- Mann-Whitney test [53, 54] when comparing two independent distributions (non-parametric equivalent of the t-test)
- Paired-samples Wilcoxon test [55] when comparing two matched distributions (non-parametric equivalent of the paired t-test)
- Kruskal-Wallis analysis of variance [56, 57] when comparing more than two distributions, with Bonferroni corrections [58] when we perform post-hoc pairwise multiple comparisons after a statistically significant result

We use standard parametric tests (e.g. t-test) when appropriate. Effect sizes are reported with Cohen's d [59] or normalized gains $\langle g \rangle$ [60]. Finally, although we mostly use non-parametric tests, we describe distributions by their mean and standard deviation ($M \pm SD$) or mean and standard error ($M \pm SE$) when we want to characterize and compare groups of measurements or means, respectively. Chapter 4 goes into detail about every statistical analysis we performed on our data as they come up in the discussion of program assessments.

1.5.5 Limitations of the Study

All our study participants are first-year Ph.D. students in the School of Physics at Georgia Tech. As mentioned earlier, Georgia Tech is an R1 Institution, and the School of Physics is a relatively large physics department in terms of graduate enrollment. Therefore, our results can be considered a case study of a specific subset of physics GTAs. Some of our results may be generalizable to the overall physics GTA population in the United States, while others may be strongly influenced by local factors. We will not be able to ascertain this for sure until we have a nationwide landscape of physics GTA preparation (see Section 5.2.2 for details about this future project).

Likert-type data, while good at measuring self-efficacy [61], can be subject to certain biases due to its nature as a self-reported measure [e.g., 62, 63, 64, 65]. We assume that our study participants were honest when completing Likert-type assessments. We also assume that our participants took the assessments seriously and did not answer them randomly. We are fairly confident of this last assumption, given the observed time it took the participants to complete the in-person paper assessments.

Finally, the presented work focuses on the GTAs' perceived usefulness of the GTA preparation class, and the course's effects on GTAs' attitudes about teaching, pedagogical understanding, and teaching effectiveness (albeit the latter is an indirect measurement). More work is needed to determine the degree to which the GTA preparation class has affected the GTAs' actual classroom practices.

1.6 Enrollment in Physics GTA Preparation

The Physics GTA Preparation course was first offered in Fall 2013. Since then, a total of 152 grad students have participated in the class during their first semester of graduate school, and all but three of them were concurrently working on their first GTA assignment. The course was originally required of all first-year Ph.D. students, even if they did not have a GTA assignment in their first semester. In 2016 this requirement was changed to first-year Ph.D. students *who are also concurrently GTAs* in their first semester. The reason for this change is that GTAs need to be able to apply what they are learning in a real teaching context in order to fully absorb it [66].

Table 1.1 summarizes the number of graduate students enrolled in the class, as well as

Table 1.1: Total enrollment in the Physics GTA Preparation course, and number and percentage of participants from whom we obtained informed consent. The research study began in earnest in 2014, which is why we did not obtain informed consent from the graduate students enrolled in the first year of the course (2013). The 2019 course is ongoing at the time of this writing, and we will not know who has signed the informed consent forms until the semester is over. The research study is therefore limited to participants between 2014 and 2018, where 89 out of 112 graduate students (79%) signed informed consent forms to participate in the study.

Year	Enrollment	Informed consent
2013	22	0 (0%)
2014	13	8 (62%)
2015	34	29 (85%)
2016	23	19 (83%)
2017	26	20 (77%)
2018	16	13 (81%)
2019	18	pending
Total 2014-2018	112	89 (79%)

the number and percentage of students who signed informed consent each year. The 2013 cohort is excluded from the research study since we do not have signed consent from those graduate students, and the 2019 cohort is excluded because the class is still ongoing at the time of this writing. Two grad students started the course but dropped partway through it, one in 2016 and another in 2017, so they are not included in their years' headcounts; however, any anonymous assessments they completed before dropping cannot be differentiated from their peers', so any such assessments will still be included in the analysis. In summary, this dissertation focuses only on data from 2014 to 2018, giving us a total of 112 graduate students, and 89 of them signed informed consent to participate in the study.

Table 1.2 summarizes the demographics of the graduate students participating in our study, specifically their gender and nationality. These data are similar to the demographics data for all incoming first-year Ph.D. students in the School of Physics, though not identical since we are only including students from whom we have informed consent. Overall, 3/4

Table 1.2: Demographics of graduate students in the Physics GTA Preparation course from whom we obtained informed consent. Yearly percentages are based on the number of participants who signed informed consent each year. Overall percentages are based on the total number of participants with informed consent between 2014 and 2018, which is 89.

	Gender		Nationality	
Year	Male	Female	International	Domestic
2014	88%	12%	38%	62%
2015	72%	28%	28%	72%
2016	79%	21%	47%	53%
2017	85%	15%	50%	50%
2018	46%	54%	15%	85%
Overall	74%	26%	36%	64%

of our participants are men, and and 2/3 are US citizens. An important thing to note is that the cohorts with a large percentage of international students include a significant portion of non-native English speakers.

Most first-time GTAs are assigned to teach a lab or recitation for one of the Introductory Physics courses (follow the yellow brick road in Figure 1.5). For a full (anonymized) list of study participants and the details of their first GTA assignment, see Appendix A.

1.7 Related Work Not Included in this Dissertation

We worked on two other projects while doing the research for this dissertation. We are listing them here for the sake of completeness, as they are directly related to the main project.

1.7.1 Physics GTA Resources Website

When the GTA prep class first went into effect, we realized that the School of Physics did not have anything resembling a TA Handbook. In 2016 we wrote two documents titled "Things a new PHYS 2211/2212 GTA needs to know," one for M&I and another for

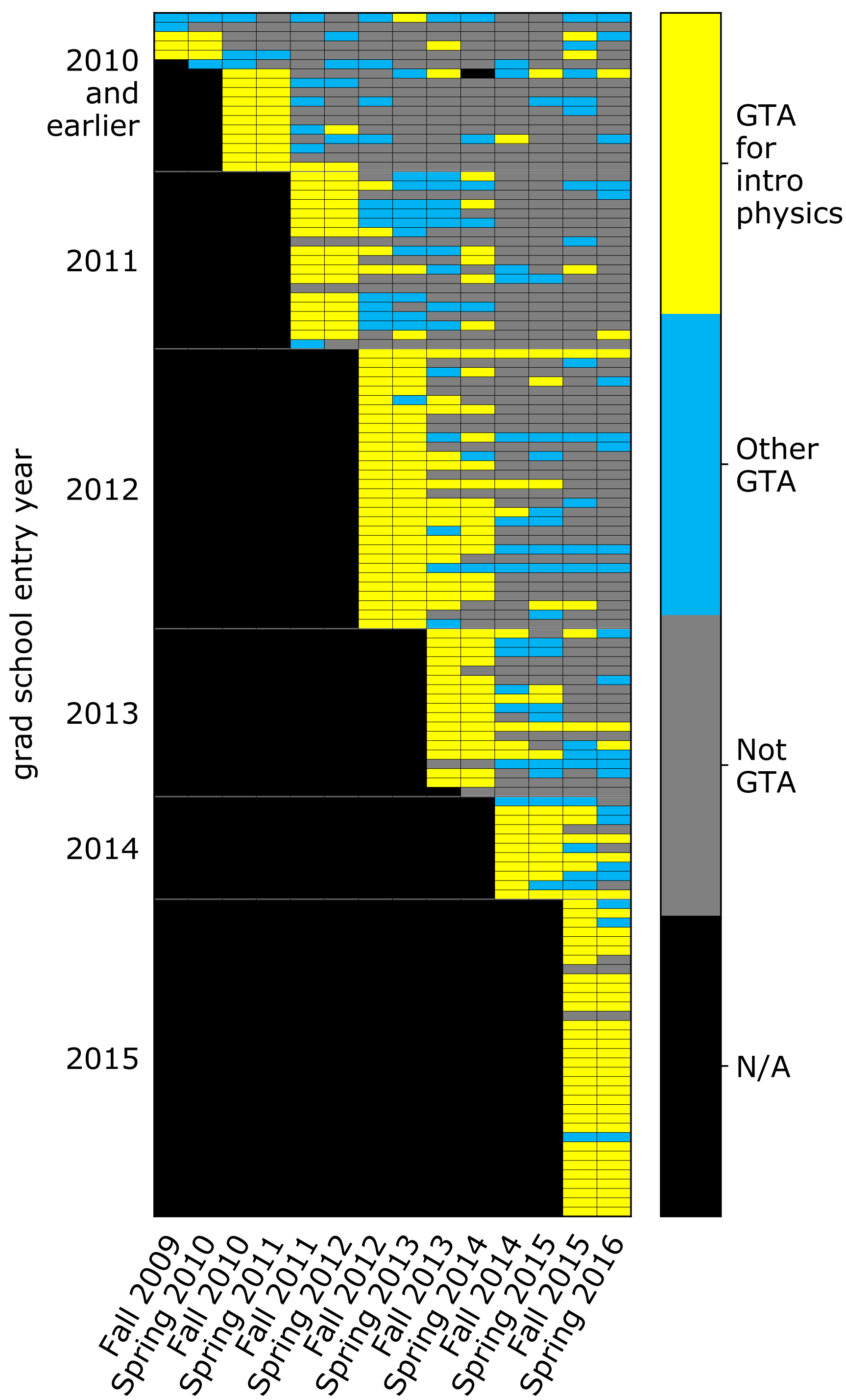

Figure 1.5: The vast majority of first-time GTAs, who are most often also first-year Ph.D. students, are assigned to teach for one of the Introductory Physics courses.

Traditional. These documents were included in the handout packet for the first class meeting of the GTA prep course. At the end of the semester, some students suggested to us that the documents would be more user-friendly if they were posted online. The following year, we created a website titled "Handbook for New Intro Physics GTAs," that covered the content of the previous year's documents and was hosted on Google Sites. In 2018 we renamed the website to "Physics GTA Resources" and migrated it to its current home, `https://gta.physics.gatech.edu`.

The Physics GTA Resources website has information about TA duties, teaching a lab or recitation, proctoring, and grading exams, for Traditional and M&I GTAs. In the near future, we will add information about IPLS GTA responsibilities, as well as information to support grader-only GTAs. The URL is now given to students in the GTA prep course at the beginning of the semester, and they are reminded of its existence at several times throughout the course.

1.7.2 National TA Workshop

In an effort to propagate evidence-based pedagogies in the training of GTAs, we have coordinated and facilitated four National TA Workshops, in 2014, 2015, 2017, and 2019. Initial funding for the workshops came from the Cottrell Scholars Collaborative, with additional support over the years from the National Science Foundation (NSF), the Georgia Tech College of Sciences, the University of Utah Center for Science and Mathematics Education (CSME), the American Physical Society (APS), the American Association of Physics Teachers (AAPT), and the American Chemical Society (ACS).

These workshops were targeted at physics and chemistry departments. Each departmental workshop team consisted of one faculty member (preferably someone in charge of supervising GTAs) and one experienced GTA, and each team needed to have a letter of support from their department chair. A total of 28 chemistry departments and 29 physics departments participated in the four years of the workshop.

During the workshop, each team worked on the development of an Action Plan for GTA preparation that they would present to their department administration for later implementation. The Action Plan was built in stages, throughout and around the six workshop sessions: (1) Principles of Instructional Design, (2) Program Assessment, (3) Establishing a GTA Identity, (4) Facilitating Group Work, (5) Teaching and Learning in the Laboratory, and (6) Structuring TA Support.

The workshops were co-chaired by Mike Schatz (Georgia Tech) and Jordan Gerton (University of Utah). The workshop sessions were facilitated by Ken Heller (University of Minnesota), Melanie Cooper (Michigan State), Marilyne Stains (University of Nebraska), Jacquelyn Chini (University of Central Florida), Justin Carmel (Florida International University), and the author of this dissertation. Preliminary results from post-workshop surveys indicated that the majority of workshop participants were considerably or fully satisfied with the workshop, and six months after the workshop a majority of teams indicated that their Action Plans had already been implemented at least in part, if not entirely.

CHAPTER 2
REVIEW OF LITERATURE ON GTA PREPARATION

> "In his inaugural oration as first president of Johns Hopkins University in 1876, Daniel Coit Gilman expressed the pious hope that graduate schools would help to develop the teaching ability of future professors. This hope has remained largely unfulfilled to date." — Charles Süsskind, 1957 [67]

The above quote sounds dire, and indeed the landscape of GTA preparation (both in general and physics-specific) was essentially non-existent before the 1970s. But things are much different 60 years later. The '70s saw the first inklings of GTA training, the '80s witnessed calls for accountability and evaluation of GTA training initiatives, the '90s experienced an explosion of research-based instructional strategies and the subsequent need to prepare GTAs to teach in these non-traditional settings, and the new millennium has flourished with research on various aspects of GTA preparation and development. While it still cannot be said that every GTA receives adequate preparation for teaching, the trend is towards more and better training and professional development.

2.1 The Need for GTA Preparation

A good portion of an undergraduate student's classroom time in the sciences is spent under the supervision of Graduate Teaching Assistants (GTAs). GTAs usually have many different teaching responsibilities: lecturing, running review sessions, meeting and advising students, grading homework or lab reports, proctoring and grading exams, facilitating group discussions, and often also providing technical support [1]. But GTAs are also students, and as such they have many other additional responsibilities, such as their own coursework and getting started with research [4, 68, 69, 70]. Although GTAs play a major role in providing quality education for undergrads (who perceive GTAs as more approachable than faculty [70, 71]) and can even influence retention [72], in most places the institutional culture [73] tends to not adequately value the importance of teaching [74]. The primary purpose of most doctoral programs is to prepare students to conduct independent research by following an apprenticeship model [75], and indeed the majority of graduate students receive substantial preparation for research – however, the same cannot be said for getting grad students prepared for teaching [76].

A 1999 survey of more than 4000 graduate students at 27 universities representing 11 different arts and sciences disciplines revealed that only one third of respondents had participated in some kind of GTA preparation for teaching [77]. When an institution does not take GTA preparation seriously, they send the message that teaching is not valuable [78] and may lead to GTAs feeling unappreciated and exploited [79]. Physics culture, in particular, is well-known for having an "asymmetry" between research and education, which is evident in the attitudes and beliefs of physicists [80, 81]. For a physics graduate student, teaching may feel tertiary to coursework and research, a belief that is often reinforced by some faculty members [68, 82]. Grad school is a critical period in the preparation of future physicists, and integrating teaching into the professional development of grad students may help shift the culture towards valuing pedagogical skills alongside research skills [83].

Grad students themselves recognize the necessity of teaching preparation, and complain when they are simply thrown into teaching with little or no guidance [84, 85]. GTAs are novice teachers, and therefore lack the knowledge of pedagogical language and techniques that a more experienced teacher possesses [71]. They are also not helped by the frequent disconnect between how they are expected to teach (with active engagement strategies) and how they themselves are taught in their graduate physics classes (with traditional lectures). In physics culture there is a certain attitude for teaching that "as the instructor you hold the secrets of the universe, and you disclose them through an elegant and impressive presentation. If students fail to understand it is because they are not as well prepared as they should be" [86]. As one physics graduate student told Lin [69]:

> "The physics [grad] curriculum is focused on "you have thirty books to learn

> in the next four years worth of material, I'm downloading this information as fast as my ethernet connection can go from my brain to your brain." That's the point of the physics classroom lecture situation. It's very efficient at simply transferring data because all you do is literally you put it on the board, they put it in their book, presumably they put it in their head. It's just a transferring of data." — Nathan [69]

Novice faculty tend to model their teaching on the way they were taught [87], often having transmissionist views, where lecturing and passive learning are considered ideal [2], and in the absence of training, pick up teaching skills through trial and error [88, 89]. It is not unreasonable to expect novice GTAs to follow the same patterns. GTAs generally want to do a good job in teaching, but without guidance and support they may lose that motivation [69]. Being a successful GTA is a function of many factors, such as preparation, attitude, time, and communication skills [4]. Even a relatively brief training program can have a positive effect on many, if not all, of those factors [84, 90].

2.2 Early Work in GTA Training

It is unclear when formalized efforts to prepare physics GTAs for teaching actually began. We consider it likely that the first such ventures were localized and never published. The earliest work we could find hails from 1971, when Stumpf published a paper in the American Journal of Physics describing the elements of a course for preparing GTAs at Ohio University [91]. Their course included discussion of new developments in physics education, practical information for teaching labs, and the opportunity to perform peer evaluations. In the end, they found the course to be perceived as beneficial in training graduate students for their teaching responsibilities.

Similar ventures happened at other institutions throughout the 1970s. The University of Missouri-Columbia established a similar program that resulted in an improved quality of teaching intro physics labs [92]. Kansas State University started providing a week-long orientation for new GTAs that was deemed useful by the grad students, especially in the area of personal interactions with students [93]. UC Berkeley created a 10-week course aimed to familiarize GTAs with teaching techniques other than lectures, which included videotaping GTAs for feedback and reflection, and resulted in better teaching that was noted and appreciated by the undergraduate students taking their classes [94]. Temple University's GTA preparation also included video recording of GTAs' teaching. They concluded that "almost anything" can be done to improve the quality of GTA training – as long as *something* is being done, GTAs will improve [95]. The '70s also saw early work in GTA preparation in other disciplines, such as geology [96], chemistry [97], and sociology [98].

In 1980, Carroll published what is likely to be the first meta-analysis of research on GTA preparation [99]. They analyzed 48 studies and found mostly descriptive accounts of GTA training programs. They characterized the results of the studies as belonging to two groups: research on GTA variables and research on student variables. GTA variables included measures of the GTAs' knowledge, measures of GTAs' attitudes, and observed teaching behavior. Student variables included student achievement, student attitudes, and ratings of instruction. Given that most of the studies they analyzed relied on self-reported measures for evaluation, they concluded with a call for more substantial assessment of the effects of GTA training programs.

Carroll's work was published at the start of the '80s. Near the end of the decade, Abbott, Wulff, and Szego [100] concurred with Carroll's findings, stating that there was still a lack of systematic research on the best way to train new GTAs for their instructional responsibilities.

2.3 Contextualizing Reforms in GTA Preparation: PER and The Rise of Interactive Engagement Teaching Practices

Physics Education Research (PER) originated as a field of physics research sometime in the 1970s or '80s [101]. Although PER was initially dismissed or received with skepticism and hostility from many in the physics community [101], its data-driven results soon started changing physicists' perceptions of the field, especially after the publication of the first concept inventories [e.g., 102, 103, 104, 105] and the then-surprising results of their administration to introductory physics students:

> "[The FCI's] impact was enormous. In department after department across the country the same conversations occurred: "This is easy. Maybe their students can't do this but our students can certainly do this." Once the exam was given locally an intellectual struggle ensued as individuals and departments tried to make sense of the dismal outcomes and the associated implications for instruction." — [101]

From its earliest moments, PER has consistently demonstrated that lecturing does not work for achieving student conceptual understanding [e.g., 60, 106, 107, 108], and that interactive, active engagement teaching practices are better at improving students' learning outcomes [e.g., 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, and many more]. This is a result that has been confirmed over and over again, and it is not limited to physics. Across all STEM disciplines, active learning increases student performance more than passive lecturing [119, 120].

In spite of the overwhelming evidence, physics faculty have not yet universally adopted research-based teaching strategies; however, some implementation has happened and continues to increase, especially at the introductory level [121, 122, 123]. At the graduate level, active engagement is seldom used, and it leaves grad students with the impression that conceptual understanding is not as important as the ability to solve mathematically challenging problems [124].

Researchers and practitioners alike have found several challenges in implementing active engagement teaching strategies, and it should not be surprising that these challenges can be magnified for novice instructors such as GTAs. Student resistance is often the primary worry [125, 126]. Sometimes students resent going to class and being expected to be actively involved instead of passively listening to a lecture [127]. These students feel that they are not "being taught" [128]. Since GTAs are often expected to teach with active learning strategies, where they need to be more of a facilitator than a commander [129], it is important to prepare them for these potential difficulties – teach them how to get students involved, how to know what kinds of questions to ask, how to cover a lot of material in a small amount of time [130]. Undergraduate students often do not know what to expect in an active learning class, so being explicit with students about the reasoning behind the instructor's pedagogical choices is essential [125, 131]. If GTAs are not properly prepared for this, they may not know these reasonings and fall back on transmissionist teaching practices [25, 132].

It is beyond the scope of this dissertation to list all the other ways in which PER has enhanced the teaching of physics. We will, however, mention one more: the study of the differences between experts and novices. It has been shown that not only do novices not have the amount of knowledge that experts do, but they also lack the knowledge structures to make patterns and deep connections within the knowledge they do have [133, 134, 135]. This is important in the context of GTA preparation – although graduate students are still developing their physics expertise [136], they are experts when compared to the undergraduate students they teach, especially when they are assigned to teach introductory physics. Many GTAs find it difficult to put themselves in their students' shoes and think about intro physics from their students' perspectives [137, 138, 139, 140]. Additionally, teaching itself can be considered a complex problem solving task [141], one in which GTAs have not developed the necessary cognitive frameworks and are therefore considered novices.

2.4 Pedagogical Content Knowledge (PCK)

Shulman defines *pedagogical content knowledge* (PCK) as "the particular form of content knowledge that embodies the aspects of content most germane to its teachability" [142]. It goes beyond knowing the subject matter, since it requires the teacher to understand what makes certain topics easy or difficult for their students to learn. It is acquired by reading education literature, watching experienced teachers, and by teaching and reflecting on one's own practice [143]. Although the framework of PCK was developed with K-12 teachers in mind, and there are some notable differences in the needs and beliefs of novice teachers and novice GTAs [7, 144], it can still be applied to the teaching preparation of GTAs [145].

PCK requires the teacher to have an understanding of their students' prior knowledge [145], preconceptions [146], and mindset for learning [147]. Novice teachers, such as GTAs, lack a theoretical background in education, and it is not enough for them to know physics to be effective physics instructors [148, 149, 150, 151]. This is especially important within the context of interactive engagement. GTAs need to be able to anticipate, engage with, and build upon student ideas in the classroom [152]. Spike goes as far as to argue that the goal of the physics teaching experience should be to develop PCK [153].

2.5 Results from GTA Preparation Initiatives

One of the oldest physics GTA preparation programs that is still ongoing is the one at the University of Minnesota [154]. When they reformed their introductory physics sequence in the early 1990s, they realized that the GTAs assigned to teach the labs and recitations needed training in how to teach in order for the instructional reforms to be effective. Their GTA preparation approach is one of cognitive apprenticeship [155], in which teaching practices are first modeled for the GTAs, then the GTAs are coached and given feedback, and the support slowly fades as the GTAs gain more experience [156]. In its earliest conception, their program resulted in GTAs who were confident in their ability to teach, effective in structuring and managing group problem solving, and felt that they were contributing to the education of their students [154].

Back when it was first implemented, the Minnesota GTA prep may well have been the only formalized program for preparing new GTAs to teach physics. Nowadays many such programs exist – and not just in physics! – each with their own structures, theoretical frameworks, recommendations, and results. GTA preparation programs now vary greatly, and they range from a few hours to a few weeks, from broad university-wide orientations to department-specific seminars [157, 158, 159].

It has been noted that there is no "one-size-fits-all" solution for GTA training [13].

Since GTAs are novice teachers, ideas for their preparation could emerge from first thinking about what it means to be a good teacher. Mitchell [82] describes what most consider to be the qualities of effective instruction: (1) promotes scientific ways of thinking; (2) actively involves students in their own learning; (3) helps students develop a conceptual framework and problem solving skills; and (4) makes use of formative assessments to appraise student understanding. These qualities need to be kept in mind when designing courses and programs to prepare GTAs for their teaching responsibilities. Most departments want GTAs to be knowledgeable, approachable, proactive, and enthusiastic [160, 161]. Simpson and Smith [162] have identified 26 competencies, arranged into six skills categories, that are important for effective GTAs. But as Abbott, Wulff, and Szego [100] declared 30 years ago, systematic research is necessary for determining the best practices for GTA preparation. This is echoed by Docktor and Mestre [163], who stated,

> "There is a need for additional research on the attitudes and beliefs of TAs, how physics TAs impact the success of instructional reforms, and the implications for professional development of TAs. There is little guidance on how to prepare teaching assistants, in terms of both the components of a teaching assistant orientation program and ongoing professional development opportunities during teaching." — [163]

Although more research is needed (but when is is not?), much work has been done in the last 20 years on various aspects of GTA preparation and best practices, including the development of full-semester or full-year discipline-specific courses in pedagogy and/or GTA preparation, both in physics [e.g., 164] and in other disciplines such as engineering [165], biology [166], and chemistry [23, 167, 168, 169, 170]. Taken together, the most salient research results are:

1. *Training improves GTAs' teaching confidence and self-efficacy* [171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183]

2. *Training improves GTA's content knowledge and PCK, and can result in adoption of learner-centered teaching styles* [42, 177, 184, 185, 186]

3. *Science GTAs benefit more from discipline-specific GTA preparation than from campus-wide initiatives* [187, 188, 189]

4. *GTAs need guidance in logistics issues such as classroom management and grading* [71, 172, 190, 191, 192]

5. *GTA experience improves graduate students' research and transferable skills* [193, 194, 195, 196]

2.6 The Six (Plus One) Principles for Best Practices in GTA Preparation

Here we synthesize what we consider to be the most important recommendations that come out of the literature on GTA preparation. None of these come from any one source, but rather from many years of research by many different researchers taken in aggregate. The reason behind the "Plus One" parenthetical will become apparent in the next section.

1. *GTA preparation should be nurturing, meaningful, and a partnership between graduate students and faculty* [79, 197, 198, 199, 200, 201]. Academic departments need to see GTAs as partners in the effort of educating students, not as sources of cheap labor. Institutional culture should acknowledge the value and importance of teaching preparation. GTA preparation should happen in a nurturing environment in which GTAs feel safe to express their concerns, and that can work to reducing GTAs' anxiety and uncertainty about teaching.

2. *GTA development needs to be an ongoing endeavor* [2, 20, 66, 202, 203, 204, 205]. Although even minimal preparation can positively influence the teaching practices of new GTAs, the process of GTA preparation needs to be an ongoing venture in order for GTAs to develop the necessary PCK to effectively implement interactive engagement teaching strategies.

3. *GTAs need to have the opportunity to practice and receive feedback* [34, 66, 152, 202, 206, 207]. In the same way that active engagement has been shown to lead to better student outcomes than passive learning, GTAs learn to teach better by "doing" than by "being told." It is important to provide GTAs with opportunities to practice their teaching, which improves their confidence in their teaching abilities. But it is not enough to simply allow GTAs to practice – giving them feedback is essential for reflection and improvement.

4. *It is important to observe GTAs' actual teaching and provide them with feedback* [25, 202, 208, 209, 210, 211, 212, 213, 214, 215]. How do you know if your GTAs have truly absorbed their training and put it into effect in their own teaching? How do you know if they interpreted their training in the way that was it was intended to be interpreted? Self-reported measures can be accurate to an extent, but the best way to know first-hand what GTAs are doing in the classroom is to watch them teach, and then provide them with useful feedback for reflection and improvement.

5. *GTA training must be grounded in research-based teaching strategies* [20, 216, 217]. In order for GTAs to learn about effective research-validated teaching such as active learning, they need to see it in action. GTA preparation should follow the principles of constructivism and active learning, with in-class activities, discussions, modeling, and observation of the teaching and learning process.

6. *GTA development must take into account the GTAs' beliefs in order to foster a sense of professional identity and buy-in for reformed teaching* [210, 218, 219, 220, 221, 222, 223, 224, 225, 226]. GTAs' beliefs about how physics "should" be taught can influence the way they teach, and it is important to understand their reasoning if we want them to improve as educators. Sometimes there is a disconnect between their perception of how they teach and the reality of how they do teach, and the discrepancy can be related to their beliefs and professional identity. Teaching beliefs

are malleable and can be shaped by professional development and ongoing support, especially since graduate students tend to think of themselves as researchers first, educators second. And it is important to help GTAs' cultivate their educator identity, as this leads to higher motivation and more learner-centered practices.

2.7 A Word About Professional Development

The term "professional development" comes up frequently in the study of GTA preparation. Professional Development (PD), at its most basic, refers to the process of evolving and maturing from newcomer to professional [227]. PD can take many forms; Schwartz and Bryan define three 'levels' of PD: (1) formal, in which there are active, intentional training opportunities such as classes or workshops; (2) non-formal, such as brown-bag lunches and development activities sponsored by professional societies; and (3) informal, which includes observing, job shadowing, and learning by example [228].

For graduate students who want to eventually become faculty, most GTA preparation can be considered good and appropriate PD. And in fact, there are several specialized opportunities for PD of future faculty, such as CIRTL[1], Preparing Future Faculty[2], and the Workshop for New Physics and Astronomy Faculty[3] [229]. But what about graduate students who *do not want to* (or cannot) become professors?

According to the American Institute of Physics (AIP), approximately 64% of the students that start doctoral studies in physics actually graduate with a Ph.D., with an average time to degree of 6.3 years [230], while a further 20% exit with a terminal MS degree [231]. About half of new Ph.D.s go into postdoctoral appointments before transitioning into a permanent position [232]. The National Science Foundation (NSF) estimates that 40% of all physics Ph.D.s work in academic institutions, but only 15-20% of people with doctorates in the physical sciences are employed in tenured or tenure-track positions [233].

[1] https://www.cirtl.net
[2] http://www.preparing-faculty.org
[3] https://www.aapt.org/Conferences/newfaculty/nfw.cfm

And although the number of new physics Ph.D.s has increased continually over the years, the number of new tenure-track faculty positions has roughly remained constant [234]. Given these numbers, it can be concluded that a high fraction of students who enter Ph.D. programs in physics end up working in non-academic jobs. And indeed, recently published articles in *Physics Today* show that Ph.D. physicists find satisfaction in a wide range of careers, not just within academia [235, 236].

Graduate education, in general and within physics, has often been criticized for providing too narrow of a professional education, leaving students unprepared for the job market outside of the ivory tower [237, 238, 239]. Doctoral students are said to lack key professional skills such as working in teams, organization, management, and leadership [239], they take too long to complete their doctoral studies[4], and are ill-informed about employment outside of academia [238]. What all of this means is that it is important to provide graduate students with professional training that goes beyond "research" and "teaching."

Transferable skills are defined as skills that can be applied across different cognitive domains or subject areas [240]. It is within the scope of graduate education to provide opportunities for grad students to enhance their transferable skills, such as oral and written communication, project management, innovative thinking, interdisciplinary teamwork, and many others [241].

There are two main categories of skills that Ph.D. physicists identify as being important in their jobs: (1) scientific and technical skills, and (2) interpersonal and management skills. The proportionality of usage of technical skills depends on the position and employment sector, but the interpersonal skills are rather common regardless of employment: working in teams, technical writing, managing projects and people, budgeting, and public speaking [242]. Notice the large amounts of overlap between this list and the list in the previous paragraph.

While physicists are resilient and they are good at applying their skills and knowledge to

[4]Hello! If you add up all the years I've been in grad school, not including the year break in-between, they could get a driver's license!

new areas [243], it is important to provide graduate students with professional development for non-academic careers. And this brings us to the “Plus One” parenthetical in the title of the previous section – what we consider to be the seventh principle for best practices in GTA preparation:

7. *GTA professional development should highlight the transferable skills that can be useful outside of an academic career* [244, 245, 246, 247, 248]. GTA preparation can be centered on teaching but it should be in the broader sense of the word, encompassing other aspects of future careers besides classroom teaching. Development of key skills should be weaved into the training and into the GTAs’ responsibilities so they can best see their relevance, thus ensuring that they develop a greater diversity of capabilities.

CHAPTER 3

COURSE DESIGN AND DEVELOPMENT

In this chapter we discuss the process of creating the Physics GTA Preparation course and its evolution over the years. Detailed descriptions about the current course contents can be found in Appendix B.

3.1 GTA Training in the School of Physics Prior to 2013

As far as we can determine, a decade ago GTA training in the School of Physics used to consist of a short orientation about course logistics followed by weekly content meetings specifically about "next week's lab" (or recitation). Around 2010, efforts began towards a more comprehensive preparation for new GTAs. By 2012, new GTAs went through four somewhat disconnected training sessions:

- New TA Orientation (NTAO) – Institute-wide, mostly about policies and a bit of pedagogy
- Meetings with GTA Supervisors – logistics and GTA duties
- Weekly lab/recitation meetings – covering the material for the following week's lab or recitation
- Pedagogy Seminars – hosted by the Center for Teaching and Learning (CTL)

Due to the piecewise nature of this training, there was a noticeable disconnect between pedagogy and physics. The GTAs learned some general pedagogy in the NTAO, and then saw more in the Seminars, but none of it was explicitly applied to how to teach physics. The weekly meetings focused mostly on troubleshooting, without much pedagogical background. The Seminars were scheduled at a very inconvenient time, which brought out quite a few grumbles from the GTAs. This resulted in unmotivated GTAs who considered teaching to be something they must get through in order to be paid, instead of an important aspect of their professional development.

3.2 The CETL 8000 Model and Pilot Semester (Fall 2013)

The Center for Teaching and Learning (CTL) began a "Super TA" program in 2012 through which they integrated GTA training into the academic units while still coordinating from a central entity [6, 7]. The School of Physics joined this effort in 2013.

A "Super TA" is an experienced GTA who is further trained in pedagogy by taking teaching and learning courses offered by CTL, and who works in conjunction with a CTL mentor to adjust the standard GTA training course into something specifically useful for their particular discipline. In Fall 2013, the author of this dissertation and another experienced physics GTA became "Super TAs" and worked with a CTL mentor to develop the pilot semester of the Physics GTA Preparation course.

The GTA Preparation courses are all coded "CETL 8000" in the Georgia Tech course catalog, and the section name indicates what discipline each course belongs to (e.g., "CH" for chemistry, "EE" for electrical engineering, "MAT" for math, etc). Section PH1 was for physics, and the class was co-taught by the two physics Super TAs. All CETL 8000 classes followed the same class structure: a day-and-a-half Orientation before the start of the semester, and five to ten Follow-Up Meetings spread out during the semester. The physics course structure was as follows:

- Orientation Day 1: Active Learning, Creating Engaging Explanations, Professionalism, Georgia Tech Policies, Time Management
- Orientation Day 2: Microteaching, Classroom Management
- Follow-Up Meetings: Group Work, Grading, Leading Discussions, Midterm Evaluations, Professional Development (writing a Teaching Philosophy)

All the lessons were taught workshop-style, with discussions and activities designed to engage the GTAs, thus modeling for them the type of instruction we expected them to implement when teaching their own classes. Additionally, we presented various teaching scenarios in the form of case studies, which are useful for GTAs to think about and reflect on what they would do if they are presented with a similar situation in the classroom [249].

While teaching the class, we were able to assess the relative success of each lesson via informal observations of how engaged the GTAs were in each class meeting. For example, the first day of the Orientation started at 9am and ended at 5pm. We could tell the GTAs were restless and grumpy and wanted to leave by around 3 o'clock in the afternoon. Some GTAs reacted with reluctance, even combativeness, towards the very concept of active learning, something that other researchers have also observed [e.g., 68]. GTAs were dismissive about the topic of leading discussions because they claimed no such thing would ever come up in a physics lab or recitation. Similarly, many GTAs said that writing a teaching philosophy was not really useful for their professional development because they did not plan on staying in academia after graduation. More concrete information came from the final reflection assignment, where GTAs elaborated on which course topics had the most impact on them. The three topics most frequently mentioned that first year of the course were Microteaching, Grading, and Midterm Evaluations. From this we could determine that GTAs in general preferred material that was practical and directly applicable to their teaching, and disliked heavily theoretical topics or topics that did not appear relevant for their future careers.

From these observations, one of the Super TAs (the author of this dissertation) took it upon herself to further modify the course contents, so the course could provide the GTAs with better preparation for their teaching duties and give them opportunities for professional development. The work presented in this dissertation had begun.

3.3 Curriculum Development: The 3P Framework

After the Fall 2013 pilot, we determined that many changes were needed in order for the course to produce motivated and effective GTAs. From the principles of instructional design [15] we knew that we first needed to develop specific objectives for the class. After several revisions, we settled onto the following five course objectives:

- Developing and applying learner-centered teaching practices to create a valuable, student-centered, learning experience
- Explaining physics concepts, addressing students' preconceptions, and facilitating problem solving
- Applying teaching principles to giving and receiving feedback to revise and improve their teaching practice
- Managing classroom dynamics and developing efficient ways of grading students' work
- Reflecting on their professional identity and identifying transferable skills utilized in teaching that are useful for their future careers as professional physicists

We then identified the major themes in these objectives: (1) Pedagogy, (2) Physics, and (3) Professional Development. In the process of trying to determine what themes were served by each of the course topics in the Fall 2013 pilot, we realized that several items could fit into one or more of the main three themes. Thus, the 3P Framework was born.

The 3P Framework can be visualized with a Venn Diagram (Figure 1.2) in which each circle corresponds to one of the P's (pedagogy, physics, professional development). The framework therefore posits that in order to have a comprehensive program for GTA preparation that is useful and valuable for GTAs in the classroom and beyond there must be full

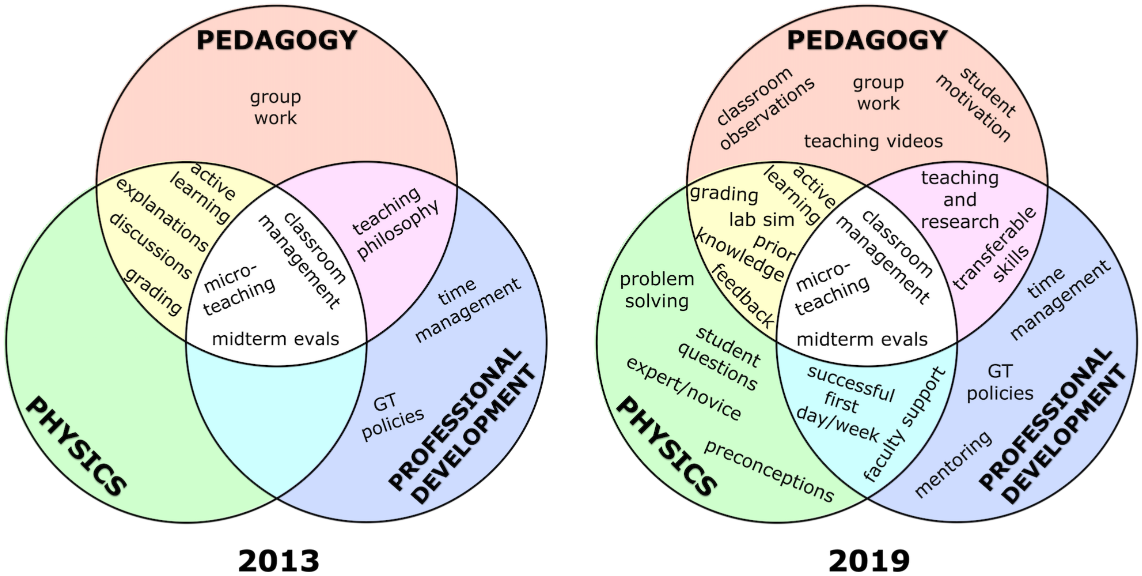

Figure 3.1: Mapping the course contents onto the 3P Framework. Left panel: the pilot semester (Fall 2013). Right panel: the most recent semester (Fall 2019). Note that the gaps present at the beginning are now filled.

integration between pedagogical knowledge, physics content, and professional development strategies. Pedagogy alone is not enough, because GTAs are novice instructors who need guidance in how to apply pedagogical knowledge to their physics teaching assignments. Physics alone is not enough, because just knowing the content does not guarantee skills in how to teach it. And professional development is crucial for motivation, so GTAs will see that teaching can help them achieve their professional goals even if they lie outside of academia. Of key importance to this framework is the fact that the intersections of the three P's are just as important as each of the P's themselves.

The left panel in Figure 3.1 shows the original mapping we did with the Fall 2013 topics onto the 3P Framework. The reasoning behind this mapping is as follows:

- The Group Work lesson did not include anything specific about physics, so we considered it purely pedagogy.

- Georgia Tech Policies and Time Management had nothing to do with physics or pedagogy, but understanding them both can help GTAs in their professional development.

- Writing a Teaching Philosophy contributes towards the professional development of GTAs but likely only if they stay in academia, in a teaching-focused position.

- Active Learning, Creating Engaging Explanations, Leading Discussions, and Grading were supposed to be pedagogical topics applied in a physics context (although in practice, in that first semester they only had some physics "sprinkles").

- We determined that Microteaching, Midterm Evaluations, and Classroom Management included aspects of all three P's, so we placed them in the center of the diagram.

Mapping the course contents this way revealed a large gap in the Physics aspect of the framework, thus indicating that the course was far from comprehensive. At that time we began the cycle of revision and implementation presented in Section 1.5.2. The right panel in Figure 3.1 represents the mapping of course topics in the most recent iteration of the course, Fall 2019. We can see that in the most recent version there are no gaps, thus the course is now robust and comprehensive. It should be noted that the main structure of the class (Orientation and Follow-Up Meetings) remains unaltered, but with some additional out-of-class activities. And although the total contact hours for the class have increased, this increase was not large – from 17 hours in 2013 to 20 hours in 2019. The present-day structure of the class is detailed in Table 3.1.

3.4 Evolution of the Curriculum

How did the course evolve from the left panel to the right panel in Figure 3.1? A timeline diagram of the curriculum evolution is shown in Figure 3.2. Each topic is color-coded according to how it maps onto the 3P Framework. The early gaps in the curriculum are clearly visible here, and we can also see the course become more comprehensive over the years.

Table 3.1: Physics GTA Preparation course structure (2019). For details on the content of each module, please see Appendix B.

Module	Brief Description
	Orientation
Intro & GT Policies	GTA duties and expectations; Georgia Tech Policies
Teaching Physics	Active learning; explaining concepts and addressing preconceptions; the novice/expert divide and anticipating student questions; facilitating problem-solving
Classroom Management	Strategies for classroom management; facilitation of group work; how to keep students motivated
Lab Simulation	Practice teaching in a lab environment using real introductory physics lab experiments
Microteaching	Practice teaching problem-solving, and giving and receiving feedback from peers and instructors
	Follow-Up Meetings
Grading	Strategies for fair and efficient grading, including rubrics; grading practice with old exam problems
Midterm Evaluations and Time Management	Strategies for collecting teaching feedback from students; strategies for effectively managing the time spent on different tasks
Teaching Videos	Watch and critique video recordings of past physics GTAs at Georgia Tech
Teaching and Research	Identifying transferable skills in teaching that can help in future careers beyond the classroom
Concluding Remarks	Final thoughts and reflections at the end of the first semester of graduate school
	Activities
Workload Surveys	Weekly surveys to indicate the time spent on various GTA and graduate student duties
Classroom Observations	An instructor observes each GTA twice per semester and provides them with feedback
GAP Mentoring Meetings	Peer mentoring sessions with the Graduate Association of Physicists (GAP)

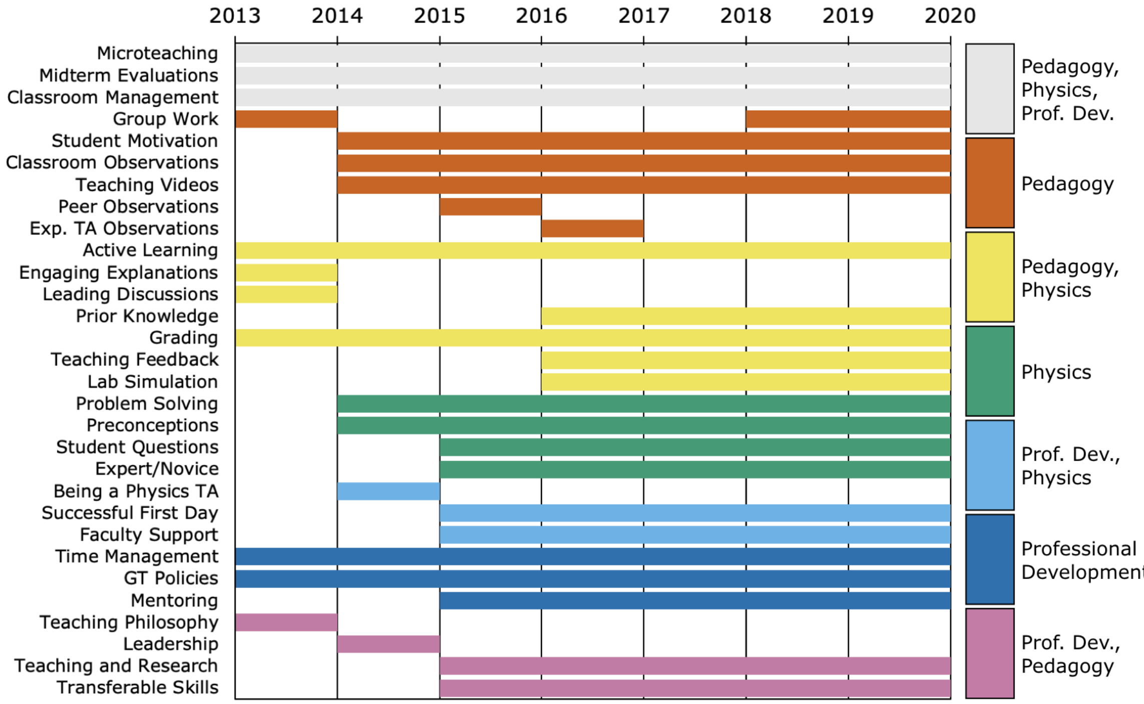

Figure 3.2: Evolution of the curriculum over the years. Each class module, topic, or activity is color-coded according to how it maps onto the 3P Framework. Note that some course elements have been there since the beginning, others came and went, and others still started later and have since remained. In the end, the present-day curriculum is more robust and comprehensive than when the course first started.

Instead of chronologically explaining all the changes we made each year, we will focus on the course elements that have persisted since the beginning, the elements that failed and were eliminated quickly ("false starts"), and the elements that were added later and have proven successful.

3.4.1 Persistent Over the Years

Microteaching is the first opportunity the new GTAs have to practice teaching in front of an audience and to receive feedback on their performance [36]. In our experience (Section 4.2.2.1) and that of other researchers [e.g., 204], first-time GTAs consider it to be a highly valuable and useful experience. The Physics GTA Preparation course has included a Microteaching activity from the very beginning; however, the activity itself has not remained static. In 2013 and 2014, GTAs were given a list of physics topics, and each person would pick a topic and prepare a 10 minute lesson on their selected topic. Although GTAs in general considered Microteaching to be very useful, some indicated that they would prefer to have more guidance on what they are supposed to present while microteaching. Thus in 2015 we changed the format. Instead of selecting a topic, each GTA would select an intro physics problem that they would then facilitate for their peers. The new format continues to this day.

Midterm Evaluations is a dual-purpose lesson. First, the GTAs provide the instructor with feedback on the GTA prep course, and then the GTAs are assigned a project in which they have to write their own midterm evaluations and administer them to their students to receive feedback from them, then write a report about their results. This is another lesson that has existed since the start, and for this one the format has not changed much over the years. The only difference is that over the years we have collected midterm evaluation questions from GTAs, and now we provide the new GTAs with sample midterm evaluations based on the work done by previous first-time GTAs. The GTAs are now given the opportunity to write their own questions, or mix-and-match questions from the samples, or copy a sample midterm evaluation wholesale, as long as they explain their reasoning for using those questions and the type of feedback they sought from their students.

Classroom Management is another session title that has existed since the beginning, though the contents have changed over the years. It started as a short session with tips to manage a classroom and discussion of a handful of case studies. Group Work, which was a session on its own in 2013, was absorbed into Classroom Management in 2014. Between 2014 and 2017, Group Work was discussed in a very minimal way during Classroom Management, in the context of one single case study. However, we realized that GTAs were having issues managing groups of students, so we re-expanded Group Work while keeping it within the Classroom Management session. This session now also includes information about what to do on the first day of class and how to motivate students.

Active Learning was originally a separate session which only happened in 2013. The concept of active learning, however, has remained an integral part of the class, particularly in the Teaching Physics lesson (Section B.1.2), since we want GTAs to teach their labs and recitations by interactively engaging with the students. We now also provide the GTAs with references from PER [e.g., 60] to emphasize how important and effective this style of teaching is. Another difference is that in the first two years of the course, we included a discussion of Bloom's Taxonomy [250]. We have since removed this discussion given that it is not essential for the GTAs as novice instructors.

Grading is a necessary part of any GTA preparation course, especially when a majority of the first-time GTAs have no prior teaching experience. From the beginning, the lesson starts by discussing rubrics. It is interesting to note that many GTAs in the early years of the course said they had never heard of rubrics, but in later years most GTAs report knowing what a rubric is. The changes that have been made to the Grading lesson have been necessitated by the different types of grading done in each GTA assignment. As explained in Section 1.2, first-time GTAs are generally assigned to teach Introductory Physics, but at Georgia Tech there are different 'flavors' of that class, and each flavor comes with its own separate GTA duties. Starting in 2016, we divided the Grading lesson into two separate sessions, one for GTAs teaching the Traditional flavor of Intro Physics, and another for GTAs teaching the M&I flavor of Intro Physics. In the Traditional session we discuss the particulars of grading lab reports and recitation worksheets (done in breakout groups with experienced GTAs from 2018 onward), in addition to going over the exam grading rubric and doing a grading practice. In the M&I session we discuss the exam grading rubric and do a grading practice. The method of grading changed from on paper to online in 2017, and as a result we began to include information on how to use the online grading software. Eventually, discussion of (and practice with) the grading software was separated into its own separate session (in 2019).

Time Management is a very important skill that will help GTAs not just in perform-

	URGENT	NOT URGENT
IMPORTANT	**STRESS** Things that are both important and urgent, like a rapidly approaching (or already passed) deadline. Try to avoid falling into this quadrant too often, to prevent fatigue/burnout.	**VALUE** When things are important but not urgent. This is where projects fall into when you work on them well before their due date. Effective time management will result in most of your work being in this quadrant.
NOT IMPORTANT	**FILLER** When you do things that are not important but they seem to be urgent. Examples: cleaning your inbox, organizing your desk, alphabetizing your MP3 collection. These are things that can wait to be done later.	**PROCRASTINATION** Things that are not important and not urgent, but you do them anyway when you should be working, just to avoid doing your actual work. Note that procrastination is not the same as relaxation.

Figure 3.3: Time management matrix displaying tasks according to the two dimensions of Important/Not Important and Urgent/Not Urgent. Adapted from [251].

ing their teaching duties but also in their coursework and in their future careers. From the beginning, the Time Management lesson has introduced GTAs to the Eisenhower Important/Urgent Principle [251], in which tasks are categorized according to whether or not they are important and whether or not they are urgent. Figure 3.3 shows the matrix as it is given to the GTAs in a printed handout during the Time Management lesson. In later years we have added case studies and a spreadsheet for GTAs to list how many hours each of their weekly tasks require. Additionally, in 2015 we began assigning weekly Workload Surveys for GTAs to reflect on the time spent on their different teaching tasks.

Georgia Tech Policies is a topic that needs to be covered since GTAs are employees of the Institute. There are four policies that are always discussed: Academic Integrity, the Office of Disability Services, Sexual Misconduct, and FERPA; additionally, we make sure to emphasize the importance of the Institute's Policy of Nondiscrimination. The lesson always includes case studies to discuss the nuances of each policy. In 2017 we created a game called "OK/NOT-OK" to further discuss the policies in a fun and engaging manner (see Section B.1.1 for details). It was an instant hit. The GTAs were deeply engaged with the game, lots of laughs were had at the obvious scenarios, spirited discussions sprouted around the non-obvious scenarios, and everyone in general (including the course instructor) seemed to have a great deal of fun.

3.4.2 False Starts

Engaging Explanations was a separate lesson in the first year of the course that was streamlined and absorbed into the Teaching Physics lesson (see Section B.1.2.

Leading Discussions was a session in which we talked about strategies for a GTA to lead a discussion, and how to respond to questions for which they do not know the answer. This session only existed in the first year of the course. Feedback from the GTAs indicated that they felt it was useless for their actual teaching assignments, and that we spent too much time on it that could have been spent on more hands-on practical activities. The session was thus eliminated, and the topic of what to do if you do not know the answer to a question was absorbed into Classroom Management.

Teaching Philosophy was the way in which we injected professional development into the first year of the course. The GTAs said it was not useful for them since most of them planned on careers in industry. In the second year of the course we replaced Teaching Philosophy with *Leadership*, in which we discussed styles of leadership and how to develop leadership skills. The GTAs that year did not consider this useful either, so it was also eliminated.

Being a Physics TA was a big portion of the Introduction and Policies session in 2014, and it was designed to help GTAs develop their identity as educators. It was not well-received because GTAs felt it was "preachy." We eliminated this as an explicit discussion and instead focused on developing activities within the other course modules to help GTAs develop their professional identity.

Peer Observations was an activity we included in 2015, in which GTAs would observe each other in groups of three – given three people A, B, and C, the observations would go: A observes B, B observes C, C observes A – and gave each other feedback. This activity received a lukewarm response, with some people enjoying it and other people hating it. Some GTAs said that they did not feel qualified to give useful feedback to their peers, while others said their peers were not qualified to give them useful feedback. In 2016 we replaced it with *Experienced TA Observations*, in which each first-time GTA was assigned to observe an experienced GTA who was also teaching the same class that semester. This activity encountered severe logistics difficulties because on that particular semester there were very few experienced GTAs teaching the introductory physics classes. It is safe to say the activity was a disaster, and we quickly eliminated it from the curriculum.

3.4.3 Newer and Successful

Several new topics were added to the class in its second year – *Student Motivation* (included as part of the Classroom Management module), *Classroom Observations* (in which GTAs are observed by an instructor and given feedback for reflection and improvement), *Teaching Videos* (in which GTAs watch videos of experienced GTAs and critique them), and *Problem Solving* and *Preconceptions* (in which GTAs participate in activities to help them facilitate problem solving and identifying student preconceptions). All of these topics have remained largely unchanged over the years, with very few subtle improvements. For example, originally each GTA was only observed once per semester; now they are observed twice, once in early September and again in late October. In the present-day Teaching Videos lesson the GTAs watch videos from past years' classroom observations, so the GTAs they are watching and critiquing are first-time GTAs instead of experienced GTAs. The Problem Solving and Preconceptions topics are part of the Teaching Physics module (see Section B.1.2), and the only changes they have experienced over the years is the inclusion of new problems for the GTAs to solve.

Anticipating Student Questions, *Experts and Novices*, and *Prior Knowledge* were all added to the Teaching Physics module, making it even more comprehensive, to the point that it is among the top-three most useful course topics according to the GTAs (see Section 4.2.2.1).

Strategies for having a successful first day of class were added to the Classroom Management module, to ensure that GTAs would start their teaching on the right foot. In 2018 we also included an assignment to reflect on the first week of teaching. This way GTAs keep in mind the things that went well and identify the things that could have gone better and that they can improve on.

Faculty Support is something the GTAs requested time and time again. Between 2015 and 2017, we had a faculty guest speaker come into the Introduction and Policies lesson to talk to the GTAs about teaching and professional development. We have not been able to have a guest speaker in the last two years because of scheduling conflicts; however, the faculty who are in charge of supervising the GTAs (the coordinators for the Intro Physics classes) are fully on-board with the class and have provided valuable information to include in the Physics GTA Resources website (see Section 1.7.1).

Mentoring is something very important for the professional development of first-time GTAs. We initially included mentoring by creating an unstructured lesson in which GTAs were welcome to ask questions and discuss any issues or difficulties they were having. The unstructured nature of the lesson was not well-received, so we eliminated it after one year. The following year we allowed a group of senior graduate students to address the GTAs in peer mentoring. This kind of mentoring was somewhat unstructured at first, but from 2017 onward it has been well-structured into three peer mentoring sessions covering topics about academics, guidance and support, and career options. This allows the first-time GTAs to meet some of the senior graduate students in the department and learn from their experiences.

After the failure of Teaching Philosophy and Leadership, we found ourselves wonder-ing how to include more explicit professional development into the course. The answer came to us by thinking about *transferable skills* that can be developed while teaching and that can be useful for a physicist even outside of the classroom. To this end we created the *Teaching and Research* module, in which GTAs compare academic and non-academic job ads and identify the transferable skills required for each.

The most recent addition to the class is the *Lab Simulation*. This is similar to Microteaching, but in a lab environment. The activity is a fun roleplaying exercise in which GTAs take turns being "TAs" and "Students." The "Students" work on real intro physics lab experiments and the "TAs" facilitate as if they were teaching an actual lab class. An amusing aspect of this activity is that some of the GTAs are contacted in private to ask them to behave like problematic students and sabotage the experience when their peers are teaching. The GTAs really get into their roles, and most of the "TAs" recognize the problematic behaviors and act accordingly to correct them.

3.5 Discussion

The training of first-time GTAs in the School of Physics lacked cohesion and continuity. In a partnership with the Center for Teaching and Learning, we developed a Physics GTA Preparation course that would prepare and motivate GTAs for teaching. Teaching the course for the first time allowed us to identify the aspects of the course that needed changing to make it more relevant, useful, and valuable to our GTAs.

We developed the 3P Framework to better visualize the course contents. With the 3P Framework we postulate that in order to have a comprehensive GTA preparation program there must be a full integration between pedagogical knowledge, physics content, and professional development strategies. Under the guidance of the 3P Framework, we revised the course yearly and implemented changes to improve the curriculum.

Some elements of the course have been present from the start, such as Microteaching, Midterm Evaluations, Grading, and Time Management. But even these have gone through changes, some subtle and some drastic, to make them better and more useful year after year. Other elements were unfortunately awful failures that lasted only one year. Nevertheless, we persisted with the yearly revisions and developed new activities that have stood the test of time.

By the time of this writing, the Physics GTA Preparation course is a well-established, comprehensive, stable, and long-running professional development program for first-time GTAs in the School of Physics. Not only has the course been effective at improving GTAs' self-efficacy and approaches to teaching (see Chapter 4), but it has also been mostly well-received by the GTAs themselves. See, for example, the following quotes taken from the Final Surveys between 2015 and 2018:

> "You made a course that everyone would likely have absolutely hated if there was any other instructor seem worthwhile and enjoyable. Thanks."

> "Simply how it helped build my confidence in teaching students. I was SO nervous at first, but once we did the microteaching and labsim and I could see what my peers were doing, I felt way better."

> "I loved the awareness and reflection this class brought to my teaching. I would not have grown as a TA nearly as much without this class."

> "It was an eye-opener. A lot of mistakes were avoided because of this class."

> "I would have been a thoroughly mediocre TA had it not been for this course. Thank you!"

Of course, not everything has been sunshine and rainbows. We consider it almost tradition by now to get one extremely negative comment each year – here's an example: "All things considered, this course demonstrated an insulting lack of respect for our professionalism as well as our limited time" (ouch!!). We do not yet have statistics about what kinds of comments we receive the most (this will be done in future work), but our yearly review of GTAs' comments and feedback give us the impression that there are significantly more positives than negatives.

CHAPTER 4
PROGRAM ASSESSMENT

We measured the effectiveness of our Physics GTA Preparation course primarily with a combination of surveys and pre/post assessments.

The first assessment, called the *Entry Survey*, was administered online to the incoming first-year graduate students before they arrived at Georgia Tech, and served to gauge their initial conditions (e.g., prior teaching experience, concerns about teaching, etc). The results of this assessment are discussed in Section 4.1.

The *Orientation Survey* was administered in person to the graduate students after they had completed the Orientation portion of the class. The *Final Survey* was first implemented in 2015 and administered to the graduate students during the last class meeting of the semester. The results of these surveys, discussed in Section 4.2, give us an indication of what aspects of the course the GTAs find useful.

Pre/post assessments allowed us to ascertain the change in GTAs' attitudes about teaching (Approaches to Teaching Inventory, ATI) and knowledge about pedagogical practices (Knowledge Quiz) after completing one semester of GTA preparation and teaching experience. These results are discussed in Section 4.3.

Finally, we analyzed data from end-of-semester student evaluations of first-time GTAs before and after the GTA preparation course was established, and we discuss the results of that analysis in Section 4.4.

4.1 The Initial Conditions of First-Time GTAs in the School of Physics

Every year in July, we contacted the incoming group of first-year graduate students to let them know the logistics of the Orientation portion of the Physics GTA Preparation class. At this time, the new first-years were also given a Qualtrics link to an online questionnaire

Table 4.1: Entry Survey data: for each year we list the course enrollment, the total number of Entry Survey responses, and the number of responses from participants who signed informed consent. Percentages are based on the total enrollment for each year.

Year	Enrollment	All responses	With consent
2014	13	12 (92%)	7 (54%)
2015	34	31 (91%)	27 (79%)
2016	23	21 (96%)	18 (78%)
2017	26	26 (100%)	20 (77%)
2018	16	13 (82%)	11 (69%)
Totals	112	103 (92%)	83 (74%)

which we refer to as *Entry Survey*. The Entry Survey asked, among other things, about the first-years' prior teaching experience, their concerns about teaching, whether they consider teaching to be an important aspect of their professional development, and their future career goals. Appendix C shows a paginated PDF full-export of the most recent Entry Survey (2019).

Between 2014 and 2018, we received a total of 103 Entry Survey responses, out of 112 graduate students enrolled in the class, a response rate of 92%. Focusing only on responses from students who signed informed consent, who are the only participants in the study, the numbers change to 83 responses out of a possible 89, giving us a 93% response rate. Table 4.1 shows the number of Entry Survey responses each year, and the percentages of responses based on the total enrollment. The data are visualized in Figure 4.1. Given the high response rate, we are confident that the Entry Survey data we have analyzed is representative of the full population of first-time GTAs in the School of Physics, and any discrepancies are due to sampling.

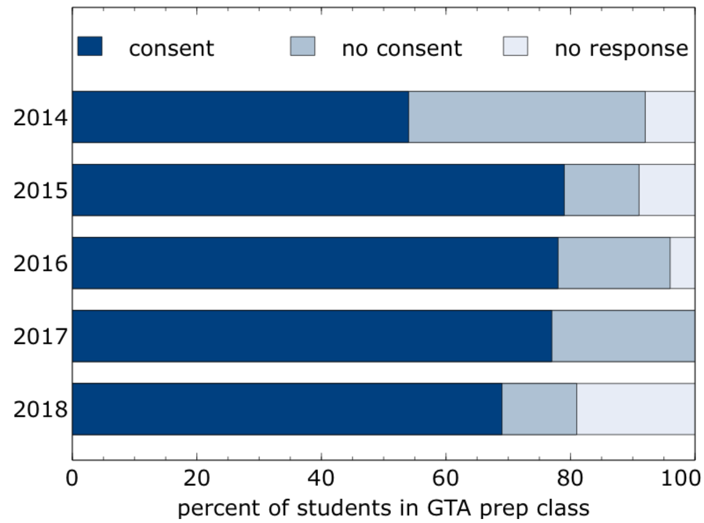

Figure 4.1: Visualization of the available data from the Entry Survey. For each year, we have indicated the percentage of graduate students who submitted a response and signed informed consent (dark blue), the percentage of students who submitted a response but did not sign informed consent (medium blue), and the percentage of students who did not submit a response (light blue). The Entry Survey generally had a high response rate, even when limiting the data only to participants who signed informed consent.

4.1.1 Previous TA Experience

Of the 83 usable responses, 41% indicated having prior TA experience, as either graduate (GTA) or undergraduate (UTA) teaching assistants in their previous institutions, and 59% indicated no prior TA experience. It should be noted that the percentage of graduate students with prior TA experience is slightly over-represented in this sample compared to the data set of all available Entry Survey responses (including 2013 and 2019), but the difference is not statistically significant ($\chi^2 = 2.898, p = 0.089$). The main takeaway from this survey item is that the majority of our first-time GTAs have no prior formal TA experience.

The 41% of respondents who indicated having prior TA experience were asked to elaborate on what teaching duties they had performed as TAs. Table 4.2 shows those teaching duties. Tutoring and grading are the most common duties performed by first-year graduate students who had been TAs before arriving at Georgia Tech.

Regardless of the response to the question of prior TA experience, we also asked every-

Table 4.2: Teaching duties (within a GTA or UTA assignment) performed by graduate students with prior TA experience. The question asked to select all that apply.

Duty	Percent
Tutoring	32%
Grading	28%
Lab	15%
Office hours	12%
Recitation	7%
Guest lecturing	5%
Other	2%

one if they had other, non-TA, prior teaching experience. Out of the 83 usable responses, 42% answered positively; of those, 69% mentioned one-on-one tutoring – either informal tutoring among friends, or formally being employed as tutors, at all education levels. A further 23% indicated having experience with PreK-12 teaching, to various degrees of involvement.

4.1.2 Teaching as Professional Development

We wanted to know what first-time GTAs think about teaching as a part of their professional development, given that a large portion of our physics Ph.D. graduates leave academia after grad school [252]. For this, in 2016 we began including the following five-point Likert question in the Entry Survey:

> Please indicate your level of agreement with the following statement: "I consider teaching to be an important part of my professional development as a physicist."

The responses for this question are visualized in Figure 4.2. An astounding 93% of the 49 available responses (2016-2018) indicate agreement or strong agreement with the question's statement. This tells us that our first-year graduate students think of teaching as important, which can indicate a desire to do well in their teaching assignments.

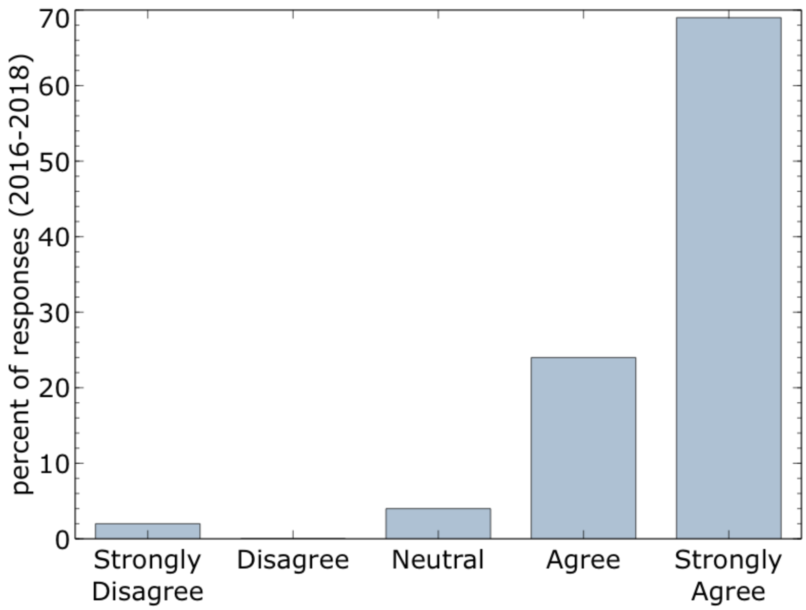

Figure 4.2: First-time GTAs overwhelmingly agree with the statement "I consider teaching to be an important part of my professional development as a physicist."

4.1.3 Concerns About Teaching

It is well-documented in the literature that new GTAs, like all novice teachers, experience anxiety and apprehension about their first teaching assignment [25, 253, 254, 255, 256, 257]. They worry about classroom management and time management and how to efficiently communicate with their students [258, 259]. In general, the kinds of concerns GTAs worry about change over time, as their professional development evolves while they gain experience and self-efficacy [260, 261]. Ronkowski [262], based on the work of Fuller [263], characterized the evolution of GTA concerns according to three stages: (1) the Survival Stage, where GTAs mostly have adequacy concerns; (2) the Mastery Stage, where GTAs worry about student learning; and (3) the Impact Stage, where GTAs self-reflect on how to improve their teaching so students can learn better.

The majority of our first-time GTAs have no prior teaching experience, so we expect their concerns to align with the Survival Stage of Ronkowski [262]. The Entry Survey includes a question about this:

> Describe your top three concerns about your teaching assignment for [this coming Fall semester].

Between 2014 and 2018, our study participants listed a total of 221 concerns, which we have coded into 19 categories. Table 4.3 shows the categories, in order from most common to least common, and a brief description of what criteria we looked for when coding the GTAs' concerns. Figure 4.3 displays the percentage of all usable listed concerns that are represented in each category. For the full list of all concerns, please see Apprendix D.

Table 4.3: Categorization of first-time GTAs' concerns about teaching.

Category	Description
Content mastery	Worries about not knowing or understanding physics well enough to teach, or about forgetting basic material.
Time management	Concerns about balancing teaching duties and graduate coursework.
Language, culture, communication	Comments about being a non-native English speaker and how to communicate effectively with students when there is a language and cultural barrier.
Labs and technology	Worries about having to use unfamiliar lab equipment, experiments, and troubleshooting.
Grading	Concerns about fairness and consistency in grading, grading guidelines, and generally how and what to grade.
Engaging and motivating students	Assuming that most of their students will be non-physics majors, and wanting to know how to motivate them and get them interested in physics.
Nervousness and public speaking	Mentions of stage fright, nerves, fear of speaking in front of a group.
Dealing with students	What to do about difficult students (disciplinary problems, sexual harassment situations), how to address students' requests, and remembering student names.
Explaining concepts and ideas	Worries that their explanations of physics concepts will not be understandable to undergraduate students.
Teaching techniques	Concerns about teaching styles and how to teach different topics.

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Table 4.3 – continued from previous page

Category	Description
Preparing for teaching	Questions about how best to prepare for their teaching assignments.
Choosing what to teach	Wanting to know if they will be able to choose what classes to teach.
Getting respect from students	Worries about students not taking them seriously; being trusted and respected by the students.
Professors and supervisors	Worries that they will not get along with the professor supervising their teaching.
Administrative matters	Questions about procedures, resources, and feedback on job performance.
Lack of prior teaching experience	Mentions of having no prior teaching experience and being worried about not teaching adequately because of it.
Class size	Wanting to know how many students they will be in charge of, or worries about being in charge of too many students.
Scheduling	Questions about timing of GTA duties, including questions about time off.
Students' prior knowledge	Questions about the background knowledge students have or lack.

Unsurprisingly, the most common concerns revolve around content mastery. Most first-year graduate students are just coming out of undergrad, and are therefore worried that they do not know or understand physics well enough to teach it [70]. Here are some examples:

> "I'm afraid of being assigned material that I did not fully understand as an undergraduate, and having to teach it to my students"

> "That I will not have complete enough knowledge to answer all questions"

> "I'm pretty uncomfortable with the idea of teaching physics. My degree in college was in biology, and I didn't take very much physics. I'm worried that students will get a homework problem that I don't know how to solve."

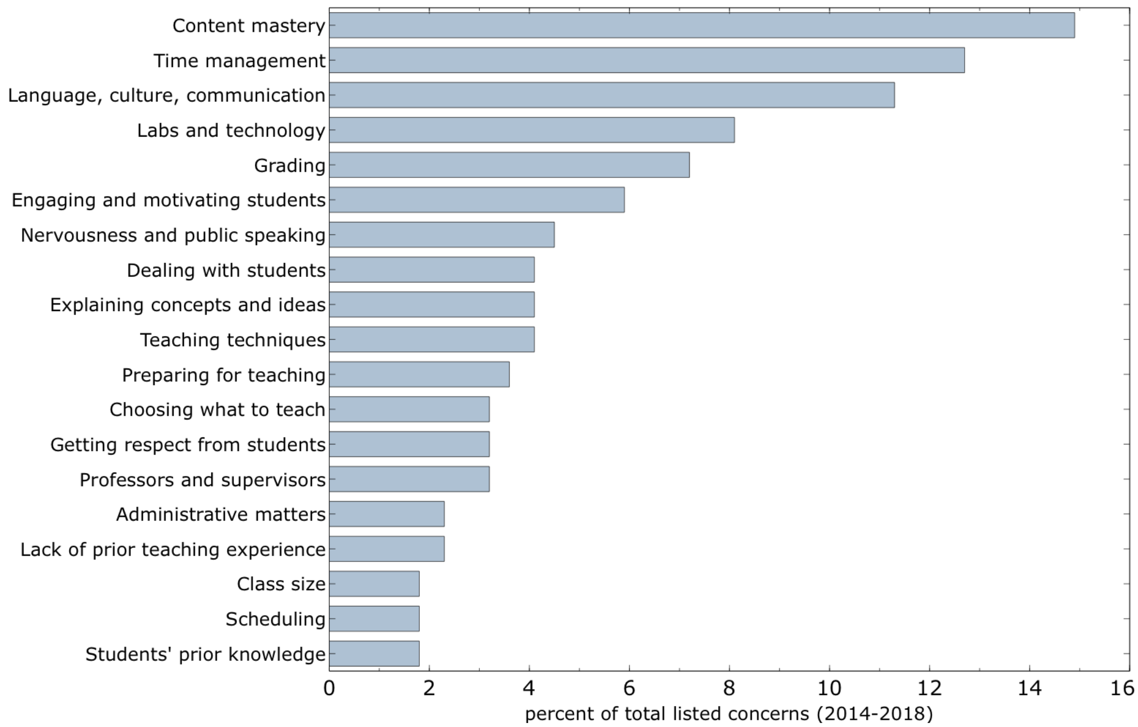

Figure 4.3: First-time GTAs reported several concerns about teaching. Their cumulative top 3 concerns were: content mastery; time management; and language, culture, communication. Labs and technology, grading, and engaging and motivating students were also well-represented.

Others are worried more about forgetting basic material than about not knowing physics in general:

> "I suck at basic physics and math. It's hard to teach physics without using Lagrangians, etc."

> "I'm worried that I will tell students something wrong! My biggest fear is completely forgetting an answer to a relatively simple physics problem."

> "I've been out of school for two years, and I'm concerned that some of my physics knowledge has become rusty."

While both types of concern (not knowing enough and not remembering well enough) fall under the category of content mastery, it can be argued that the two are different when looked at from the lens of how memory works [264, 265, 266]. According to Holder, Poproski, and Subiño Sullivan [267], there are three mechanisms for forgetting things: filtering, failing to encode, and fading. Filtering is when only some aspects of external stimuli are absorbed into working memory. Failing to encode happens when a piece of knowledge does not make it out of working memory and into long-term memory. Fading happens when something within long-term memory is not accessed for a while. Within this framework, the GTAs' concerns about not knowing enough can be categorized as failing to encode, and the concerns about not remembering well enough can be categorized under fading. Both of these align well with the Survival Stage of GTA development [262], and if we recall Figure 1.1, we can see that as they move past the first stage of development, GTAs will improve their physics knowledge and therefore their confidence in teaching physics.

We consider it important to reassure first-time GTAs that yes, they do know physics well enough to teach it, and it will come back to them if they have forgotten it. Every year we make sure to emphasize this during the Orientation, in particular during the problem solving activity in the Teaching Physics module and during the Microteaching activity. We also emphasize to them that "I don't know" is a perfectly acceptable answer to a question for which they do not know the answer, since no one expects them to know everything about physics. All of this works towards improving first-time GTAs' self-confidence for teaching.

The second most common type of concern is about time management, in particular about balancing teaching duties with the workload for their own first-year graduate classes. Examples:

> "The TA workload will eclipse the amount of study necessary for 4 concurrent graduate courses, which, due to my lack of TA experience, will lead to poor performance from me as a TA and student."

> "Would there be sufficient time to work as a TA and simultaneously studying for my courses?"

> "Being overwhelmed balancing being a TA while being a student myself."

> “I’m concerned about balancing classwork and TA responsibilities.”

These are all very valid concerns. Graduate physics coursework is tough and time-consuming, and most first-year Ph.D. students in our School take four such courses in their first semester (Classical Mechanics I, Electromagnetism I, Quantum Mechanics I, and Mathematical Methods of Physics I). Each of those classes likely involves weekly problem sets, and one or more midterm exams during the semester. The GTA workload is supposed to not exceed 13 hours per week as an overall semester average, though in reality some weeks have more work than others (for example, compare a week in which GTAs need to grade exams with a week in which there are no lab/recitation meetings due to an Institute holiday). Time management is a topic covered in one of the Follow-Up Meetings. An activity done during this meeting involves breaking down the 168 hours available in one week into the various categories of work- and life-related things that students need to do during any particular week. Additionally, the weekly Workload Surveys given to the first-time GTAs help them to be conscientious about the time they spend on their teaching duties.

The third most common category of teaching concerns is about language, culture, and communication. The majority of the concerns listed in this category come from international students, who are mostly non-native English speakers, and who made up half of the 2016 and 2017 groups, the third and second largest cohorts, respectively, in the history of the GTA preparation class. For example:

> “Not a native English speaker, may be difficult to communicate with the students”

> “Culture of classroom in USA.”

> “My spoken English may not be good enough to interpret everything clearly.”

> “Being an international student, I might not be able to communicate what i want to say in the best possible way.”

> "Adapting to the different teaching/classroom atmosphere and the role of a TA in Georgia Tech, as I am an international student."

There is a significant and growing body of research focused specifically on the preparation of international teaching assistants [e.g., 216, 268, 269, 270, 271, 272, 273, 274, 275], most of which centers around the issues of language and culture. At Georgia Tech, the Center for Teaching and Learning and the Language Institute offer an Orientation for International Teaching Assistants (ITAO) that goes over some of the cultural and language issues that international TAs may have. Some ITAO topics include: the American student (diversity, demographics of undergrads at Georgia Tech, characteristics of the typical Georgia Tech undergrad), the American classroom (e.g., expectations about interaction and classroom participation), preparing for the first day of classes, and improving English proficiency skills. We require our first-time international GTAs to attend the ITAO, and within the Physics GTA Preparation course they have the opportunity to practice their English during the Microteaching activity.

The next three most represented categories are labs and technology, grading, and engaging and motivating students. It is not surprising that first-time GTAs would be nervous about teaching a lab – using unfamiliar equipment and the possibility of equipment failure feature repeatedly in their comments:

> "Having to instruct on equipment I have not used before."

> "Being able to handle unexpected situations in the classroom/lab (equipment malfunctions, etc)"

> "Troubleshooting and solving problems with equipment, setups, materials, etc. in lab courses. Who do I go to if I cannot solve a problem with the lab equipment?"

When it comes to grading, first-time GTAs are concerned about being fair (not too harsh and not too lenient), being consistent, and being efficient at grading large quantities of students' work:

> “My only other concern is adjusting to the grading policies so that all I am consistent with the other TA’s.”

> “Grading problem sets uniformly (not taking a point from the 48th problem set that I gave to the 4th problem set).”

> “grading, and making sure it’s fair amongst all TAs. My experience as an undergrad with TAs was that it’s very inconsistent.”

First-time GTAs are also concerned about engaging and motivating students. They are aware that most, if not all, of their students will not be physics majors and therefore might not be as interested in the material as the GTAs would like:

> “I will be assigned an Intro/101 class (a.k.a. required course for engineers) filled with apathetic engineering students who don’t care at all about physics and only care about their grade.”

> “Being assigned to TA for an intro level physics course and teaching students who are not interested in learning the material (this is inevitable in any course I know, but I still worry).”

> “Motivating the students to care about the topic they are involved in.”

4.1.4 Career Goals

We presented the first-year graduate students with a list of career options and asked them to select all the options that they are considering for their post-Ph.D. career goals. Their responses are represented in Figure 4.4, organized from most common to least common. The majority of incoming graduate students want to stay in academia, but non-academic careers such as industry, data science, and government are also attractive options. Only about 20% of first-year grad students indicate being undecided about their future career goals. It would be interesting to ask this question again to senior graduate students, those who are close to defending, to see how well (or how badly) the first-year career goals align with the reality near the end of the doctorate.

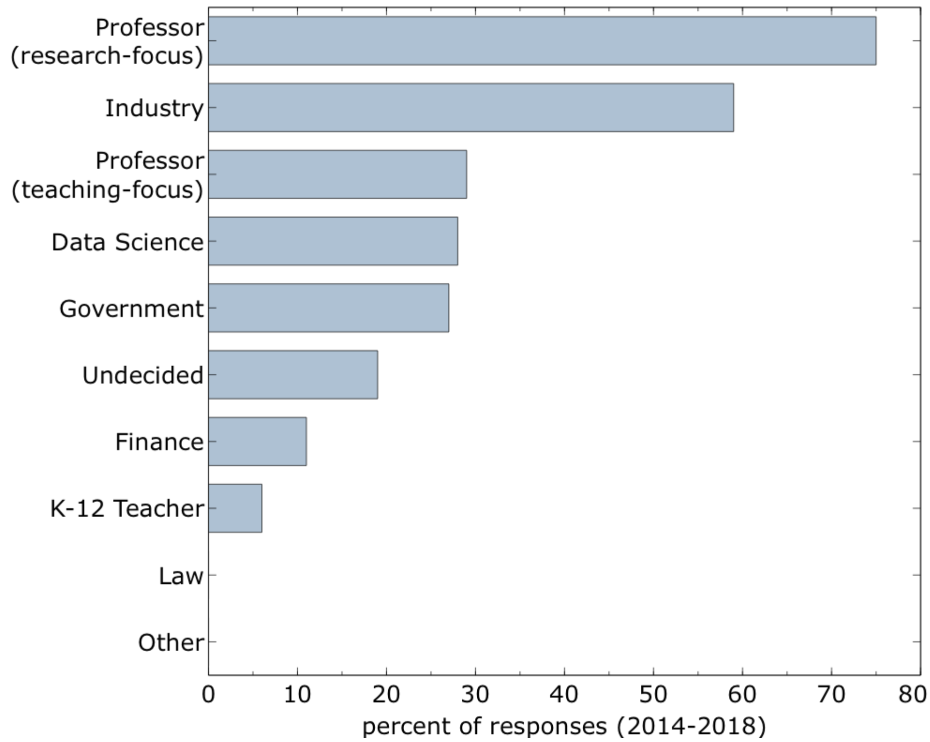

Figure 4.4: First-time GTAs' post-Ph.D. career goals lean mostly towards academia, but industry, data science, and government are also well-represented, and roughly 20% of GTAs are undecided. Please note that the question asked GTAs to select all that apply.

4.1.5 Preparedness for Teaching

Starting in 2016, the Entry Survey included the following five-point Likert-type question:

> How prepared do you feel for your first GTA assignment at Georgia Tech?

The question was then repeated in the Orientation Survey at the end of the Orientation portion of the course. By asking the same question before and after the Orientation, we are able to do a pre/post analysis of the self-reported level of preparedness of our first-time GTAs, using the Entry Survey as the pre and the Orientation Survey as the post. The results are displayed in Figure 4.5. There is a noticeable visual difference between the pre ($N = 49$) and post ($N = 64$) distributions, with the post-distribution leaning more towards higher self-reported preparedness than the pre-distribution. This indicates that first-time GTAs feel better prepared for teaching after going through the Orientation. Note that we

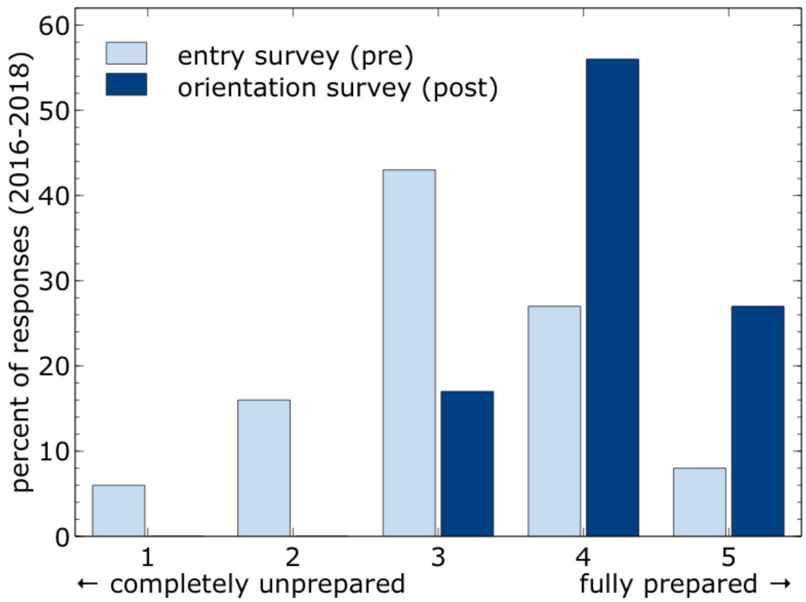

Figure 4.5: First-time GTAs report feeling better prepared for teaching after participating in the Orientation portion of the GTA preparation class. The pre-distribution (light blue, $N = 49$) comes from the Entry Survey, and the post-distribution (dark blue, $N = 64$) comes from the Orientation Survey. The distributions are visually and statistically different (Kolmogorov-Smirnov test, $D = 0.481$, $p < 0.001$), and the effect size is very large (Cohen's $d = 1.133$).

have more responses for the Orientation Survey than for the Entry Survey because the Orientation Survey is anonymous.

We performed a Kolmogorov-Smirnov test to determine if the pre and post distributions are statistically different. The results of the test were significant ($D = 0.481$, $p < 0.001$). There is also a sizeable difference between the means of the pre ($M = 3.14, SD = 0.99$) and post ($M = 4.09, SD = 0.65$) distributions. We calculated the effect size for this difference using Cohen's d:

$$d = \frac{M_{\text{post}} - M_{\text{pre}}}{SD_p} \tag{4.1}$$

where M_{pre} and M_{post} represent the pre and post means, respectively, and SD_p is the pooled standard deviation of the pre and post distributions,

$$SD_p = \sqrt{\frac{(SD_{\text{post}})^2 + (SD_{\text{pre}})^2}{2}} \tag{4.2}$$

The calculated effect size was very large ($d = 1.133$), which is unsurprising given the stark visual contrast between the two distributions.

4.2 Surveys

We used two surveys to assess how satisfied the graduate students were with the GTA preparation course. The Orientation Survey is administered at the end of the Orientation, and the Final Survey is administered during the last class meeting of the semester. Both of these surveys are anonymous.

4.2.1 Orientation Survey

At the end of the Orientation, the GTAs are presented with the Orientation Survey, a series of statements to assess their level of satisfaction with different aspects of the Orientation (Class Activities, Guests, Materials, Timing, and Usefulness), via a five-point Likert-type scale, from strongly disagree (1) to strongly agree (5). It should be noted that the number of questions asked varied with each year. Table 4.4 summarizes the number of questions asked in each year's Orientation Survey according to the five aforementioned categories. We can see that the number of questions related to Materials and Timing decreased or disappeared entirely after 2016. This makes sense, as by that point the class materials and timing of the lessons had been well-established. The number of questions about Class Activities did not change by much, whereas the number of questions about Usefulness increased significantly. Finally, questions about Guests were only asked on years in which we had guest speakers participating in the Orientation.

A sample Orientation Survey (the most recent one, 2019) can be found in Appendix E. The full list of all statements ever included in the Orientation Survey, along with their categories, the years in which each statement was included, and the number of responses available for each statement, can be found in Table 4.5. A request for open-ended comments was included at the end of the Orientation Survey every year (Section 4.2.1.6).

Table 4.4: Distribution of Orientation Survey statements over the years, by category.

Category	2014	2015	2016	2017	2018
Class Activities	4	4	3	3	3
Guests	0	1	2	1	0
Materials	3	3	1	1	1
Timing	3	3	1	0	0
Usefulness	6	8	9	10	10
Total statements	16	19	16	14	14

Table 4.5: All possible statements in the Orientation Survey. For each statement, we include the category it belongs to (Class Activities, Guests, Materials, Timing, and Usefulness), the years in which the statement was included in the Orientation Survey, and the number of responses available for analysis.

Code	Statement	Category	Years	N
J1	The handouts/worksheet packets have been useful.	Materials	2014-2018	109
J2	There was a good balance between lecture and activities.	Class Activities	2014-2018	108
J3	There were enough breaks during the long three-hour sessions.	Timing	2014-2015	44
J4	The pair and group activities were useful.	Class Activities	2014-2018	109
J5	The PowerPoint slides were relevant and used effectively.	Materials	2014-2015	44
J6	There were too many pair/group writing and discussion activities.	Class Activities	2014-2015	44
J7	The three-hour sessions were an effective use of time.	Timing	2014-2016	68
J8	I would have preferred more lecturing than activities.	Class Activities	2014-2018	108

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Table 4.5 – continued from previous page

Code	Statement	Category	Years	N
J9	Going through [Orientation] before the TA job begins is helpful to me.	Usefulness	2014-2018	106
J10	My worries and concerns about teaching were addressed properly.	Usefulness	2014-2018	108
J11a	I would have preferred [Orientation] to be in two 6-hour sessions.	Timing	2014	12
J11b	I would have preferred [Orientation] to be just one full day (9am-6pm).	Timing	2015	31
J12	The [Orientation] sessions were a waste of time.	Usefulness	2014-2018	107
J13	I feel better prepared to be a TA now that I've gone through [Orientation].	Usefulness	2014-2018	109
J14	There were too many handouts/worksheets.	Materials	2014-2015	45
J15	Microteaching was a valuable practical experience.	Usefulness	2014-2018	109
J16	I expect the [Follow-Up] Meetings during the semester will be useful.	Usefulness	2014-2018	108
J17	Watching TA videos gave me a good idea of what to expect as a TA.	Usefulness	2015-2016	56
J18	I appreciated having a professor come talk to us about teaching.	Guests	2015-2017	82
J19	I liked getting to work on real introductory physics problems.	Usefulness	2015-2018	97
J20	I appreciated having a guest speaker talk to us about LGBT+ concerns.	Guests	2016	24

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Table 4.5 – continued from previous page

Code	Statement	Category	Years	N
J21	The Lab Simulation was a valuable practical experience.	Usefulness	2016-2018	64
J22	The ok/not-ok game was useful for clarifying GT policies.	Usefulness	2017-2018	40
J23	The ok/not-ok game was an entertaining way to learn about GT policies.	Usefulness	2017-2018	40

There were ten statements that appeared in every Orientation Survey from 2014 to 2018. The other statements appeared anywhere from only once to four out of the five years in the study. A Kruskal-Wallis test was performed for each statement that appeared on two years or more (Table 4.6), revealing no statistical difference between the yearly distributions of all statements except for J16 ("I expect the [Follow-Up] Meetings during the semester will be useful)." Post-hoc pairwise comparisons for that one statement revealed a statistical difference between the 2015 and 2017 groups ($p = 0.023$, adjusted with the Bonferroni correction for multiple comparisons). It should be noted that the mean rating in 2015 was the lowest out of the five years ($M = 3.69, SD = 0.93$). Given the stability of distributions across the years, we will report the results of this survey in aggregate, calculating the mean score for each statement with all available data.

4.2.1.1 Class Activities

There were four statements in the Class Activities category, which measures the level to which students are satisfied with the active engagement style in which the class is taught. Two of the statements were positively worded, and the other two statements were negatively worded. Table 4.7 presents the overall scoring ($M \pm SD$) for each of the four Class

Table 4.6: Comparison of yearly distributions of Orientation Survey responses, using a Kruskal-Wallis test (H is the test statistic, df is the degrees of freedom, p is the p-value). Statement J16 is the only one for which the test was statistically significant.

Statement Code	H	df	p
J1	1.544	4	0.835
J2	1.374	4	0.849
J3	0.481	1	0.488
J4	2.848	4	0.583
J5	3.308	1	0.069
J6	0.000	1	1.000
J7	1.011	2	0.603
J8	5.647	4	0.227
J9	2.726	4	0.605
J10	3.186	4	0.527
J12	0.994	4	0.911
J13	2.930	4	0.570
J14	0.198	1	0.657
J15	2.774	4	0.596
J16	11.245	4	0.024
J17	0.177	1	0.674
J18	1.031	2	0.597
J19	1.562	3	0.668
J21	2.259	2	0.323
J22	0.893	1	0.345
J23	0.381	1	0.537

Activities statements. The two positively worded statements were rated high, indicating that students think the class has a good balance of lecture and activities and that the activities themselves are useful. The two negatively worded statements scored low, which indicates that students think there was an appropriate amount of activities and that they would not have preferred to have more lecturing. Taken all together, we can conclude that GTAs enjoy the interactive nature of the class.

Table 4.7: Orientation Survey statements categorized under "Class Activities."

Statement	Score ($M \pm SD$)
Positively worded	
There was a good balance between lecture and activities.	4.34 ± 0.64
The pair and group activities were useful.	4.29 ± 0.74
Negatively worded	
There were too many pair/group writing and discussion activities.	2.34 ± 0.86
I would have preferred more lecturing than activities.	2.27 ± 0.93

4.2.1.2 Guests

From 2015 to 2017, a faculty member attended the Orientation to give a short (∼15 minute) talk about teaching. This was generally well-received ($M = 3.88, SD = 0.83$). Attendance by a faculty member is dependent on their schedule and availability, which is why we have only included this statement on three out of the five years of the study.

In 2016, another guest speaker attended to give a short talk about LGBT+ concerns when teaching, with a mildly positive reception ($M = 3.68, SD = 0.93$). In subsequent years, LGBT+ concerns were included in the OK/NOT-OK game which is now part of the first day of the Orientation.

4.2.1.3 Materials

The Orientation Survey included three statements about class materials (handouts and slides). Two of the statements were positively worded, and were scored highly ("The handouts/worksheet packets have been useful," $M = 4.28, SD = 0.76$; and "The PowerPoint slides were relevant and used effectively," $M = 4.16, SD = 0.75$). One statement was negatively worded, and scored low ("There were too many handouts/worksheets,"

$M = 2.49, SD = 0.89$). We can conclude that students think the class materials are adequate and useful. Only the first question, about the usefulness of the materials, remains in the Orientation Survey to date.

4.2.1.4 Timing

The statements about timing are limited to the first 2-3 years of the class, because the Orientation schedule became fixed after that. These statements ask the students if there were enough breaks during the three-hour sessions ($M = 4.20, SD = 0.70$), and if the three-hour sessions were an effective use of time ($M = 3.74, SD = 0.87$). These results tell us that the students were mostly satisfied with the timing of the Orientation sessions.

Two additional statements were included in the first two years of the study, one asking if the students preferred six-hour sessions as opposed to three-hour sessions (2014, $M = 1.42, SD = 0.51$), and another asking if the students would have preferred the Orientation to be one full day instead of having the sessions spread out over several days (2015, $M = 2.52, SD = 1.55$). Given the low scores of these two statements, it can be concluded that short sessions spread over many days are preferred over marathon sessions lasting one single day. This result agrees with our observations of the GTAs' moods on the full day of Orientation in the pilot semester (2013).

4.2.1.5 Usefulness

The majority of the statements in the Orientation Survey focus on the perceived usefulness of the class (Figure 4.6). This is especially true in later years, where the "Usefulness" category makes up more than 2/3 of the Orientation Survey. All but one of the questions are worded positively. The one question that is worded negatively. "The [Orientation] sessions were a waste of time," is also the lowest scored statement ($M = 1.68, SD = 0.80$), which tells us that the GTAs generally do not consider the Orientation to be a waste of time.

The three highest scored statements in this category are also the overall highest scored out of all the Orientation Survey statements:

1. "Microteaching was a valuable practical experience" ($M = 4.54, SD = 0.66$)

2. "Going through [Orientation] before the TA job begins is helpful to me" ($M = 4.49, SD = 0.75$)

3. "The ok/not-ok game was useful for clarifying GT policies" ($M = 4.40, SD = 0.67$)

From this we can see that students think very highly of Microteaching, think the Orientation is useful before starting their teaching duties, and appreciate the OK/NOT-OK game as a useful way to learn about Institute policies. The GTAs also considered the OK/NOT-OK game to be entertaining ($M = 4.28, SD = 0.78$).

Short videos of past GTAs teaching their labs or recitations were first included in the Orientation in 2015. For two years, we included a statement in the Orientation Survey on whether watching those videos gave the GTAs a good idea of what to expect. The reception was lukewarm ($M = 3.48, SD = 0.99$). In later years, we have included more and varied GTA videos, but we have not asked about them again in the Orientation Survey since there is also another class session exclusively dedicated to watching GTA videos later in the semester.

First-time GTAs in general feel better prepared for teaching after going through the Orientation ($M = 4.31, SD = 0.65$), and agree that their worries and concerns about teaching were addressed adequately ($M = 4.21, SD = 0.76$). They enjoy working on real introductory physics problems as part of their problem-solving practice ($M = 4.29, SD = 0.71$), and consider the Lab Simulation to be a valuable experience ($M = 4.15, SD = 0.80$). Finally, at the end of the Orientation, students have high expectations for the usefulness of the Follow-Up Meetings during the semester ($M = 4.06, SD = 0.85$).

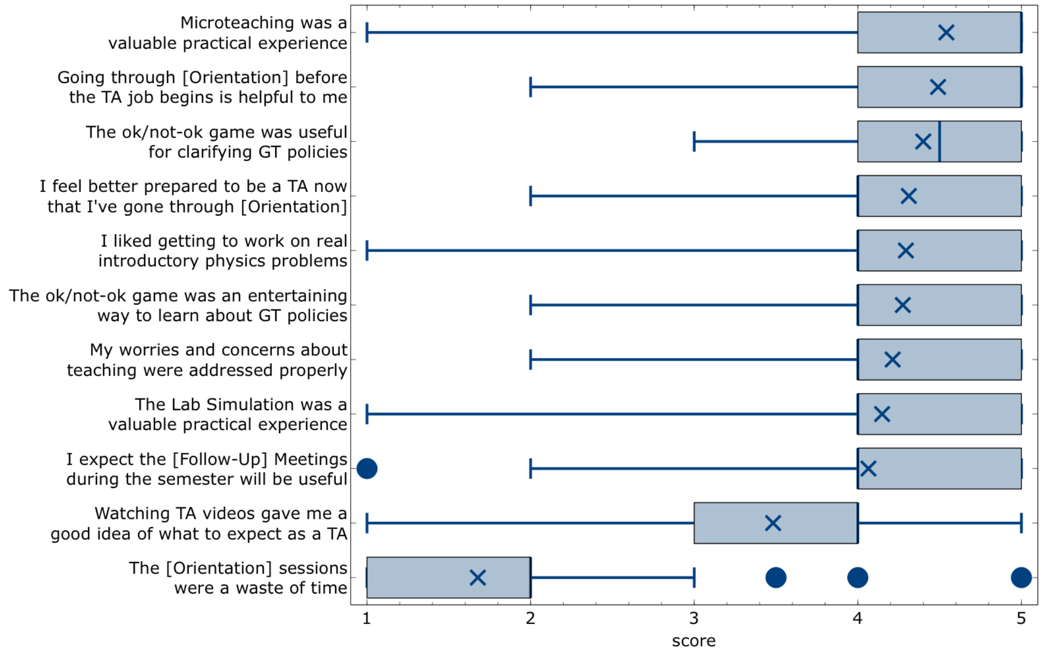


Figure 4.6: Box and whisker plots for the statements in the Orientation Survey that fall under the category "Usefulness." The vertical line within each box is the median, the cross is the mean, the whiskers denote 1.5 interquartile range (IQR), and filled circles show outliers. Ten of the statements were positively worded, and were highly scored. The one statement that was negatively worded scored accordingly low, indicating that students in general find the Orientation to be useful.

4.2.1.6 Open-Ended Comments

At the end of the Orientation Survey, the students were presented with one final question: "Do you have any additional comments?" Roughly a quarter of the responses (28 comments, 26% of all available responses) included an answer to the question. We have coded the comments into six categories (see Table 4.8 for descriptions of each category and the number of comments in each). The full list of comments can be found in Appendix F.

Overall, the open-ended comments left in the Orientation Surveys were generally positive. The largest category covered comments that mentioned how useful the Orientation was, or how the student feels better prepared after participating in the Orientation. Some comments explicitly thanked the course instructor, and a couple of comments were simply of a positive nature. Only three comments were generally negative. Two people, who had

Table 4.8: Categorization of additional comments in the Orientation Survey, and number of comments represented in each category.

Category	Count	Description
Usefulness / feeling better prepared	9	Any comments that mentioned thinking the Orientation was useful and/or that after going through the Orientation they feel better prepared for teaching.
Suggestions / constructive criticism	8	Any comments that suggests or requests changes to the Orientation content and/or structure.
Gratefulness	4	Comments that thank the instructor and/or indicate appreciation for the effort made by the instructor.
Generally negative	3	Any comments that are generally negative in nature.
Generally positive	2	Any comments that are generally positive in nature.
People with extensive prior teaching experience	2	Comments in which specific suggestions are given regarding participants who have extensive prior teaching experience.

extensive prior teaching experience, suggested that there should be a shorter, alternative Orientation for people like them.

The second-largest category, with eight comments, was "Suggestions / constructive criticism." We will address each of those comments here.

> "I would have appreciated more guidance in microteaching. The open-ended nature made the task more difficult."

The above comment appeared in the 2014 Orientation Survey. The Microteaching activity was revamped in 2015 to make it more specific and provide more guidance to the students about what is expected of them in the activity.

> "I would have liked more concrete information (The TA videos were GREAT, would have liked more), more "roleplaying" like microteaching, would be useful. FERPA was good, haven't seen it before"

This comment came in 2015. The following year, we added the Lab Simulation activity, thus adding more "roleplaying" to the Orientation. Additionally, we created the Physics GTA Resources website (Section 1.7.1) to include many more details about each GTA assignment.

> "Maybe LabSim could be combined with microteaching to take less time - split the class, we can still learn from experience"

This is not something that we will be doing. We consider it important for all GTAs to participate in both Microteaching and in the Lab Simulation. Microteaching helps the GTAs understand the difference between lecturing and coaching/facilitating, which is useful in all GTA contexts. The Lab Simulation helps GTAs realize that they need to have spatial awareness and be mindful of all the students in the room. While this is definitely more useful in a lab setting, it is also convenient in a recitation, particularly once the students are working in groups.

> "Maybe more videos/examples of lab/teaching scenarios"

More videos and examples have been added, particularly to the Classroom Management module.

> "Lab simulation may/should be longer than 10 minutes"

Due to time constraints, we cannot acommodate this request. We agree that it would be better if each participant's turn during the simulation lasted more than 10 minutes, but scheduling logistics prevent us from doing that.

> "All of the activities were USEFUL, but they were not time-efficient and took longer than they could have."

We have tried to make all the activities as time-efficient as possible, and would have appreciated more details in this suggestion.

> "Would have preferred to be better prepared for LabSim than the "students" to better simulate the environment"

The Lab Simulation materials are distributed through the course Canvas site (T-Square for 2017 and earlier). Therefore, the participants in the "TA Role" should indeed be better prepared than the participants in the "Student" role, and they have always had the opportunity to do so.

> "I wish we could receive our assignment faster so that we can prepare"

To clarify, what this person meant by "our assignment" is their teaching assignments, i.e., what exactly they will be teaching (M&I Lab, Traditional Lab, Recitation, IPLS, or something else). This is something that is not under our control, although we have repeatedly requested earlier determinations of GTA assignments from the relevant parties (sometimes it even works and we get the first-time GTAs' assignments a week before Orientation... but other times it does not and we do not receive the information until well into the Orientation period, sometimes even later).

4.2.2 Final Survey

First-time GTAs in 2014 were asked at the end of the semester to make a list of their top three most interesting and useful course topics. Microteaching and Midterm Evaluations topped the list, followed by Classroom Management, and then Teaching Videos. Some GTAs made comments indicating that what they considered the "most interesting" was not necessarily the "most useful" for them, and vice versa. In order to get more detailed information, including separating "interesting" and "useful," from 2015 onward GTAs were asked to complete a Final Survey instead. This survey consists of two five-point Likert-type questions, six open-ended questions (seven in 2015), and space for additional comments. A sample Final Survey (the most recent, from 2019) can be found in Appendix G. Although the responses to the open-ended questions were used in the yearly process of revising the curriculum, a detailed analysis of these responses is not included in this dissertation.

Table 4.9: Topics and activities mentioned in Question 1 (how interesting) and Question 2 (how useful) of the Final Survey, the years in which they were included, and the number of available responses for each question.

Code	Item	Years	N Q1	N Q2
	Orientation			
O1	Intro & Georgia Tech Policies	2015-2018	94	94
O2	Teaching Physics	2015-2018	93	94
O3	Classroom Management	2015-2018	93	94
O4	Lab Simulation	2016-2018	60	61
O5	Microteaching	2015-2018	93	94
	Follow-Up Meetings			
F1	Grading	2015-2018	92	94
F2	How's it going?	2015	34	34
F3	Midterm Evaluations	2015-2018	94	93
F4	Time Management	2017-2018	39	39
F5	Teaching Videos	2015-2018	94	94
F6	Teaching & Research	2015-2018	93	93
F7	Concluding Remarks	2015-2018	93	92
	Activities			
A1	Individual Classroom Observations	2015-2018	93	93
A2	Workload Surveys	2015-2018	95	92
A3	Peer Classroom Observations	2015	33	33
A4	Experienced TA Observations	2016	22	22
A5	GAP Mentoring Meetings	2017-2018	37	38

The two Likert-type questions ask the GTAs to rate how interesting (Question 1) and how useful (Question 2) they found each of the class meetings and activities, on a scale of 1 (not interesting/not useful) to 5 (highly interesting/highly useful). Table 4.9 lists the items GTAs were asked to rate in the two questions, the years in which they appeared in the Final Survey, and the number of available responses for each item and question. It should be noted that "Time Management" is only explicitly asked about in 2017 and 2018; in previous years, this topic was absorbed into other class meetings and therefore not asked about as a separate entity.

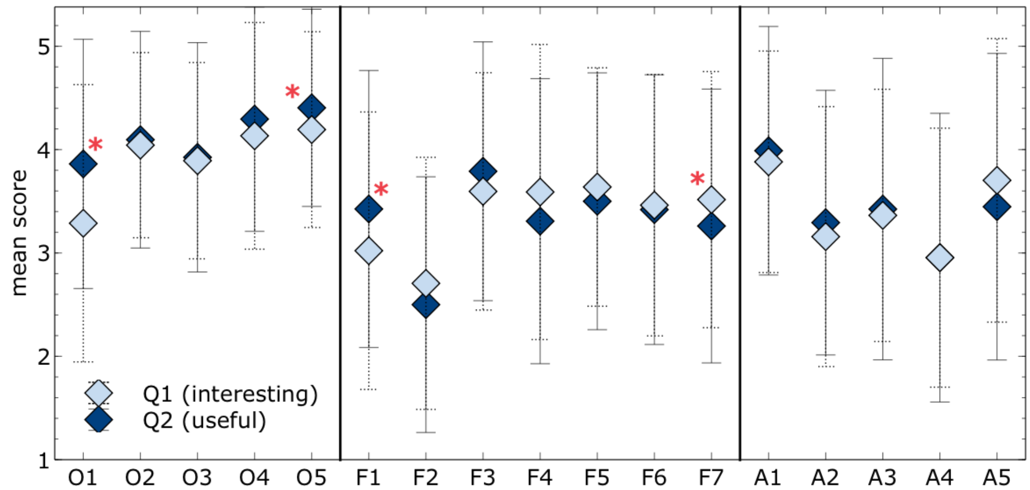


Figure 4.7: Visualization of mean scores (and standard deviations) for Question 1 (how interesting) and Question 2 (how useful) in the Final Survey. See Table 4.9 for an explanation of what each code represents. Asterisks indicate items for which there is a statistically significant difference between the “Interesting” “Useful” distributions, as determined by a paired-samples Wilcoxon test.

A visual inspection (Figure 4.7) of the mean scores for each item shows very little difference between the overall “Interesting” responses (Question 1) and the overall “Useful” responses (Question 2). Looking at the distributions of responses for each item (Figures 4.8, 4.9, and 4.10) yields the same impression. Since the data are not normally distributed, we performed a paired-samples Wilcoxon test to determine whether there was a statistically significant difference between the distributions for each item in Question 1 (Interesting) versus Question 2 (Useful). The results of this test (Table 4.10) showed no statistically significant difference between Question 1 and Question 2 for all items except:

- O1: Intro & GT Policies ($V = 173, p < 0.001$; more useful than interesting)
- O5: Microteaching ($V = 192.5, p = 0.020$; more useful than interesting)
- F1: Grading ($V = 264, p < 0.001$; more useful than interesting)
- F7: Concluding Remarks ($V = 341.5, p = 0.005$; more interesting than useful)

Table 4.10: Paired-samples Wilcoxon test (V is the test statistic, p is the p-value) to compare the distributions for Question 1 ("interesting") and Question 2 ("useful") in the Final Survey. Only items O1, O5, F1, and F7 revealed statistically significant differences between the two questions.

Item Code	V	p
O1	173	< 0.001
O2	253	0.610
O3	324.5	0.891
O4	54.5	0.168
O5	192.5	0.020
F1	264	< 0.001
F2	117	0.358
F3	283.5	0.074
F4	153	0.052
F5	463	0.073
F6	368	0.355
F7	341.5	0.005
A1	283	0.176
A2	312	0.176
A3	25	0.832
A4	10.5	1.000
A5	52.5	0.077

Furthermore, by looking at the overall means we can determine the top-three most interesting and top-three most useful course topics:

1. Microteaching (interesting: $M = 4.19, SD = 0.95$; useful: $M = 4.40, SD = 0.95$)
2. Lab Simulation (interesting: $M = 4.13, SD = 1.10$; useful: $M = 4.30, SD = 1.09$)
3. Teaching Physics (interesting: $M = 4.04, SD = 0.90$; useful: $M = 4.10, SD = 1.05$).

It should be noted that Microteaching being considered the most useful course topic is something that other researchers have found in their own work with first-time GTAs [204].

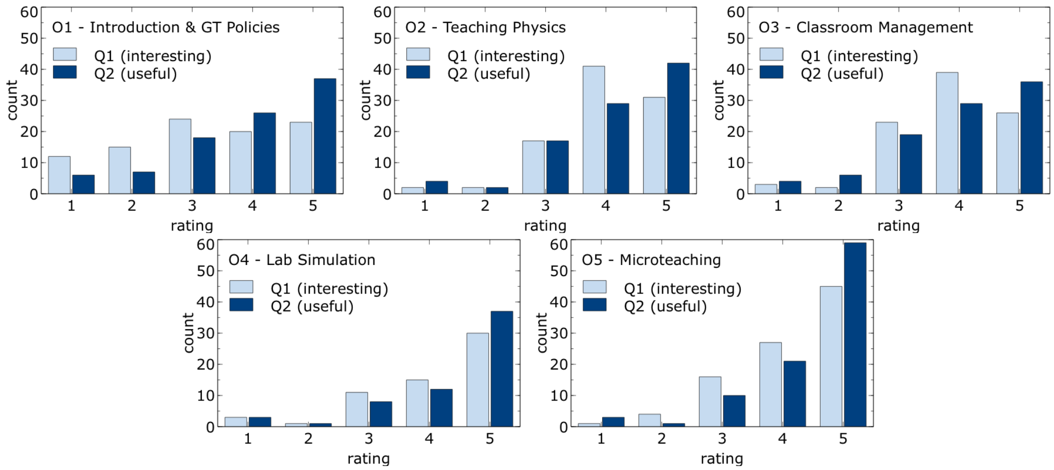


Figure 4.8: Distributions of responses to Question 1 (how interesting, light blue) and Question 2 (how useful, dark blue) in the Final Survey, for items in the category "Orientation." The distributions for "Interesting" and "Useful" are statistically identical (paired-samples Wilcoxon test), except for "Introduction & GT Policies" and "Microteaching."

Similarly, we can find the bottom two topics by looking at the overall means. These are: "How's it going?" (interesting: $M = 2.71, SD = 1.22$; useful: $M = 2.50, SD = 1.24$), and "Experienced TA Observations" (interesting: $M = 2.95, SD = 1.25$; useful: $M = 2.95, SD = 1.40$). The former was not well-received because of the lack of structure of the lesson, and the latter was not well-received because of logistics issues (too many first-time GTAs observing too few experienced GTAs). As such, these two items were eliminated from the curriculum after only one year.

From this comparison analysis we can see that, in spite of comments to the contrary being expressed in 2014, GTAs generally do not distinguish between "interesting" and "useful" when it comes to class topics and activities. As such, from now on we will focus only on the results from Question 2, about the perceived usefulness of the course topics and activities. The first thing we want to do is to determine if there is a difference in perceived usefulness of course topics from one year to another. For this, we performed a Kruskal-Wallis test (Table 4.11), which revealed statistically significant differences between yearly distributions for only the following four items:

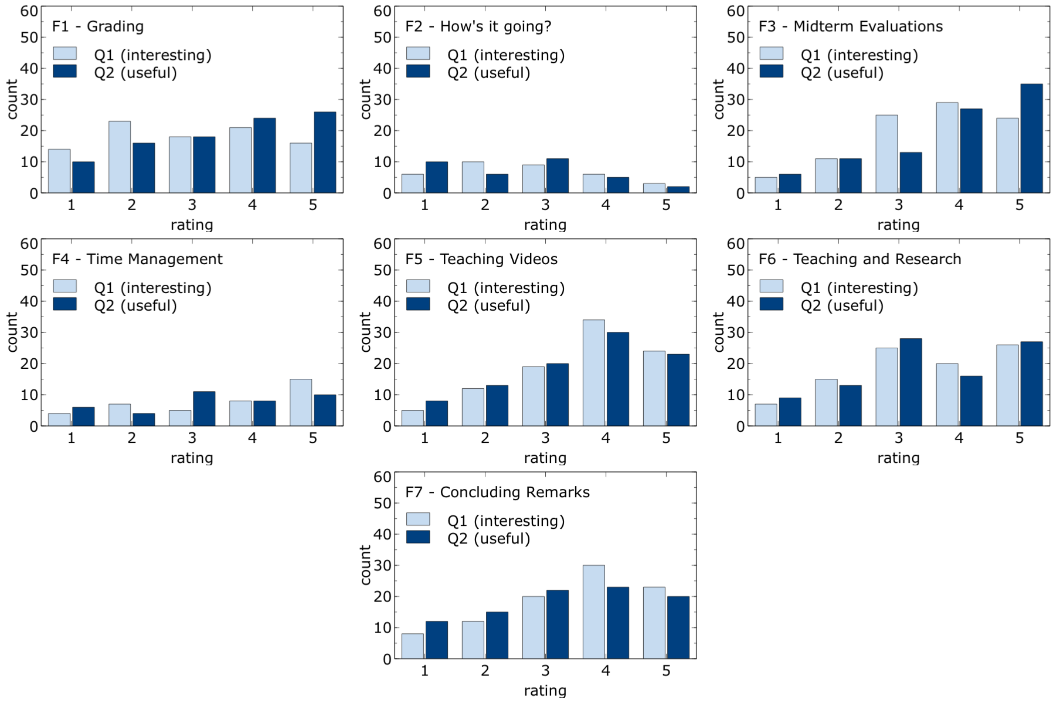


Figure 4.9: Distributions of responses to Question 1 (how interesting, light blue) and Question 2 (how useful, dark blue) in the Final Survey, for items in the category “Follow-Up Meetings.” The distributions for “Interesting” and “Useful” are statistically identical (paired-samples Wilcoxon test), except for “Grading” and “Concluding Remarks.”

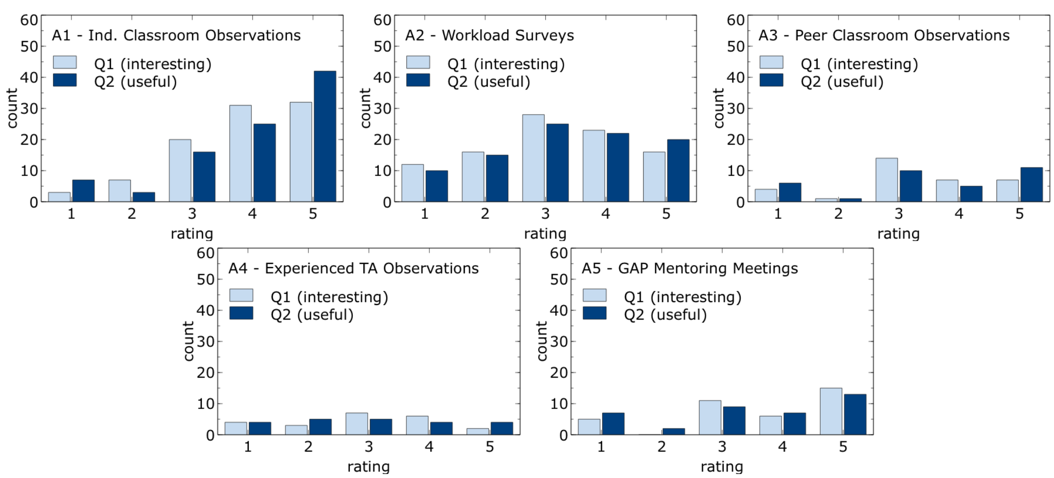


Figure 4.10: Distributions of responses to Question 1 (how interesting, light blue) and Question 2 (how useful, dark blue) in the Final Survey, for items in the category “Activities.” The distributions for “Interesting” and “Useful” are statistically identical (paired-samples Wilcoxon test).

Table 4.11: Year-to-year comparisons of responses to Question 2 ("useful") in the Final Survey, using a Kruskal-Wallis test (H is the test statistic, df is the degrees of freedom, p is the p-value). Note that items F2, A3, and A4 are not included in this analysis since they each appeared in one year only. Items O2, O3, F6, and F7 showed statistically significant results.

Item Code	H	df	p
O1	7.129	3	0.068
O2	8.215	3	0.042
O3	7.960	3	0.047
O4	4.656	2	0.097
O5	3.465	3	0.325
F1	6.401	3	0.094
F3	1.900	3	0.593
F4	0.987	1	0.321
F5	3.427	3	0.330
F6	9.476	3	0.024
F7	20.888	3	< 0.001
A1	1.456	3	0.692
A2	6.179	3	0.103
A5	0.853	1	0.356

- O2: Teaching Physics ($H = 8.215, df = 3, p = 0.042$)
- O3: Classroom Management ($H = 7.9604, df = 3, p = 0.047$)
- F6: Teaching & Research ($H = 9.4758, df = 3, p = 0.024$)
- F7: Concluding Remarks ($H = 20.888, df = 3, p < 0.001$)

We performed post-hoc pairwise comparisons for each of the four items that had a statistically significant Kruskal-Wallis. Interestingly, we did not find any statistically significant pairwise differences for any items except for one – in F7 (Concluding Remarks) there was a statistically significant difference between the 2015 and 2017 groups ($p < 0.001$, adjusted with the Bonferroni correction for multiple comparisons). By plotting the yearly distributions (Figure 4.11) we can clearly see the reason for this: the 2015 distribution

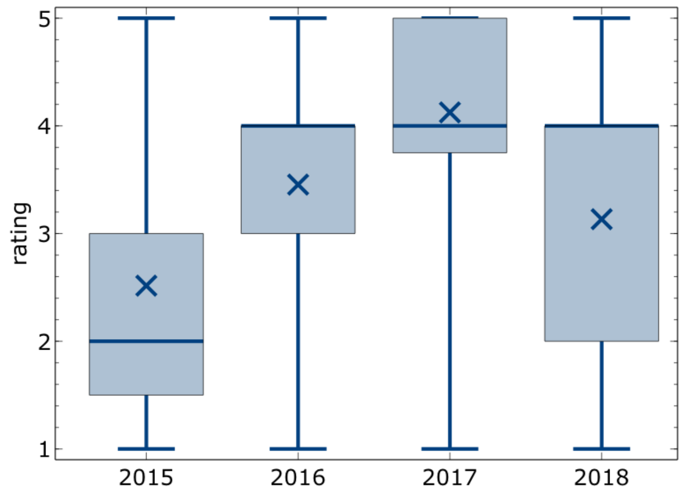


Figure 4.11: Box and whisker plots for item F7 (Concluding Remarks) in the Final Survey, showing the yearly distributions. The horizontal line within each box is the median, the cross is the mean, and the whiskers denote 1.5 interquartile range (IQR). The 2015 distribution skews lowest, while the 2017 distribution skews highest.

is more concentrated towards lower ratings, while the 2017 distribution is concentrated towards the highest ratings.

4.2.2.1 Top Three Most Useful

We know that when we look at overall mean scores, the students consider Microteaching, Lab Simulation, and Teaching Physics, to be the most useful course topics/activities. But when we look at the yearly data, the results are more nuanced. Microteaching and Teaching Physics still show up each year, but we also see Individual Classroom Observations and Intro & Georgia Tech Policies breaking into the top three. For a detailed list of top three most useful topics, please see Table 4.12. It should be noted that in 2017 the most useful topic was Intro & Georgia Tech Policies, and that was the year when we introduced the OK/NOT-OK game. Additionally, although we do not yet have statistics on the open-ended comments in the Final Survey (as we mentioned in Section 3.5), we do recall seeing several comments about how the GTAs considered the classroom observations to be useful (and man are we glad they found it useful, since for us that is THE most time-consuming

Table 4.12: Yearly top three most useful topics and activities, as determined by the GTAs participating in the course.

Rank	Item	Score ($M \pm SD$)
	2015	
1	Microteaching	4.38 ± 1.07
2	Individual Classroom Observations	3.79 ± 1.29
3	Teaching Physics	3.76 ± 1.06
	2016	
1	Microteaching	4.32 ± 0.72
2	Teaching Physics	4.23 ± 0.69
3	Individual Classroom Observations	4.09 ± 1.11
	2017	
1	Intro & Georgia Tech Policies	4.38 ± 0.82
2	Microteaching	4.35 ± 1.07
3	Teaching Physics	4.29 ± 1.20
	2018	
1	Lab Simulation	4.80 ± 0.41
2	Microteaching	4.67 ± 0.82
3	Teaching Physics	4.33 ± 1.11

aspect of teaching the class), and in earlier years when there was only one observation per semester, GTAs repeatedly requested more observations to be done.

4.2.2.2 Utility Scores

As a way to determine the perceived usefulness of the course as a whole, and whether this has changed over the years, we have devised a measure that we call *utility score*. The utility score (u) is defined as a mean of means, and has a range from 1 (low) to 5 (high). Let M_i be the mean score for an item in Question 2 of the Final Survey, and N be the total number of items. The overall utility score for the course is thus,

$$u = \frac{1}{N} \sum_i M_i \tag{4.3}$$

Table 4.13: Utility scores for the Physics GTA Preparation course: yearly, categorical, and overall. Scores are reported with mean and standard error.

	u ($M \pm SE$)	u_c ($M \pm SE$)		
Year	Yearly overall	Orientation	Follow-Up	Activities
2015	3.37 ± 0.15	3.81 ± 0.20	3.07 ± 0.20	3.40 ± 0.23
2016	3.68 ± 0.12	4.05 ± 0.11	3.41 ± 0.11	3.48 ± 0.33
2017	3.99 ± 0.09	4.28 ± 0.04	3.86 ± 0.09	3.75 ± 0.26
2018	3.80 ± 0.16	4.41 ± 0.14	3.41 ± 0.18	3.57 ± 0.30
Course overall	3.58 ± 0.12	4.12 ± 0.10	3.31 ± 0.15	3.42 ± 0.17

We can use the same formula to calculate the overall utility score for each year, by focusing on the yearly means for each item instead of the overall means. Similarly, we can calculate a category utility score (u_c) by focusing only on the means and number of items within a single category (Orientation, Follow-Up Meetings, Activities). The results of these calculations are summarized in Table 4.13 and visualized in Figure 4.12.

The overall utility score (green line, cross markers in Figure 4.12) for the course is $u = 3.58 \pm 0.12$. We can see that the yearly overall u for 2015 was below this value, but the other three years are above it, with a peak at 2017. When we focus instead on the categorical utility scores, we see that overall the Orientation (pink line, round markers) scores highest, followed by the Activities (blue line, diamond markers), and with the Follow-Up Meetings (orange line, square markers) last. This tells us that students find the Orientation to be the most useful part of the course, and its perceived usefulness increases every year. It should be noted that the Orientation comprises roughly 75% of the total contact hours for the class, so it makes sense that students would find it the most useful. This general pattern repeats every year (except 2017, when Follow-Up Meetings outranked Activities), with the Orientation always at the top. Given that the Follow-Up Meetings are generally considered the least useful part of the course, this is where we need to concentrate our efforts in improving the curriculum. It should be noted though that for 2015 and 2016 we

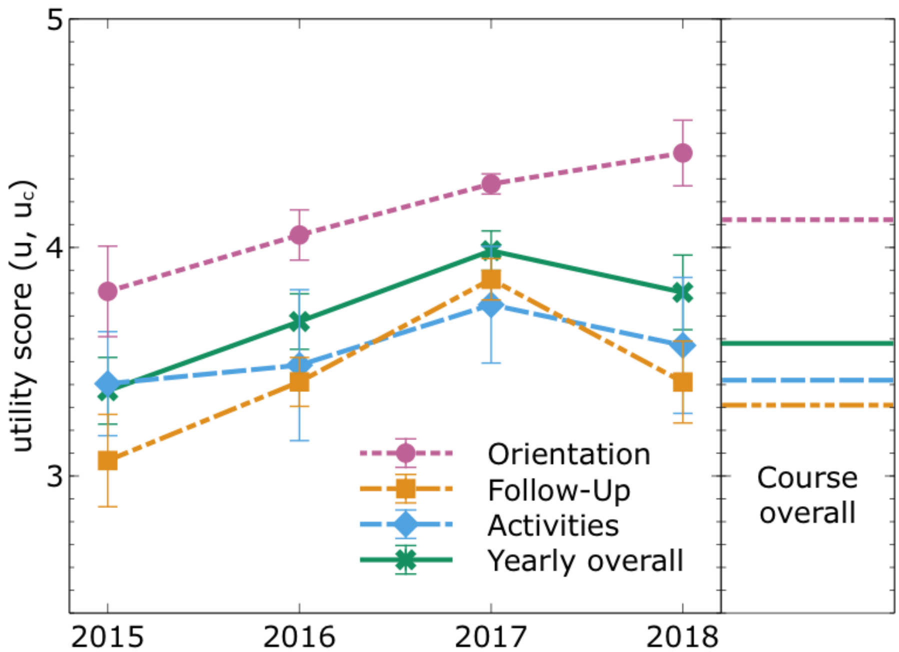


Figure 4.12: Visualization of utility scores for the Physics GTA Preparation course. Left panel: yearly overall and yearly categorical utility scores. Right panel: course overall and overall categorical utility scores.

have two items in the Follow-Up Meetings that were rated the least useful, and as such this could be dragging down the utility score averages for that category in those particular years. It will be interesting to see where the 2019 course (which is currently ongoing) will fall in this diagram.

4.3 Pre/post Tests

Two pre/post assessments were used to determine the change in GTA attitudes and knowledge about teaching. Each assessment was administered before the first class meeting of the Orientation, and at the conclusion of the final Follow-Up class meeting.

4.3.1 Approaches to Teaching Inventory (ATI)

The Approaches to Teaching Inventory (ATI) is a research-validated instrument [276, 277] that consists of 16 five-point Likert scale items that measure how teacher-centered or learner-centered is an instructor's approach to teaching. Appendix H reproduces the instrument, as it is given to the class participants.

Eight of the items in the ATI measure "Information Transmission / Teacher-Focused" (ITTF) approaches to teaching, and the other eight items measure "Conceptual Change / Student-Focused" (CCSF) approaches. We refer to these as *teacher-centered* and *learner-centered*, respectively. An example of a teacher-centered item is statement number 4:

> I feel it is important to present a lot of facts to students so that they know what they have to learn for this subject.

And an example of a learner-centered item is statement number 8:

> I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.

GTAs are asked to answer the ATI from their perspective as lab and recitation instructors for Introductory Physics classes. Each statement has a rating from 1 ("only rarely") to 5 ("almost always"), and GTAs were asked to circle one number per statement – although some of them left some statements blank, or wrote in an intermediate value (e.g., 3.5). Although it has been suggested that multiple imputation methods could be better than complete case analysis when there are missing data [278], in our ATI analysis we have decided to compare only matched pre/post pairs that included responses to every item (i.e., complete case analysis), giving us a total sample size of $N = 80$ responses from GTAs who signed informed consent between 2014 and 2018. For each GTA, we calculated the mean score for the teacher-centered items and the mean score for the learner-centered items, in the pre-test and then again in the post-test. Figure 4.13 shows the ATI pre/post data, for teacher-centered items (top, orange) and for learner-centered items (bottom, blue).

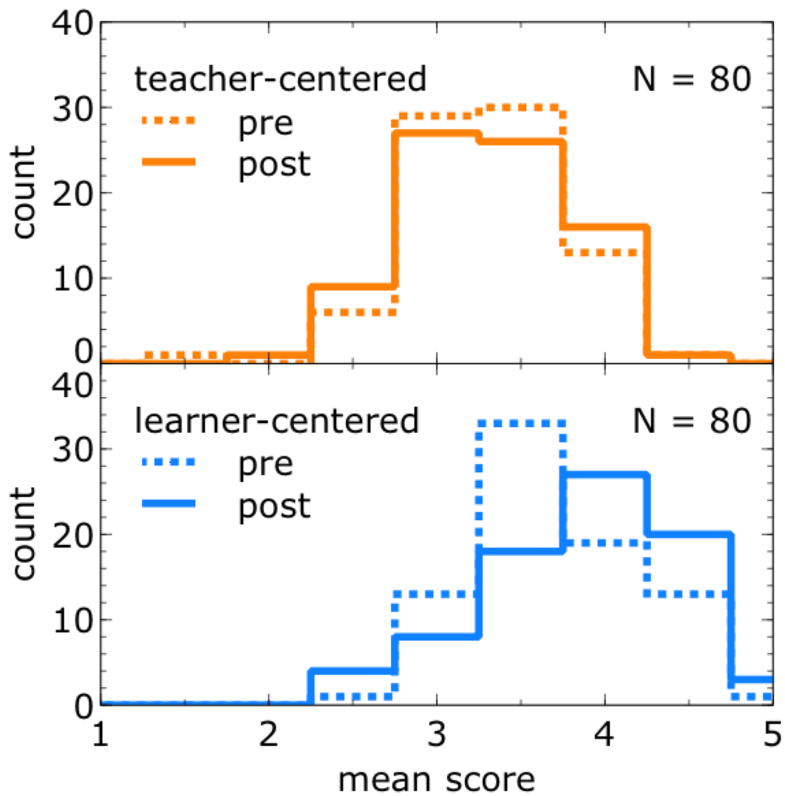


Figure 4.13: First-time GTAs' approaches to teaching are more learner-centered after one semester of GTA preparation and teaching experience. Top panel: histogram of pre (dotted) and post (solid) teacher-centered mean scores. Bottom panel: histogram of pre (dotted) and post (solid) learner-centered mean scores.

Preliminary results using only data from 2014 to 2016 indicated no difference in the pre/post distributions for teacher-centered items, and a statistical difference in the pre/post distributions for learner-centered items [279]. The current analysis, which includes data from 2014 to 2018, agrees with the preliminaries. We performed a Kolmogorov-Smirnov test to compare the pre/post distributions for teacher-centered and learner-centered items. We found no statistical difference between the pre/post distributions for teacher-centered items ($D = 0.150, p = 0.304$), but we did find a statistical difference between the pre/post distributions for learner-centered items ($D = 0.213, p = 0.046$), which is unsurprising given the visualization of the data (Figure 4.13). A paired-samples t-test comparing the pre/post grand means yielded similar results: no statistical difference between the teacher-centered pre/post means ($t = -1.256, p = 0.213$; pre-test: $M = 3.16, SD = 0.46$; post-test: $M = 3.10, SD = 0.50$), but a statistically significant difference between the learner-centered pre/post means ($t = 2.125, p = 0.037$; pre-test: $M = 3.54, SD = 0.49$; post-test: $M = 3.68, SD = 0.59$). We then calculated the effect size for the statistically significant pre/post difference in learner-centered scores using Cohen's d. The resulting effect size for the learner-centered difference was small ($d = 0.254$), although we do measure that the post-test mean is larger than the pre-test mean. All of this tells us that after one semester of GTA preparation, GTAs' teacher-centered approaches to teaching do not appear to change, but there is an increase in their learner-centered approaches. Our results agree with previous studies that have used the ATI. For example, Gibbs and Coffey [184] found an increase in learner-centered teaching approaches in instructors who participated in teacher preparation concurrently with their teaching practice, but no change in a control group that did not participate in teacher preparation while teaching. On the other hand, Gibbs and Coffey also found a decrease in teacher-centered approaches in their treatment group, whereas we found no such change (or rather, we found no significant change).

4.3.2 Knowledge Quiz

In order to gauge how much pedagogical and practical knowledge the students gained after one semester of GTA preparation, we devised a pre/post assessment that we call *Knowledge Quiz*[1]. The Knowledge Quiz is a multiple choice test given at the start and again at the end of the GTA preparation course. Appendix I shows a sample Knowledge Quiz (the most recent, from 2019), with the correct answers highlighted in yellow. We have a bank of 35 total questions that assess five categories of teaching knowledge (Administrative, Pedagogical Content Knowledge, General Pedagogy, Professional Development, and Teaching Practice). All the questions, answer options, correct answers, categories, and years in which the questions were included in the survey can be found in Appendix J. Table 4.14 lists the

[1] In the reproduced class materials in the Appendices, the Knowledge Quiz is referred to as "Knowledge Survey." We have changed the name in this discussion to make its purpose more clear.

Table 4.14: Categorization of questions in the Knowledge Quiz. For details of the questions please see Appendix J.

		Number of questions per year				
Category	Question Codes	2014	2015	2016	2017	2018
Administrative	K28(a/b), K29(a/b), K32, K33, K34, K35	6	6	6	4	4
Pedagogical Content Knowledge	K9(a/b), K15	2	2	2	2	2
General Pedagogy	K1, K2, K3, K5, K6, K8, K13, K17(a/b), K18, K19, K20, K21, K22	10	9	9	7	7
Professional Development	K7(a/b), K11(a/b), K14, K30(a/b), K31(a/b)	3	5	5	4	4
Teaching Practice	K4, K10, K12, K16(a/b), K23, K24, K25, K26, K27	9	8	8	5	5
Totals	35	30	30	30	22	22

questions in each category and how many of them appeared in the Knowledge Quiz on different years. Note that the 2014-2016 tests had 30 questions, while the 2017-2018 tests had only 22 questions. Some questions were eliminated and others were added as the content of the class evolved. The number of questions was later reduced to decrease the time for the students to take the test, and in consideration of non-native English speakers who expressed concern at the length of the test. Additionally, some questions underwent slight rewording to make them clearer.

Each question in the Knowledge Quiz has five answer options and only one correct answer, with two exceptions:

- Question K4 ("As a TA, I have the authority to introduce some learner-centered teaching approaches into my teaching assignment.”). The answer options for this question are Likert-type, from strongly agree to strongly disagree. This question appeared in every version of the test.

- Question K7a (“What are your primary professional roles, now that you’re a graduate student at Georgia Tech? Select all that apply.”) and K7b (“What do you think are your primary professional roles, now that you’re a graduate student at Georgia Tech? Select all that apply.”). There is no one correct answer for this question, as it asks about self-perception. This question was only included from 2014 to 2016.

Since question K7 was only limited to three years of data, we eliminated it from the analysis. Question K4 had data for every year of the study, so we analyzed it separately. First we eliminated any non-matched pre/post pairs (e.g., students who took the pre-test but not the post-test, or vice versa), and then we performed a Kolmogorov-Smirnov test to determine if there were any pre/post differences each separate year. We found no statistically significant differences between the pre and post distributions in any year that this question appeared in the Knowledge Quiz (Table 4.15). Putting all the years together into overall pre and post distributions also show statistically non-significant differences. If we let “Strongly Agree” be equal to 5 and “Strongly Disagree” be equal to 1, the overall post-test ($M = 4.30, SD = 0.85$) has a higher mean than the overall pre-test ($M = 4.05, SD = 0.75$), but again, this difference is not statistically significant.

After removing questions K4 and K7 from the overall analysis, we then eliminated all unmatched pairs by eliminating responses from students who had taken the pre-test but not the post-test or vice versa. We did additional data clean-up by taking care of blank responses to individual questions. We consider a blank response to be an incorrect answer. Although the instructions indicated the need to select only one answer for each question, some of the students selected two or more answers in some of the questions. We dealt with multiple answers as follows:

Table 4.15: Results of statistical analysis for question K4, using a Kolmogorov-Smirnov test (D is the test statistic, p is the p-value). No statistically significant differences were found between the pre and post distributions, for both yearly comparisons and in an overall comparison.

Year	N	D	p
2014	8	0.250	0.980
2015	29	0.207	0.572
2016	17	0.294	0.465
2017	20	0.250	0.571
2018	13	0.154	0.999
Overall	87	0.172	0.151

- If someone selected all the answers, their response is marked as incorrect, since they are simply guessing.
- If none of the answers they selected is the correct answer, the response is marked as incorrect.
- If at least one of the selected answers is right, the response is marked as correct.

We are then left with matched pairs of responses, from students who signed informed consent, giving us a total sample size of $N = 87$. Each student's response to each question is either correct or incorrect, and each person's test score is determined by their percentage of correct responses.

Although the test questions varied over the years, it is still valuable to look at the overall test results for each year, to see if there are any gains within each yearly cohort. These results are displayed in Table 4.16. On each year, the post-test mean was higher than the pre-test mean, and the difference is statistically significant for each yearly cohort. We cannot calculate overall pre-test and post-test mean scores because the tests were different every year.

Table 4.16: Results from the yearly analysis of the full Knowledge Quiz, to illustrate within-cohort pre/post differences. N is the number of students for which we have matched pre/post data. M_{pre} and M_{post} are the pre and post mean scores for each group. The test statistic and p-value from a paired-samples t-test are reported as t and p, respectively. The normalized gain, as defined in Equation 4.4 is represented by $\langle g \rangle$, and the effect size is calculated with Cohen's d, as defined in Equation 4.1. We did not calculate statistics for the course overall because the test was different every year.

Year	N	M_{pre}	M_{post}	t	p	$\langle g \rangle$	d
2014	8	56.70%	75.45%	4.406	0.003	0.43	1.595
2015	29	69.70%	80.54%	6.100	< 0.001	0.36	0.930
2016	17	69.54%	76.05%	2.861	0.011	0.21	0.556
2017	20	69.76%	85.00%	7.100	< 0.001	0.50	1.793
2018	13	76.92%	89.38%	7.115	< 0.001	0.54	1.069

We used two measures to determine what the overall improvement was between the pre-test and the post-test for each yearly cohort. The first is normalized gains, defined as:

$$\langle g \rangle = \frac{M_{\text{post}} - M_{\text{pre}}}{100 - M_{\text{pre}}} \tag{4.4}$$

where M_{pre} and M_{post} are the group's mean pre-test and post-test scores, respectively, expressed in percentages. The normalized gains for each year separately were mostly moderate. Given that $\langle g \rangle$ is biased towards higher pre-test means [280], we have also calculated a second measure to determine the overall improvement. The second measure we used was the effect size, calculated with Cohen's d, as defined in Equation 4.1. The yearly effect sizes were mostly large.

These results are promising, and they tell us that GTAs are really learning in the class. However, since the tests were different every year, we cannot make any inferences about their actual gains on specific topics. For that we need to limit our analysis to common questions across the years.

We found that there are 19 questions that repeated on every year of the study (2014-

Table 4.17: Results from the analysis of the 12 questions in the Knowledge Quiz that repeat every year without rewording. N is the number of students for which we have matched pre/post data. M_{pre} and M_{post} are the pre and post mean scores for each group. The test statistic and p-value from a paired-samples t-test are reported as t and p, respectively. The normalized gain, as defined in Equation 4.4 is represented by $\langle g \rangle$, and the effect size is calculated with Cohen's d, as defined in Equation 4.1.

Year	N	M_{pre}	M_{post}	t	p	$\langle g \rangle$	d
2014	8	63.54%	80.21%	3.742	0.007	0.46	1.536
2015	29	68.68%	76.44%	2.897	0.007	0.25	0.512
2016	17	64.71%	73.04%	2.432	0.027	0.24	0.508
2017	20	68.33%	81.67%	5.287	< 0.001	0.42	1.269
2018	13	75.00%	85.26%	2.997	0.011	0.41	0.950
Course overall	87	68.30%	78.64%	7.274	< 0.001	0.33	0.752

2018). Of these, seven had experienced a rewrite. One of the reworded questions was K28 ("ADAPTS is: / ODS is:"). This question was reworded in 2016, when the policy for accommodating students with disabilities was renamed, from ADAPTS (Accessible Disabled Assistance Program for Tech Students) to ODS (Office of Disability Services). By eliminating this question, we are left with 18 items repeating throughout all the years of the study, six of which went through a rewrite in 2017:

- Administrative: K29(a/b), K32, K35
- Pedagogical Content Knowledge: K9(a/b), K15
- General Pedagogy: K1, K2, K3, K5, K18, K19
- Professional Development: K17(a/b), K30(a/b), K31(a/b)
- Teaching Practice: K16(a/b), K23, K24, K26

The 12 questions that repeat with the exact wording are the focus of our next analyses. We did the analysis first for all 12 questions, and then again focusing only on the questions

Table 4.18: Results from the categorical analysis of the Knowledge Quiz data, focusing only on questions about General Pedagogy and Pedagogical Content Knowledge, that repeat every year without rewording (7 questions). N is the number of students for which we have matched pre/post data. M_{pre} and M_{post} are the pre and post mean scores for each group. The normalized gain, as defined in Equation 4.4 is represented by $\langle g \rangle$, and the effect size is calculated with Cohen's d, as defined in Equation 4.1.

Year	N	M_{pre}	M_{post}	t	p	$\langle g \rangle$	d
2014	8	67.86%	76.79%	1.930	0.095	0.28	0.764
2015	29	69.95%	76.35%	1.991	0.056	0.21	0.392
2016	17	59.66%	73.95%	3.011	0.008	0.35	0.737
2017	20	69.29%	78.57%	2.371	0.028	0.30	0.654
2018	13	74.73%	84.62%	2.420	0.032	0.39	0.736
Overall	87	68.31%	77.67%	5.138	< 0.001	0.30	0.587

about General Pedagogy and Pedagogical Content Knowledge that remained unchanged through the years (7 questions).

The results of the year-by-year and course overall analysis of the 12 repeating Knowledge Quiz questions can be found in Table 4.17, and the course overall pre and post distributions are visualized in the left panel of Figure 4.14. Paired-samples t-tests showed statistically significant differences between the pre-test and post-test means each year and for the course overall, with the post always being higher than the pre. The normalized gain for the course overall was $\langle g \rangle = 0.33$, which is moderate. The normalized gains for each year separately were low to moderate. We found a large effect size for the course overall ($d = 0.752$). Each individual year showed moderate to large effect sizes.

The results of our categorical analysis, focusing only on General Pedagogy and Pedagogical Content Knowledge, can be found in Table 4.18, and visualized in the right panel of Figure 4.14. The overall effect size for the pedagogy questions was moderate ($d = 0.587$). Looking at the data year-by-year, all but one of the yearly effect sizes were large, except 2015 which was moderate. It should be noted that all the post-test means were higher than the pre-test means, and a visualization of the distributions shows that the pre-distribution is

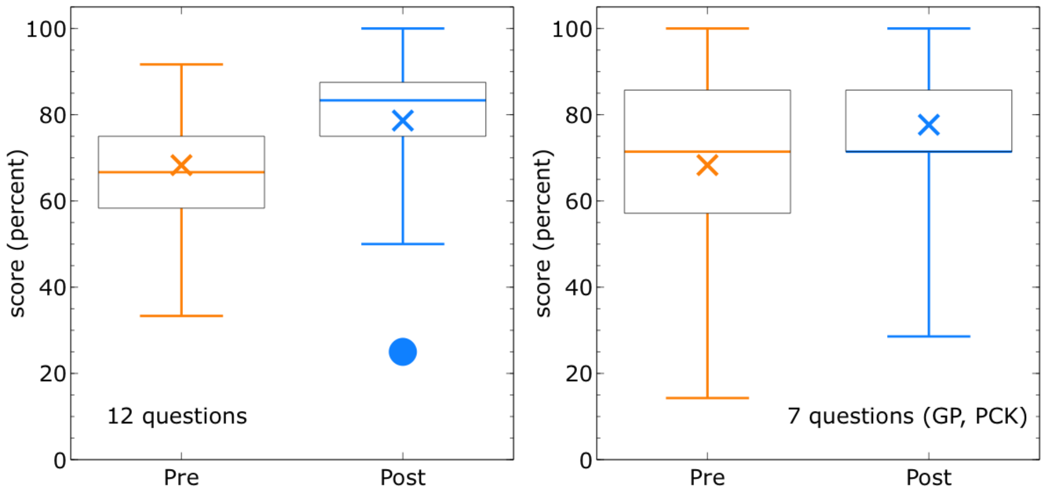


Figure 4.14: Visualization of the pre/post distributions of Knowledge Quiz answers. Left panel: pre/post responses for all 12 questions that repeat every year without rewording (Table 4.17). Right panel: pre/post responses for only the 7 questions about General Pedagogy (GP) and Pedagogical Content Knowledge (PCK) that repeat every year without rewording (Table 4.18). In each panel, the left-side box (orange) represents the distribution of pre-scores, and the right-side box (blue) represents the distribution of post-scores. The horizontal line within each box is the median, the cross is the mean, the whiskers denote 1.5 interquartile range (IQR), and filled circles show outliers. We can see that for the overall analysis (12 questions), the post-distribution is higher than the pre-distribution, and in the pedagogy analysis (7 questions), the pre-distribution is more spread out than the post-distribution.

much more spread out than the post-distribution.

4.4 Student Evaluations

If going through a GTA preparation course improves the teaching skills of physics graduate students, we would ideally like to know what impact this improvement has on student learning outcomes. However, it is very difficult to separate the GTAs' effect on students' grades from all other factors that can affect them (e.g., professor, incoming GPA, major, etc). As such, we are looking at an indirect effect, focusing on what the students think of their GTAs, with the caveat that student evaluations of teaching are subjective. Several arguments have been made in favor and in opposition of using student evaluations as assess-

Table 4.19: Items in the end-of-semester student evaluations.

Item Code	Description
T1	Oral communication skills
T2	Written communication skills
T3	Explained concepts clearly
T4	Familiarity with course concepts
T5	Respect for students
T6	Attitude about their teaching role
T7	Stimulated interest in subject
T8	Approachability
T9	Level of preparedness
T10	Classroom management
T11	Actively engaged students
T12	Overall effectiveness

ments of teaching effectiveness and student learning [e.g., 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, and many, many more]. However, it has also been claimed that students "are in a good position to observe several aspects of teaching that contribute to effectiveness, such as clarity, pace, legibility, audibility, and availability" [293], and as such, we are using end-of-semester student evaluations as an indirect measure of teaching effectiveness. Of course, we are using student evaluations as *a* metric to measure the impact of the GTA-PD course on GTAs' teaching, but certainly not the *only* metric.

The Georgia Tech Office of Academic Effectiveness conducts end-of-semester student evaluations for all instructors in the Institute. Teaching assistants are evaluated with an instrument called "Teaching Assistant Opinion Survey" (TAOS). This evaluation consists of 12 five-point Likert items and three open-ended response questions. The questions, as they appear in the Office of Academic Effectiveness website, can be found in Appendix K. For the purposes of this study, we focus only on the 12 Likert items. Table 4.19 lists each item and their code in our analysis.

To determine if the Physics GTA Preparation course has had any impact on GTA teach-

Table 4.20: Number of GTAs in each analysis group.

Group	First Fall	First Spring
Pre-intervention (no GTA prep)	51	49
Post-intervention (with GTA prep)	69	64

ing effectiveness, we look at end-of-semester student evaluation scores and do a pre/post analysis. The pre-intervention group consists of GTAs whose first teaching assignment happened in 2011 and 2012, before the GTA prep class went into effect. The post-intervention group consists of GTAs who participated in the first three years of the class, from 2013 to 2015[2]. The collected data report the interpolated median for each Likert item, for each class section (lab or recitation) taught by each GTA every semester. We calculated each GTA's mean score for each of the Likert items, for only their first Fall semester and first Spring semester of teaching, since we want to look at differences between GTAs at the same stage, when they first begin to teach. It should be noted that the distributions of student evaluation scores were concentrated towards higher ratings, suggesting that Intro Physics students at Georgia Tech are reluctant to give low ratings to their GTAs.

Between 2011 and 2012, we have student evaluation scores for $N = 51$ GTAs in their first Fall semester of teaching and $N = 49$ GTAs in their first Spring semester of teaching (the pre-intervention group). For the post-intervention group (2013-2015), we have scores for $N = 69$ GTAs in their first Fall, and $N = 64$ GTAs in their first Spring. The pre-intervention and post-intervention groups are independent of each other, as each GTA can only belong to one or the other. This is summarized in Table 4.20.

Since the groups are independent and the scores are not normally distributed, we performed a Mann-Whitney test to determine if there were any pre/post differences for each item in the first Fall semester of teaching, and again in the first Spring semester of teach-

[2]We currently do not have access to the 2016-2018 data, but are in the process of acquiring them and we will be analyzing them as part of future work.

Table 4.21: Results from the analysis of end-of-semester student evaluation data, for first Fall and first Spring semesters of teaching. “No Prep” is the group of GTAs who had their first teaching assignment before the GTA preparation class came into existence (2011-2012, $N = 51$ in Fall, $N = 49$ in Spring). “GTA Prep” is the group of graduate students who participated in the Physics GTA Preparation class concurrently with their first teaching assignment (2013-2015, $N = 69$ in Fall, $N = 64$ in Spring). Mean student evaluation scores and standard errors ($M \pm SE$) are given for each group (No Prep, GTA Prep) for each item. We performed a Mann-Whitney test to compare the No Prep and GTA Prep distributions for each item. U statistic and p-value are given in the table for each comparison. All items have statistically significant differences between the No Prep group and the GTA Prep group, except T5 (Respect for students), T6 (Attitude about their teaching role), and T10 (Classroom management) for first Fall of teaching. Effect sizes, calculated with Cohen's d, are moderate for all items.

	First Fall					First Spring				
Item	No Prep	GTA Prep	U	p	d	No Prep	GTA Prep	U	p	d
T1	3.91±0.10	4.18±0.08	1351	0.030	0.411	4.06±0.09	4.30±0.07	1186.5	0.027	0.392
T2	4.16±0.07	4.39±0.05	1291	0.013	0.467	4.21±0.06	4.48±0.05	890	< 0.001	0.653
T3	4.05±0.09	4.31±0.06	1330	0.022	0.459	4.14±0.08	4.45±0.06	939.5	< 0.001	0.604
T4	4.48± 0.06	4.72±0.03	1212	0.003	0.615	4.58±0.04	4.74±0.03	977	< 0.001	0.573
T5	4.53±0.06	4.67±0.04	1398	0.053	0.386	4.49±0.05	4.70±0.04	895	< 0.001	0.574
T6	4.32±0.06	4.47±0.05	1394	0.051	0.367	4.24±0.07	4.48±0.06	995.5	0.001	0.489
T7	3.75±0.09	4.02±0.07	1312.5	0.017	0.473	3.78±0.08	4.10±0.07	1015	0.002	0.579
T8	4.34±0.08	4.56±0.05	1299	0.014	0.454	4.41±0.07	4.58±0.06	1125	0.010	0.372
T9	4.35±0.08	4.57±0.04	1345	0.027	0.484	4.46±0.06	4.66±0.04	999.5	0.001	0.567
T10	4.32±0.08	4.49±0.05	1453.5	0.103	0.354	4.39±0.06	4.60±0.05	996.5	0.001	0.510
T11	4.24±0.07	4.42±0.05	1345.5	0.027	0.394	4.25±0.08	4.46±0.06	1105	0.007	0.400
T12	4.27±0.07	4.48±0.05	1349	0.029	0.434	4.29±0.08	4.54±0.07	973	0.001	0.460

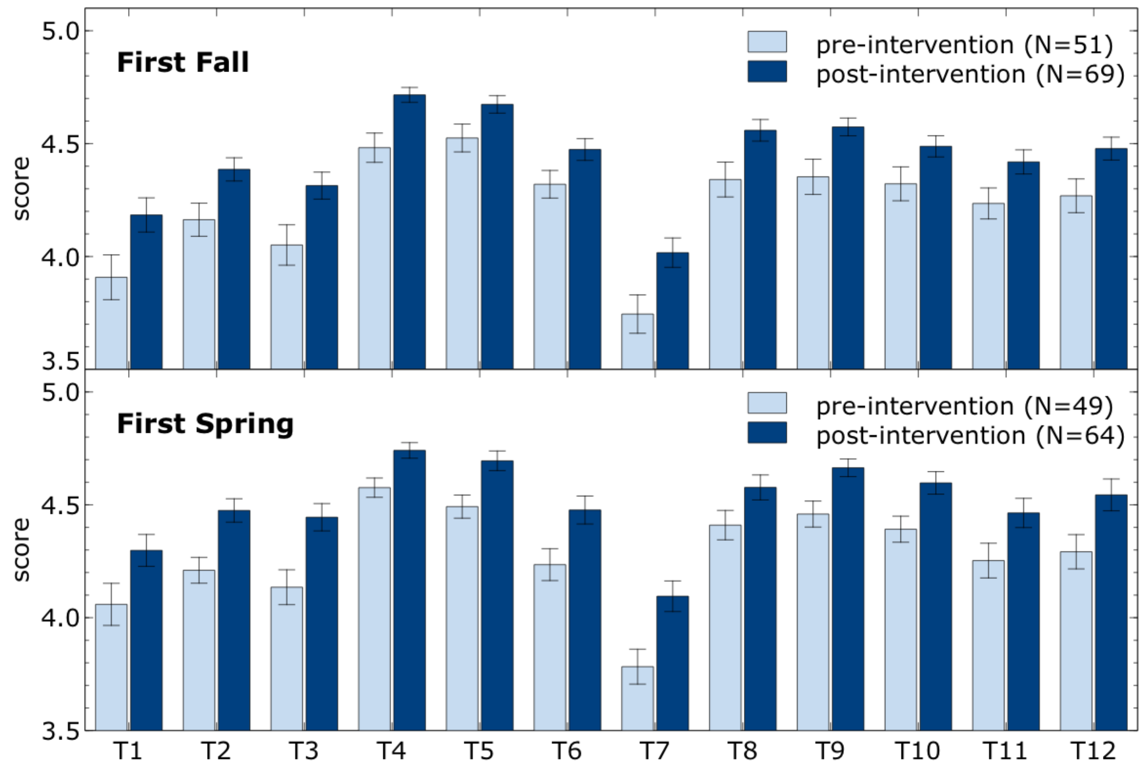


Figure 4.15: Visualization of the results from the analysis of end-of-semester student evaluations (data from Table 4.21. Top panel shows the results for the first Fall semester of teaching; bottom panel shows the results for the first Spring semester of teaching. Light blue bars represent the group of GTAs whose first teaching assignments happened before the GTA preparation class went into effect (2011-2012); dark blue bars represent the group of GTAs who participated in the GTA preparation class (2013-2015). The length of the bars represents the mean for each item, and error bars represent the standard error. Grad students who participated in the GTA preparation class consistently score higher in the student evaluations than grad students who did not have a formal GTA preparation course.

ing. The full results of the analysis can be found in Table 4.21, and are visualized in Figure 4.15. We found that the post-intervention group consistently scored higher than the pre-intervention group, with statistically significant differences for all items except T5 (Respect for students), T6 (Attitude about their teaching role), and T10 (Classroom management) in the first Fall semester of teaching. In the first Spring semester all items show statistically significant differences.

We additionally calculated the effect size for each pre/post comparison using Cohen's d, and found moderate effect sizes for all items. It should also be noted that for the majority

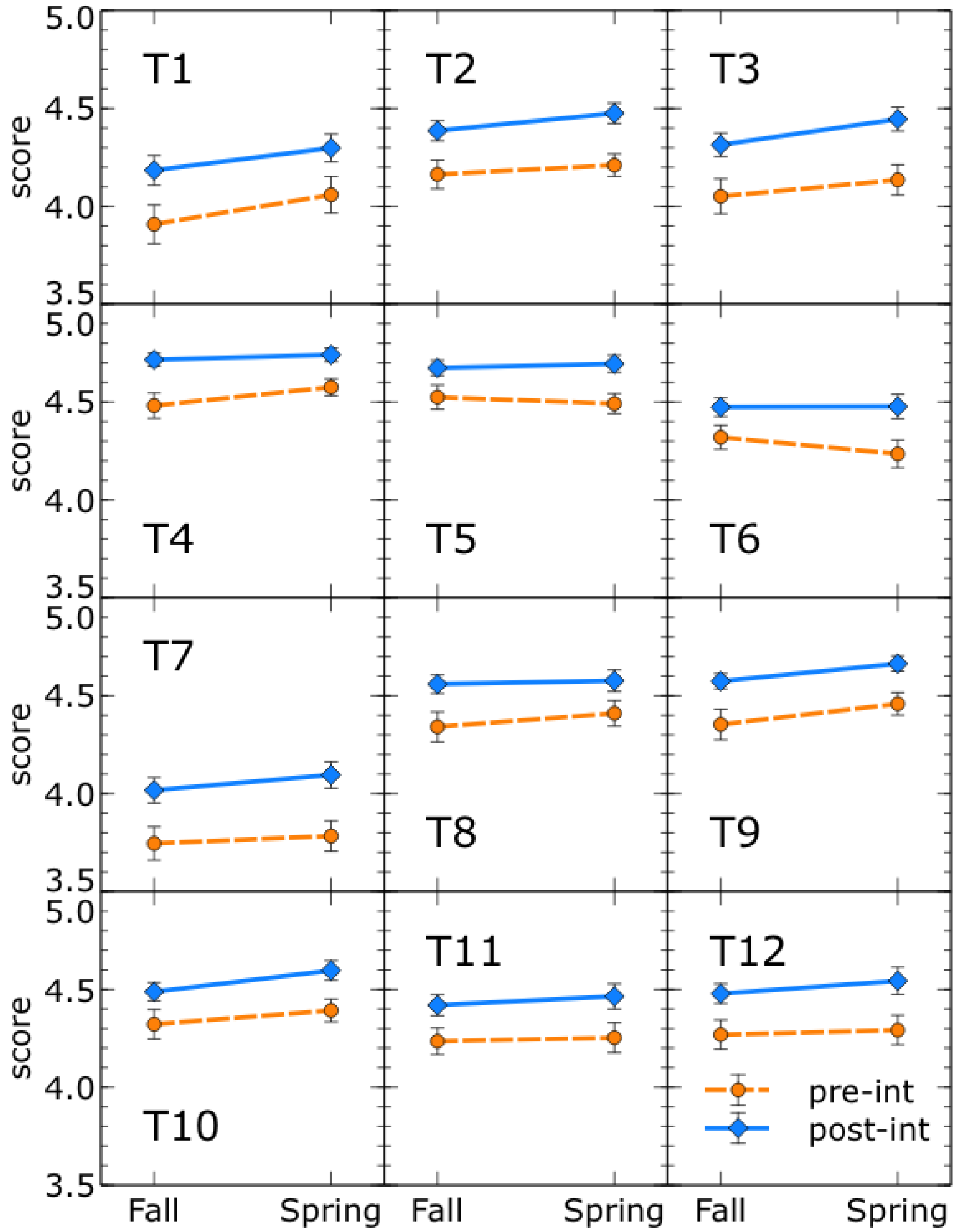


Figure 4.16: Comparison of Fall and Spring student evaluation scores for the pre-intervention and post-intervention groups. Each panel represents one Likert item in the end-of-semester student evaluations. Dashed lines (orange, round markers) represent the pre-intervention group (2011-2012, before the GTA preparation class went into effect). Solid lines (blue, diamond markers) represent the post-intervention group (2013-2015, who participated in the GTA preparation class). The post-intervention group scores consistently higher than the pre-intervention group. Scores are generally higher in the first Spring of teaching than in the first Fall of teaching, except for items T5 (Respect for students) and T6 (Attitude about their teaching role) for the pre-intervention group.

of the items, for both the pre-intervention and post-intervention groups, the mean scores in the first Spring semester are higher than in the first Fall semester. This makes sense, since by the first Spring each new GTA has already had one semester of teaching experience under their belt and would presumably do a better job as they hone their teaching skills.

Figure 4.16 shows a visual comparison of the Fall/Spring difference for each item. The dashed orange line represents the pre-intervention group and the solid blue line represents the post-intervention group. The post-intervention group scores were always higher than the pre-intervention group, which is consistent with the previously stated results. Scores are also generally higher in the Spring than in the Fall, except for items T5 (Respect for students) and T6 (Attitude about their teaching role) for the pre-intervention group. We can see here (and it is also noticeable in Figure 4.15) for which items the GTAs are more highly ranked and which items they are most lowly ranked by the students. Items T4 (Familiarity with course concepts), T5 (Respect for students), T8 (Approachability), and T9 (Level of preparedness) tend to be highly ranked. Based on these student rankings, we can conclude that GTAs are perceived to be familiar with the concepts and well-prepared for teaching, and they are also approachable and respectful of their students. On the other hand, item T7 (Stimulated interest in subject) is very clearly the lowest-ranked item. This means the GTAs in general do not spark much interest in physics in their students. How to improve this requires more thinking. We do wonder what undergrads tend to rank their physics professors (who teach the lectures) on the equivalent item in the end-of-semester evaluations for faculty ("Instructor's ability to stimulate my interest in the subject matter"[3]). If there is a marked difference between professor and GTA scores, with professors scoring higher than the GTAs, then it would be clear that we need to figure out ways for GTAs to better inspire their students. If the professors score *lower* than the GTAs... then that would be an issue *quite* outside of the scope of this dissertation. And if GTAs and professors score roughly the same, we could invoke several possible causes such as physics not being

[3]`https://academiceffectiveness.gatech.edu/surveys/cios/corequestions`

all that interesting in general (lies! blasphemy!), or maybe that our undergrads do not enjoy physics for one reason or another. But that, also, is outside the scope of this dissertation.

4.5 Discussion

By surveying the incoming first-year graduate students we learned about the initial conditions of first-time GTAs in the School of Physics. The majority of first-time GTAs have no prior TA experience, but a sizeable proportion have experience with one-on-one tutoring. In spite of their lack of teaching experience, a vast majority of the first-time GTAs consider teaching to be an important part of their professional development as physicists, which bodes well for their motivation do to a good job as GTAs.

First-time GTAs have several concerns about teaching. Primarily they are worried about their own mastery of physics – whether they understand physics well enough to teach it, or whether they remember enough basic physics. GTAs are also concerned with balancing their teaching workload along with their own coursework and other responsibilities. Given the large fraction of first-time GTAs who are non-native English speakers, it is unsurprising that another major concern revolves around issues of language, culture and communication.

When they first start grad school, most GTAs are thinking about future careers in academia, though careers in industry, data science, and government are also appealing to them. Only about 20% of first-year grad students are undecided about what to do after grad school.

Before participating in any kind of GTA preparation, first-time GTAs feel only somewhat prepared for teaching. After the Orientation, GTAs feel significantly better prepared to teach. This tells us that the Orientation is successful at increasing their self-efficacy.

We measured how satisfied GTAs are with the GTA-PD course with two surveys, one at the end of the Orientation and one at the end of the semester. The Orientation Survey included statements about Class Activities, Guests, Materials, Timing, and Usefulness. The results were very positive overall. GTAs agreed that Microteaching was a valuable practical experience and that going through the Orientation was helpful to them. The majority of the open-ended comments received for this survey expressed that GTAs felt better prepared for teaching after going through the Orientation.

The Final Survey, which happens at the end of the semester, included two quantitative questions in which GTAs were asked to rate how interesting and how useful they found the course topics. We found that for the most part, GTAs do not distinguish between "interesting" and "useful," so we focused our analysis on the question about usefulness. The overall top-three most useful course topics and activities were Microteaching, Lab Simulation, and Teaching Physics. It should be noted that the first two are practical activities in which the GTAs get to "perform" as teachers for the first time and receive useful feedback for reflection and improvement, and the third focuses on the pedagogical content knowledge needed for teaching physics. From the GTAs' usefulness ratings we calculated Utility Scores, which are defined as means of means. We calculated the Utility Score that each yearly cohort gave to the course, and the course overall Utility Score including all the study participants. Additionally, we calculated Utility Scores for each section of the course: Orientation, Follow-Up Meetings, and Activities. We found that the Orientation was consistently rated as the most useful part of the course, and its reported usefulness increased every year. The Follow-Up Meetings rate the lowest Utility Scores, which tells us that we need to work on improving the content of these meetings to make them more useful to the GTAs.

We measured the effect of the course on GTAs' attitudes and knowledge via two pre/post tests. The Approaches to Teaching Inventory (ATI) was used to determine the extent to which GTAs' teaching approaches are teacher-centered or learner-centered. We found that the level of teacher-centered teaching did not significantly change after the course, but the GTAs' learner-centered approaches significantly increased in the post-test.

The Knowledge Quiz, a multiple-choice assessment, was used to determine the improvement in GTAs' pedagogical knowledge. We found that within each yearly cohort, the post-test class average was always higher than the pre-test class average. In order to make full course comparisons, we re-did the analysis focusing only on the test questions that had been repeated every year with the exact same wording. We found statistically significant increases in the post-test mean compared to the pre-test mean, with low-to-moderate normalized gains and moderate-to-high effect sizes. A third analysis focused only on questions about pedagogical knowledge. For these, the post-test class average was always higher than the pre-test class average but the difference was not statistically significant for every year. Normalized gains were still low-to-moderate and effect sizes were still moderate-to-high.

We used end-of-semester student evaluations to indirectly determine the effect of the GTA prep program on GTAs' teaching effectiveness. To do this, we compared student evaluation data for the first Fall semester and first Spring semester of teaching for graduate students that predated the GTA prep class and graduate students who participated in the first three years of the GTA prep class. The results revealed that GTAs who participated in the prep class were rated consistently higher than GTAs who predated the course. We also found that the first Spring semester scores tended to be higher than the first Fall semester scores, which makes sense because by the Spring semester new GTAs already have one semester of teaching practice under their belt. From student evaluations we can conclude that GTAs are perceived to be well-prepared for teaching and familiar with the course concepts, approachable and respectful of their students, but unfortunately do not much stimulate their students' interest in physics.

CHAPTER 5
CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

In this work, we set out to create a physics GTA preparation program that integrated not just pedagogy and physics but also professional development strategies, in order to prepare graduate students for their teaching duties and for their future careers, be they academic or non-academic.

The course, CETL 8000 PH1: Physics GTA Preparation, was first offered in Fall 2013. The first iteration of the course was more akin to "pedagogy and logistics with a few physics sprinkles." Through a cycle of implementation and revision, and guided by the 3P Framework we developed, the course evolved into a robust and comprehensive professional development program.

The course is targeted at first-time GTAs (i.e., first-year Ph.D. students) in the School of Physics at Georgia Tech. The incoming first-year graduate students mostly do not have prior teaching experience, but the majority of them consider teaching to be an important aspect of their professional development as physicists. First-time GTAs have several concerns about teaching, including content mastery and time management. A large fraction of them are also non-native English speakers who are also concerned about language, culture, and communication. When they first arrive, first-time GTAs feel only somewhat prepared for teaching, but after participating in the Orientation portion of the GTA-PD class they feel significantly better prepared.

We assessed the effectiveness of the course through various quantitative and qualitative assessments, with a combination of self-reported measures and pre/post testing. We ascertained how satisfied the GTAs were with the course with two surveys, one at the end of the Orientation (Orientation Survey) and another at the end of the semester (Final Survey). The results for the Orientation Survey were very positive overall, with GTAs reporting that going through the Orientation was helpful to them. Open-ended comments in the Orientation Survey were also mostly positive, with the majority expressing that now they felt better prepared for teaching.

The Final Survey asked GTAs how useful they found the course topics and activities. The overall three most useful topics identified by the GTAs were Microteaching, Lab Simulation, and Teaching Physics. We calculated Utility Scores for each aspect of the course and found that the Orientation was consistently considered the most useful part of the class, and the Follow-Up Meetings are the least useful. This suggests that we still need to work on improving the Follow-Up Meetings.

We determined how effective the course was in improving GTAs' attitudes and knowledge with two pre/post tests. The Approaches to Teaching Inventory (ATI) was used to determine how teacher-centered or learner-centered the GTAs' teaching styles are. We found that after one semester of GTA preparation, GTAs' learner-centered teaching approaches significantly increased, while their teacher-centered approaches stayed mostly the same.

We used a multiple-choice test we call Knowledge Quiz to determine if there was an improvement in the GTAs' pedagogical knowledge. Every year, the post-test class average was higher than the pre-test class average. In order to make cross-year comparisons, we then did another analysis focusing only on the questions that repeated in every year's quiz with the same exact wording. By doing this, we found that the post-test class averages (yearly and overall) were statistically higher than the pre-test class averages, with low-to-moderate normalized gains and moderate-to-high effect sizes.

We used end-of-semester student evaluations as an indirect measure of the effect of the GTA-PD class on GTAs' teaching effectiveness. We compared student evaluation data for the first Fall and first Spring semesters of teaching for GTAs who predated the GTA-PD class and for GTAs who participated in the first three years of the course. We found that all across the board, GTAs who participated in GTA-PD received higher student evaluation ratings than GTAs who predated the class.

5.1.1 Answering the Research Questions

In Section 1.3 we identified the three research questions that drove the specific program assessments we analyzed in this work. Here we answer these questions, based on the results summarized above.

RQ1. What elements of a formal GTA preparation program do GTAs perceive as the most useful or beneficial for their professional development?

GTAs identified Microteaching, Lab Simulation, and Teaching Physics as the three most useful class modules. This suggests that GTAs appreciate hands-on activities in which they get to practice teaching and getting feedback on their performance, and they are also interested in developing the pedagogical content knowledge necessary for teaching introductory physics.

RQ2. What effect does a formal GTA preparation program have on graduate students' teaching self-efficacy and attitudes about teaching?

GTAs report feeling better prepared for teaching after participating in the first part of the course, the Orientation. Using the Approaches to Teaching Inventory (ATI) we were able to determine that GTAs' approaches to teaching become more learner-centered after participating in GTA-PD.

RQ3. Does a formal GTA preparation program have an effect on graduate students' teaching effectiveness, as determined by end-of-semester student evaluations?

GTAs who participate in a formal GTA preparation program score consistently higher in end-of-semester student evaluations than GTAs whose first teaching experience predated the establishment of the GTA-PD class.

We have been able to answer our research questions, and the results indicate that our GTA-PD program has been both well-received by GTAs and successful at preparing them for their first teaching experience.

5.1.2 Agreement with Best Practices

In Section 2.5 we identified the five most salient results from the literature on GTA preparation:

1. Training improves GTAs' teaching confidence and self-efficacy
2. Training improves GTA's content knowledge and PCK, and can result in adoption of learner-centered teaching styles
3. Science GTAs benefit more from discipline-specific GTA preparation than from campus-wide initiatives
4. GTAs need guidance in logistics issues such as classroom management and grading
5. GTA experience improves graduate students' research and transferable skills

The results of our analyses agree with items 1 and 2. Our personal observations of GTA preparation in Fall 2012 agree with item 3. GTAs' feedback and comments on what they want more of in the class agree with item 4. Our course provides GTAs with the opportunity to develop the skills mentioned in item 5, but we currently lack a method of directly measuring this effect.

Additionally, in Sections 2.6 and 2.7 we identified what we consider the seven principles for best practices in GTA preparation:

1. GTA preparation should be nurturing, meaningful, and a partnership between graduate students and faculty
2. GTA development needs to be an ongoing endeavor
3. GTAs need to have the opportunity to practice and receive feedback

4. It is important to observe GTAs' actual teaching and provide them with feedback
5. GTA training must be grounded in research-based teaching strategies
6. GTA development must take into account the GTAs' beliefs in order to foster a sense of professional identity and buy-in for reformed teaching
7. GTA professional development should highlight the transferable skills that can be useful outside of an academic career

Our Physics GTA Preparation course satisfies all seven principles. We have worked very hard over the years to create a nurturing and meaningful experience for the first-time GTAs (item 1) to ensure that the GTAs feel like they are partners in the educational goals of our School. Our GTA-PD course is front-loaded but we do have continuing preparation meetings throughout the semester (item 2). However, we currently lack continuing support for experienced GTAs; this is something that is outside the scope of this dissertation (since the target audience for the class were first-time GTAs) but it is something that we will endeavor to rectify in the near future. The Microteaching and Lab Simulation activities provide GTAs with the opportunity to practice teaching in a safe and low-risk environment (item 3). Every GTA is observed at least once (twice in recent years) during their first semester of teaching and they are provided with detailed feedback from the course instructor and/or one of her assistants (item 4). Our course development is rooted in the principles of instructional design, and all activities are based on constructivism and active learning, so GTAs learn to teach in the same way that they are expected to teach their students (item 5). Although it is not very explicit, each year we make sure to respectfully consider the GTAs' beliefs about teaching and learning as we assist them in developing their professional identity and improving their teaching skills (item 6). And finally, the cornerstone of our approach is the fact that we provide professional development for our GTAs that will be useful for them even if they never teach again in a classroom setting after their GTA assignment is over (item 7).

5.1.3 Contribution to PER

There is no "one-size-fits-all" approach for GTA preparation. What works in one institution may not work in another institution; what may work for preparing lab GTAs may not work for preparing recitation GTAs. However, the method through which we developed and improved our GTA preparation course, the 3P Framework, can provide universal guidance that can then be tailored to fit the institutional context. With the 3P Framework we ensure that broader professional development is an integral part of the preparation that graduate students receive for their first teaching assignment. A full integration of pedagogy, physics, and professional development can result in a robust and comprehensive GTA preparation program that is useful for grad students regardless of their career aspirations.

The 3P Framework can be extended to other non-physics disciplines. In the process it loses its elegant alliterative name, but we have come up with a more generalized version of it: instead of "3P" it becomes "PDP," for "pedagogy, discipline-specific content, and professional development." The key ideas remain the same: the integration of the three main themes and the importance of their intersections.

5.1.4 Summary of Results

- "Physics GTA Preparation" is a course for first-year Ph.D. students who are concurrently working on their first teaching assistantship, that successfully integrates pedagogy, physics, and professional development.

- Our GTA prep course satisfies the principles for best practices in GTA preparation present in the research literature.

- Our method of curriculum development, the 3P Framework, can provide universal guidance for GTA preparation that is useful for graduate students no matter what their career goals are.

- First-time GTAs mostly do not have prior teaching experience, but consider teaching to be an important part of their professional development.
- First-time GTAs are concerned about knowing physics well enough to teach it and balancing their teaching duties with their graduate coursework, and non-native English speakers are also worried about language and culture issues.
- GTAs report that the course is useful for them, with Microteaching identified as the most useful activity, and the Orientation identified as the most useful portion of the class.
- GTAs' approaches to teaching are more learner-centered after one semester of GTA preparation.
- GTAs' pedagogical knowledge increases after one semester of GTA preparation.
- GTAs who participate in the GTA preparation course receive higher student evaluation ratings than GTAs who predated the course.

5.2 Future Work

There is much more to be done in the study of GTA preparation. Our future work will consist of more in-depth analysis of our program assessment data, and exploring the landscape of physics GTA preparation nationwide.

5.2.1 Additional Analyses

Each year the course is taught, we collect additional data. For example, by the start of the Spring 2020 semester we will have the full data for Fall 2019. These data will be incorporated into our analyses to continue assessing the success of our GTA preparation program. We will perform the analyses discussed in this work, and additional analyses as described below.

5.2.1.1 Repeated Measures ATI and Faculty Comparisons

From our current analysis we know that graduate students who participate in the GTA preparation class exhibit an increase in their learner-centered teaching approaches (Section 4.3.1). We would like to know if this continues beyond their first semester of teaching. For this, we will administer the ATI to study participants who have worked as GTAs again after their first year in grad school. Additionally, we will administer the ATI to the faculty in the School of Physics, so that we may compare the approaches to teaching of graduate students to those of faculty.

5.2.1.2 In-Depth Analysis of Knowledge Quiz Data

Two additional analyses will be performed with the pre/post Knowledge Quiz data (Section 4.3.2). The first is an item-by-item analysis to determine the fraction of GTAs who get each question correct and incorrect. Once this is done, we will be able to do a reliability analysis [294] and validation of the Knowledge Quiz as a research instrument. Additionally, we will perform a remapping of the categorization of the Knowledge Quiz questions to see where each question falls within the 3P Framework (Section 3.3).

5.2.1.3 Demographic Analysis of End-of-Semester Student Evaluations

The data for end-of-semester student evaluations includes information about the nationality of each GTA. An exploratory analysis reveals that undergrads consistently rate domestic GTAs (i.e., US citizens, native English speakers) higher than international GTAs, a result obtained by other researchers as well [295]. The planned analysis will determine if this difference is statistically significant. Further data collection would be required to identify the potential causes for the difference.

At the time of this writing we are also in the process of acquiring student evaluation data for the GTAs who participated in the GTA-PD class between 2016 and 2018. When that data are collected, we will be able to repeat the analysis described in Section 4.4 to include a more complete data set, by comparing the pre-intervention group, the 2013-2015 group, and the 2016-2018 group. It would be interesting if we find a difference between the 2013-2015 and 2016-2018 groups.

5.2.1.4 Additional Quantitative and Qualitative Analyses

The majority of the program assessment presented in this dissertation focused on quantitative data analysis, with a couple of exceptions (Sections 4.1.3 and 4.2.1.6). However, we have additional qualitative and quantitative data that we are still analyzing or have yet to analyze. Among the quantitative data that are partially analyzed are the responses for the weekly Workload Surveys that have been administered to the GTAs in the preparation class since 2015. This analysis will inform us not only about the overall teaching workload of first-time GTAs, but also about what aspects of their teaching duties are the most time-consuming. Preliminary results suggest that recitations are the most time-consuming of the various GTA assignments. The qualitative data yet to be analyzed are more extensive, and include:

- *Microteaching Essays.* As part of the Microteaching activity, GTAs write an essay reflecting on the feedback they received about their teaching from their peers and instructor. A qualitative analysis of these data will determine areas frequently identified for improvement at the beginning of a new GTA's first semester of teaching.

- *Lab Simulation Questions.* At the end of the Lab Simulation activity, the GTAs answer a series of questions about their thoughts on teaching labs (see Section B.1.4). A qualitative analysis of these data will help us identify common themes among first-time GTAs in what they consider the best and most challenging aspects of teaching in a lab environment.

- *Midterm Evaluations of GTA-PD.* Every time the class is taught, halfway through the semester the GTAs are asked to provide feedback about how much the class has helped them so far in the semester. We will look at these data to identify common themes.

- *Midterm Evaluations of GTAs.* As part of their Midterm Evaluations Project, GTAs write a report where they summarize the feedback they received from their students. We will analyze the reports to determine what undergrads think are the positives and negatives of their GTAs' teaching halfway into the semester.

- *Feedback to GTAs on their Individual Classroom Observations.* We will look at the completed observation rubrics and identify the type of feedback that GTAs have received from the observers. In particular, for semesters in which there were two observations, we want to determine if there were changes or improvements in the way GTAs were evaluated.

- *Free-response questions in the Final Survey.* In this work (Section 4.2.2) we discussed the analyses we performed for the first two questions in the Final Survey, which were quantitative. The rest of the questions in that survey are open-ended. Although we have read all these responses every year in preparation for making changes and improvements to the following year's curriculum, we have not yet compiled and coded the comments to identify frequent responses, or how the responses change after every year. Thus, we will be performing said analysis in the near future.

- *Thoughts about GTA Experience.* This is a short four-item questionnaire about the GTAs's first teaching experience at Georgia Tech (see Section B.2.5). Although the questions are not directly related to the GTA-PD class, we still want to know the GTAs' thoughts about how their teaching experience went, because we want to make sure it was a good experience – and if it was not, then we want to find ways to improve it. The responses will be coded to identify what are the most common good and bad aspects of being a first-time GTA in the School of Physics.

- *Final Refection Essays.* In this last assignment of the semester, GTAs are instructed to describe in detail their thoughts about the most interesting and useful aspects of the GTA-PD class and the ways in which the course activities may have helped them improve their teaching, among other things. An extensive qualitative analysis of these data will give us more insight into what aspects of the class have the most impact on the GTAs.

Additionally, we currently have over half a terabyte of video data from the classroom observations (well over 100 hours of video) that need to be transcribed, coded, and analyzed. For this analysis we will use one of the many research-validated observation protocols that exist (e.g., RIOT [68, 296, 297], TA-IOP [208], RTOP [298, 299], COPUS [300], LOPUS [301]), although at this point in time we have not decided on which one would be most appropriate to use. The analysis will help us ascertain the degree to which the GTA preparation class has affected the GTAs' actual classroom practices.

5.2.2 National Survey of GTA Preparation in Physics Departments

There is a conspicuous gap in the PER literature on GTA preparation, and it is that there are no studies exploring the current landscape of physics GTA preparation nationwide. As such, we are currently in the planning stages for a National Survey of Physics GTA Preparation. The research questions driving this survey are:

1. What kind of preparation do physics departments provide for their first-time and returning GTAs?
2. Are there differences in GTA preparation depending on the size of the department or type of institution?
3. How do physics departments evaluate the success of their GTA preparation?
4. What are the elements of a successful GTA preparation program?

The survey will focus on physics Ph.D.-granting institutions; there are over 200 of those in the United States [10]. We expect the survey to be ready to send by late 2020. The same methodology can be applied in possible subsequent surveys exploring other fields such as chemistry, though we should note that similar surveys have been done in biology [302] and math [303, 304].

Appendices

APPENDIX A
RESEARCH PARTICIPANTS

The following table lists the graduate students enrolled in the Physics GTA Preparation course from whom we obtained informed consent, and therefore are included as participants in this study (2014-2018). Each graduate student is identified with a three-digit code, and the table gives us information about their gender, nationality, and the details of their first GTA assignment (class, type, and flavor).

The classes listed in the table are: Introductory Physics I - Mechanics (2211); Introductory Physics II - Electricity and Magnetism (2212); Special Topics: Problem Solving in Mechanics (2802); and Special Topics: Hands on Principles of Living Systems (4803). There are three different flavors for the Introductory Physics courses: Traditional (Trad), Matter and Interactions (M&I), and Intro Physics for Livings Systems (IPLS). The Help Center is a walk-in tutoring space staffed by GTAs (UTAs from 2017 onward).

Table A.1: Gender, nationality, and first GTA assignment of all graduate students participating in the study (2014-2018).

Year	Participant	Gender	Nationality	Class	Type	Flavor
2014	GTA-201	M	USA	2802	In-Class	—
2014	GTA-204	M	International	2212	Lab	M&I
2014	GTA-205	M	International	2212	Lab	M&I
2014	GTA-206	M	USA	2212	Lab	Trad
2014	GTA-207	M	International	2212	Lab	M&I
2014	GTA-209	M	USA	2211	Flipped Lab	M&I
2014	GTA-210	F	USA	2211	Lab	M&I
2014	GTA-213	M	USA	2212	Lab	M&I
2015	GTA-301	F	USA	2212	Recitation	Trad
2015	GTA-302	F	USA	2212	Lab	M&I
2015	GTA-303	F	USA	2211	Lab	M&I
2015	GTA-304	M	USA	2211	Lab	M&I

Continued on next page

Table A.1 – continued from previous page

Year	Participant	Gender	Nationality	Class	Type	Flavor
2015	GTA-305	F	USA	2211	Lab	M&I
2015	GTA-306	F	USA	2211	Recitation	Trad
2015	GTA-307	F	USA	2211	Recitation	Trad
2015	GTA-309	M	USA	2211	Recitation	Trad
2015	GTA-310	M	USA	2211/2212	Help Center	Trad
2015	GTA-312	M	USA	2211	Lab	Trad
2015	GTA-313	M	USA	—	—	—
2015	GTA-314	M	International	2211	Lab	Trad
2015	GTA-315	M	USA	2211	Lab	M&I
2015	GTA-317	M	USA	2211	Lab	M&I
2015	GTA-318	M	USA	2212	Lab	M&I
2015	GTA-319	M	USA	2212	Lab	M&I
2015	GTA-320	M	International	2211	Lab	M&I
2015	GTA-321	M	USA	2212	Lab	M&I
2015	GTA-322	M	International	2212	Lab	M&I
2015	GTA-323	M	International	2211	Lab	Trad
2015	GTA-324	M	USA	2211	Lab	M&I
2015	GTA-325	M	International	2212	Lab	Trad
2015	GTA-326	F	USA	4803	In-Class	—
2015	GTA-327	M	USA	2212	Lab	M&I
2015	GTA-328	M	International	2212	Lab	M&I
2015	GTA-331	M	International	2212	Lab	Trad
2015	GTA-332	M	USA	2211	Lab	Trad
2015	GTA-333	F	USA	2211	Lab	M&I
2015	GTA-334	M	International	2212	Lab	M&I
2016	GTA-401	F	USA	2212	Lab	M&I
2016	GTA-402	M	International	2211	Lab	M&I
2016	GTA-403	M	International	2211	Lab	M&I
2016	GTA-404	M	USA	2212	Lab	M&I
2016	GTA-405	F	USA	2802	In-Class	—
2016	GTA-406	F	USA	2211	Lab	M&I
2016	GTA-407	M	International	2212	Lab	M&I
2016	GTA-408	F	USA	2212	Lab	M&I
2016	GTA-409	M	USA	2212	Lab	M&I
2016	GTA-411	M	International	2212	Lab	M&I
2016	GTA-412	M	International	2211	Lab	M&I
2016	GTA-413	M	USA	2211	Lab	M&I
2016	GTA-414	M	International	2212	Lab	M&I
2016	GTA-417	M	USA	2212	Lab	Trad
2016	GTA-418	M	USA	2212	Lab	Trad

Continued on next page

Table A.1 – continued from previous page

Year	Participant	Gender	Nationality	Class	Type	Flavor
2016	GTA-419	M	USA	2211	Recitation	Trad
2016	GTA-420	M	International	2211	Lab	Trad
2016	GTA-421	M	International	2212	Lab	Trad
2016	GTA-422	M	International	2211	Lab	Trad
2017	GTA-501	M	International	2212	Lab	M&I
2017	GTA-502	M	USA	2211	Recitation	Trad
2017	GTA-503	M	International	2211	Lab	Trad
2017	GTA-506	M	USA	2212	Lab	M&I
2017	GTA-507	M	USA	2212	Lab	Trad
2017	GTA-509	F	International	2211	Lab	Trad
2017	GTA-510	M	International	2212	Lab	M&I
2017	GTA-511	M	USA	2211	Recitation	Trad
2017	GTA-512	M	USA	2212	Lab	Trad
2017	GTA-513	M	International	2212	Lab	M&I
2017	GTA-514	M	International	2212	Lab	M&I
2017	GTA-515	M	International	2212	Lab	Trad
2017	GTA-516	M	USA	2211	Lab	M&I
2017	GTA-517	F	USA	2212	Lab	M&I
2017	GTA-518	F	USA	2212	Lab	Trad
2017	GTA-519	M	International	2212	Lab	M&I
2017	GTA-520	M	International	2212	Lab	Trad
2017	GTA-522	M	USA	2212	Lab	M&I
2017	GTA-525	M	International	2212	Lab	M&I
2017	GTA-526	M	USA	2211	Lab	M&I
2018	GTA-601	M	USA	2211	Lab	M&I
2018	GTA-602	F	USA	2211	Lab/Recitation	IPLS
2018	GTA-603	F	USA	2211	Lab	M&I
2018	GTA-604	F	USA	2211	Rec, then Lab	Trad
2018	GTA-605	M	USA	2211	Lab, then Rec	Trad
2018	GTA-606	F	USA	2212	Lab	M&I
2018	GTA-607	F	USA	2212	Lab	M&I
2018	GTA-608	M	International	2211	Lab	M&I
2018	GTA-611	M	International	2212	Recitation	Trad
2018	GTA-612	F	USA	2212	Lab	M&I
2018	GTA-614	M	USA	2211	Lab	M&I
2018	GTA-615	M	USA	2212	Lab	Trad
2018	GTA-616	F	USA	2212	Lab	M&I

APPENDIX B

COURSE MODULES: TOPICS AND ACTIVITIES (2019)

Here we describe the contents of the most recent version of the Physics GTA Preparation course (Fall 2019).

B.1 Orientation

The Orientation is the first part of the GTA prep class. Each session is three hours long, and they are spread out over a period of several days on the week before the semester begins and the first week of the semester (GTA duties begin on the second week of the semester).

B.1.1 Introduction & Georgia Tech Policies

This three-hour module is the first meeting with the new graduate students, and it typically happens the Wednesday before the start of the Fall semester. The lesson is structured into five parts:

- *Introduction*. The course instructor introduces herself and gives her contact information, then summarizes the results from that year's Entry Survey, focusing on demographics, previous teaching experience, and concerns about teaching. Then the students introduce themselves.

- *Syllabus*. Discussion of the course syllabus, including course structure and content; requirements, assignments, and grading scale; schedule; and online resources. A sample syllabus can be found in Appendix L.

- *GTA Duties and Expectations*. Exploration of what the students' expectations are for their first semester of graduate school and for their GTA experience, including discussion of a case study about balancing research and teaching. Explanation of the different GTA assignments and what the duties and responsibilities are for each of them.

- *Georgia Tech Policies*. Discussion of Georgia Tech's Policy of Nondiscrimination, Academic Integrity, the Office of Disability Services (ODS), Sexual Misconduct, and FERPA. The last two are also explored with case studies.

- *OK/NOT-OK Game*. A game in which students are presented with a short scenario related to the previously discussed Georgia Tech policies (e.g., "Your boyfriend or girlfriend is taking the class for which you're TAing"), and they say whether the presented scenario is acceptable ("OK") or unacceptable ("NOT-OK").

The following are the scenarios presented in the OK/NOT-OK game. Included in square brackets are the correct answer and the brief explanations presented in the slides after the correct answer is revealed.

- Grad student dating an undergrad [OK – Grad students can date undergrads, as long as everyone involved is a consenting adult and there are no power imbalances (e.g., one person is not in charge of the other person's grades).]

- TA asks one of their students out on a date [NOT-OK – Power imbalance. Wait until after the semester is over.]

- Undergrad student asks their TA out on a date [NOT-OK – TA must refuse because of the power imbalance/conflict of interest. Wait until after the semester is over.]

- A professor is married to a postdoc in the same department [OK – As long as the professor is not supervising the postdoc, and they're both consenting adults, this is fine.]

- TA hears a student in the lab loudly calling another student a slur [NOT-OK – The TA must put an end to this harassment immediately. Tell the offending student this is not acceptable behavior in class. Tell TA supervisor about the situation.]
- A student approaches their TA to say that another student has been making explicit sexual comments, which makes them uncomfortable. The TA says it's probably just a joke, no big deal. [NOT-OK – This is harassment, and the TA must stop it immediately. Tell TA supervisor, and may need to report it higher up the chain.]
- Lily, one of your students, is a trans woman. The other students refer to her as "he/him/his" even though she asked them to use "she/her/hers" pronouns. [NOT-OK – The TA must put an end to this harassment immediately. Tell the offending students that this is not acceptable behavior in class. Tell TA supervisor about the situation.]
- Your boyfriend/girlfriend is taking the class for which youre TAing [NOT-OK – Tell your GTA supervisor immediately, they must reassign you to a different class/section.]
- One of your grad school friends is the TA for a class you're taking [OK – The TA must grade their friend exactly the same as all the other students in the class – grade without looking at student names if possible, to avoid potential conflicts of interest.]
- Professor puts a stack of graded homework on the desk for students to pick up at the start of class. Scores are written nice and big on the upper right corner of the top page of the homework. [NOT-OK – FERPA violation. At the very least, the grades should be written in the last/back page, hidden from public view.]
- A student tells a TA that he's here to pick up his roommate's graded exam, and it's ok because the roommate gave him a note with written permission [NOT-OK – FERPA. Even if the roommate wrote a note giving permission, you're not supposed to give someone's graded work to someone else.]

- Joe stepped out of his office for a few minutes, and left his computer unlocked. His officemate Bob notices, opens Joe's email, and sends an embarrassing and unprofessional message to all of Joe's contacts, pretending to be from Joe. [NOT-OK – This is harassment, and "unauthorized use of computer systems." Once Joe reports this, Bob will be in trouble.]
- A group of students gets together to do homework [OK – As long as every person does and submits their own work, students can get together in a group to help each other with homework (unless specified otherwise in the course policies).]
- A TA hears two students talking to each other in another language in the middle of a test. The TA tells them to stop, but one student says he only asked what time is it, not asking about the test. [NOT-OK – Students are not supposed to talk to each other at all during a test.]
- Student wears an interesting t-shirt to class. TA likes the image in the shirt, and tells the student "Love your shirt, it's awesome!" [OK – This is totally fine, as long as the comment is not sexual, provocative, shaming, or insulting. But if the student says they feel uncomfortable receiving such compliments then you should stop.]
- TA notices that a student's bra strap is showing, and tells her to cover up / TA notices a student's pants are sagging so his boxers are visible, and tells him to pull up his pants [NOT-OK – Inappropriate! Please don't comment on students' underwear!]
- Jane is a fifth year grad student, and just found out she's two months pregnant. Her thesis advisor says this shows her lack of commitment to research and fires her. [NOT-OK – This is discrimination. The professor is in BIG trouble.]
- A student tells the TA that he missed lab because he had a migraine. The TA says "too bad, but you still get a zero" [NOT-OK – If there's ODS paperwork, TA needs to comply with procedures. If no ODS paperwork, TA should at least have empathy!]

- TA is grading homework, and shares the funniest silly answers with their officemate, who was a TA for the same class last year [OK – Just don't share the students' names. And don't be mean or insult the students. They're not stupid, they're novices and learning.]
- TA holds Asian students to a higher standard (meaning, harsher grading) because the TA believes that "Asians are smarter, therefore they should always do perfect work" [NOT-OK – This is discrimination. The TA may not be aware that they are being biased, but they need to be impartial and grade everyone equally.]

The first reflection assignment of the semester, titled "My first week as a GTA," is introduced during this class meeting, and it is due at the end of their first week of teaching. The lesson ends with a prompt for the next day, asking students to think about what are the best ways to teach and learn physics. Students are also given the opportunity to write down what, if anything, is still unclear after this lesson, and the questions are answered in the following class meeting.

In the interest of using class time efficiently, the pre-tests are administered to the GTAs in a pre-class meeting.

B.1.2 Teaching Physics

The second three-hour module, usually taking place on the Thursday before the start of the semester, focuses on pedagogical content knowledge for teaching physics. It starts by asking the students to express their thoughts about the previous day's ending prompt – the best ways to teach physics and the best ways to learn physics. It then flows into a discussion of differences between experts and novices [133], and how to "unpack" students' questions. A couple of videos are shown of GTAs interacting with students who have questions; each video is followed by a discussion of the good and not-so-good things in the video. The videos feature previous GTAs in the Georgia Tech School of Physics.

The discussion about questions from students leads into a discussion about asking students questions, emphasizing the need to connect new knowledge to the students' prior knowledge. We then move on to talk about incorrect prior knowledge, in particular preconceptions and misconceptions. We introduce concept inventories, where the incorrect answers can help us identify students' preconceptions, and then do an activity titled "Identifying Misconceptions, or Why did they get it wrong?". The students are separated into groups, and each group is assigned one pre-selected problem from a concept inventory. The groups then discuss reasons why students would pick the incorrect answers and how they would address each of those misconceptions. When the activity is over, everyone takes a break.

After the break we begin with an introduction to active learning, emphasizing its effectiveness and contextualizing it within PER [e.g. 60]. We then discuss problem solving, and how experts and novices differ in their approaches to solving physics problems. In the final activity of the session, students are once again separated into groups and each group is given one introductory physics problem to solve and to identify the types of issues that students may have when attempting to solve each of the problems.

The lesson ends by introducing the Microteaching activity, with students selecting the problem they will microteach. Figure M.1 in Appendix M reproduces the entire handout packet associated with this lesson. It should be noted that approximately half of the handout packet covers topics in pedagogy and teaching physics. A large portion of these are adapted from the book "Five Easy Lessons: Strategies for Successful Physics Teaching" [305]. The handouts list all references used so GTAs may consult them directly if they so wish.

B.1.3 Classroom Management

This lesson happens on the morning of the Friday before the semester begins. It starts with a discussion of the first day of teaching – what they need to do and what they want to accomplish. We emphasize the importance of establishing credibility, and the necessity of setting expectations for the students [306].

A discussion of two case studies follows: the first is an example of what not to do if there are classroom incivilities, and the second is a worst case scenario for a lab in which too many students require the GTA's attention at the same time. Case studies are a great way for GTAs to "experience" a teaching situation, and encourages them to reflect on the decisions they would make when presented with different scenarios [249].

The case studies then flow into a discussion of how to efficiently facilitate group work, with video examples of GTAs at work in various contexts. While most of the videos feature past GTAs in the Georgia Tech School of Physics, we have also used video clips from Periscope, `https://www.physport.org/periscope` [307]. We then introduce the Individual Classroom Observations and the Lab Simulation, before taking a break.

After the break we focus on student motivation as function of three dimensions: self-efficacy, value, and environment [134]. Additional case studies are then presented for discussion. It should be noted that all the case studies covered in this lesson are based on true stories that the course instructor has experienced, observed, or heard about.

When the lesson ends, the students then have lunch with a group of experienced GTAs. Each year we invite a diverse group of experienced GTAs (i.e., with a variety of teaching assignments, grad school years, gender, and nationality), and each of them sits with a small group of first-time GTAs to chat about any teaching-related topics they may wish to know more about.

B.1.4 Lab Simulation

The Lab Simulation usually takes place in the afternoon of the first day of classes (Monday). The core graduate classes are all in the morning, and the intro physics labs and recitations are in the afternoons, but there are no labs or recitations during the first week of the semester, which allows us to schedule the Lab Simulation on Monday afternoon.

The Lab Simulation is a roleplaying activity in which the students in the GTA prep class take turns acting as "TA" and as "Students" in the lab. The participants are arranged in pairs, and each pair facilitates the lab as TAs for 10 minutes while everyone else are the Students doing the lab experiments. While the TAs are facilitating, each of them is followed by an instructor (the course instructor or an assistant) who takes notes and then provides the TA with feedback. When their turn is over, the two people who had been TAs sit at a lab station and become Students, and another pair of participants become the TAs, starting the cycle again.

The lab room contains several setups for four different experiments: one for PHYS 2211 Traditional, one for PHYS 2211 M&I, one for PHYS 2212 Traditional, and one for PHYS 2212 M&I. The number of setups depends on how many participants are enrolled in the class. To control logistics, each participant is assigned an experiment for which they will be "TA" and an experiment for which they will be "Student." Lab materials are provided in advance, and participants are responsible for familiarizing themselves with the lab for which they will be "TA." Half of the participants facilitate PHYS 2211 experiments, and the other half facilitate PHYS 2212 experiments.

To make things more interesting, roughly a third of the participants are contacted in private by the course instructor before the Lab Simulation, and are asked to *sabotage* their experiments. For example, one participant may be asked to bring their laptop and refuse to work with their assigned lab partner; another participant may be asked to play with their phone instead of working on the lab. The participants tagged for sabotage are sworn to secrecy, and the sabotage is revealed only at the end of the activity.

At the end of the Lab Simulation, participants answer the following five questions (on paper):

- What do you think is the best part about TA'ing a lab?
- What do you consider the most challenging/difficult part of TA'ing a lab?
- What do you think are your biggest strengths when TA'ing a lab?

- What do you think are your biggest weaknesses (things to improve on) when TA'ing a lab?
- Any standout moments (good or bad) in the LabSim?

Their answers help us gauge GTAs' thoughts about teaching in a lab setting.

B.1.5 Microteaching

Microteaching is the last three-hour session of the Orientation, where GTAs practice teaching in front of a group for the first time [36]. Depending on the number of students enrolled in the GTA prep class, Microteaching could last anywhere from one to three days, although each student only attends one session.

At the end of the Teaching Physics lesson, students are presented with several introductory physics problems from which to choose. Each person selects one problem and signs up for one Microteaching session. The student is responsible for solving the problem and preparing to present and facilitate it.

Each Microteaching session hosts a maximum of 10 students. Each student has 10 minutes to facilitate their selected problem. We emphasize to the students that they are not supposed to lecture; instead they must engage the audience (i.e., their peers) by asking them questions and facilitating the solution process.

While a student facilitates, their peers are split into two groups. When the facilitator is done (or 10 minutes have passed, whichever comes first), the course instructor and each group of peers fill out a Microteaching Feedback Form (last page in the Teaching Physics handouts in Appendix M). Thus, each student ends up with feedback from three different sources. They will then use that feedback to write the Microteaching Debrief Essay, an assignment that is due just before the start of their teaching duties.

The Orientation Survey is administered at the end of the Microteaching session.

B.2 Follow-Up Meetings

The Follow-Up Meetings happen during the semester, after the GTAs' teaching duties have begun. These are 50-minute class meetings on Friday afternoons, taking place roughly every 2-3 weeks.

B.2.1 Grading

The Grading lesson is split into three (formerly two) separate sessions: one for M&I GTAs only, one for Traditional and IPLS GTAs only, and one for everyone to learn how to use Gradescope.

- In the M&I session, we give GTAs information about their grading duties and the process of grading exams. We introduce them to the concept of rubrics, and then we discuss in detail the M&I exam grading rubric. This is followed by a grading practice in which we present the students with real exam solutions and ask them to identify the errors in them.
- In the Traditional and IPLS session, GTAs are given a brief overview of what the Recitation, Traditional Lab, and IPLS grading duties are. This is followed by breakout groups with experienced GTAs: one group and experienced GTA for each different teaching assignment. In these breakout groups, experienced GTAs discuss with first-time GTAs the details of grading lab reports (for Traditional Lab GTAs), worksheets (for Recitation GTAs), and quizzes (IPLS GTAs). After the breakout groups, we introduce the concept of rubrics and discuss in detail the Traditional exam grading rubric. It should be noted that the M&I and Traditional exam grading rubrics are practically identical, and the IPLS exam grading rubric takes features from both. The final activity is a grading practice, in which students are presented with real exam solutions for which they have to identify the errors.

- A third session was first added in Fall 2019 to focus specifically on the technical details of grading. All introductory physics exams at Georgia Tech are now graded electronically using an online service called Gradescope (`https://www.gradescope.com`). During this session, we explain how grading assignments work and introduce all the first-time GTAs to how to use Gradescope. The lesson ends with a Gradescope grading practice, in which the GTAs grade real introductory physics exams (from previous semesters, with students' names and IDs removed) on Gradescope.

In Fall 2019 some GTAs were having difficulty keeping their weekly grading hours to single digits. In response to this, we created a resource called "Intro Physics Grading Flowchart" (Figure M.2 in Appendix M). Its purpose is to help GTAs streamline their grading workflow. We do not yet know how much impact, if any, this flowchart has had on the GTAs' grading efficiency.

B.2.2 Midterm Evaluations and Time Management

In this hybrid session, we first give GTAs a short questionnaire that serves as mid-semester evaluation of the GTA prep class. Once they are done, we then introduce the idea of mid-semester evaluations and how they differ from end-of-semester evaluations. We then assign the Midterm Evaluations Project, an assignment in which the participants in the GTA prep class will craft their own midterm evaluation questions, administer them to their students, and then write a report with their midterm evaluation results. The GTAs are given three weeks to do this assignment.

The second half of this lesson focuses on time management. We discuss procrastination, look over the Workload Survey (Section B.3.1) data to date, then try to identify where the time goes based on the number of hours in one week. Finally, GTAs are introduced to the Important/Urgent time management matrix [251], and we discuss tips and strategies for managing their time.

B.2.3 Teaching Videos

In this session, we present GTAs with several videos of other GTAs teaching. All the videos are clips from classroom observations done in previous years. For each video we then discuss what was happening in the video, what they think the GTA in the video did well, what they think the GTA in the video needs to improve on, and what they would do differently.

B.2.4 Teaching and Research

This session focuses on the transferable skills from teaching that are useful for academic and non-academic careers. We first start by asking the GTAs what skills they have developed or improved on during their teaching assignment this semester, then compare their answers to what their expectations were before the start of the semester. We introduce the research-validated idea that teaching experience can improve graduate students' research skills [195]. We then look at their responses to the question about post-Ph.D. career goals, and look at online resources about physics Ph.D. employment [308]. We then do an activity that takes up the majority of the class time. For this activity, the course instructor places printouts of job ads for a variety of academic and non-academic jobs on the whiteboards. Each student is then asked to pick two job ads, one academic and one non-academic, then we do a think-pair-share. Individually, each person reads their selected ads and identifies the transferable skills. In pairs, they compare and contrast job ads. Then everyone shares the transferable skills they identified, how they are related to the GTA job, and whether they appear in academic or non-academic job ads (or both). We then briefly talk about the differences between academic and non-academic jobs, and we close the lesson with a list of online resources for finding jobs.

The last reflection assignment (appropriately titled "Final Reflection") is introduced during this class meeting.

B.2.5 Concluding Remarks

In the last class meeting of the semester, we revisit the Workload Survey data to see how the GTAs are spending their time. Then we ask them how their first semester in grad school has been so far, and we compare their answers to their expectations before the start of the semester. After this we discuss a couple of campus resources: the Career Development Roadmap (`https://grad.gatech.edu/career-roadmap`) and Tech to Teaching (`https://www.ctl.gatech.edu/content/tech-teaching-0`). We close the session by handing out the post-tests, Final Survey, and the "Thoughts about GTA Experience" questionnaire.

"Thoughts about GTA Experience" consists of four questions that we ask the GTAs about their experience teaching for the first time at Georgia Tech. The questions are:

- The Good – your favorite things, the highlights, the stuff that brings a smile to your face.
- The Bad – the things you like the least, or the things that annoy you the most.
- The Ugly – the things you seriously think need to change immediately.
- Apart from the [GTA-PD] class and the Friday GTA meetings, do you feel you've had enough support for your first GTA assignment? If not, please let me know what we (me, the intro coordinators, and/or the department) can do to improve this.

It should be noted that these questions are not directly about the GTA-PD class. However, we think it is important to ask them because we want to ensure that GTAs are having a good teaching experience – and if they are not, then we want to know how we can help improve it.

B.2.6 Eliminated Session: "How's it going?"

In 2015, the second Follow-Up Meeting of the semester was titled "How's it going?" and it was designed as an unstructured time for GTAs to express any issues or concerns that may have come up in their first few weeks of teaching. This session was not well-received, identified by the GTAs as the least useful thing in the class, so it was eliminated from the curriculum.

B.3 Activities

There are several activities that are part of the GTA prep course but that do not happen during class meetings.

B.3.1 Workload Surveys

Although this is not technically an "activity," we include it under this category since it happens outside of class and it is not technically an "assignment." At the end of each week, we send the GTAs a short survey (created with Google Forms) in which they indicate the amount of hours they have spent that week on their various GTA duties. A separate section of the survey also asks them to indicate the number of hours they have spent on their graduate coursework outside of going to class. The purpose of this activity is to determine if GTA duties are staying within the 12-13 hours/week time limits of the teaching assistantship, to identify the duties that take up the most time, and to find out how many hours per week the GTAs are spending on their own coursework.

B.3.2 Classroom Observations

Each GTA is observed twice during their first semester of teaching. The first observation happens early in the semester (early September) and the second observation is later in the semester (late October). The observations are scheduled after the first week of GTA duties via a Google Form, where the GTAs indicate their preference for what section they would like to be observed in. In the form, the GTAs are also asked to list one aspect of teaching in which they want additional feedback during each observation. If the GTA gives permission, the observations are video recorded. The video is only shared with the person being recorded, and at the end of the semester anyone can request that their video(s) be deleted if they so wish. Since it is logistically difficult to observe all first-time GTAs during the entirety of one lab or recitation section (particularly those labs that last three hours), we limit the observations to 30 minutes. At the start of the observation, the observer and the GTA let the students know the purpose of the recording and ask if any students prefer to not be included in the video. If any students answer positively, the observer skips their table when video recording. If the observation starts at the beginning of lab/recitation, the observer records the GTA's introduction, which should last 10 minutes or less. Throughout the observation, the observer follows the GTA around with either a video camera or a clipboard, recording the GTA-student interactions and making note of how the GTA performs according to the rubric reproduced in Figure M.3 in Appendix M.

By the time of this writing, we have accumulated approximately half a terabyte of video data from classroom observations. These videos have not been examined to analyze in detail the nature of the interactions between the GTA and the students – who initiates, the length of the interaction, what happens during the interaction [68, 309, 310] – but rather they are used to provide each GTA with almost immediate[1] feedback for improvement. GTAs are encouraged to be constantly active during the lab/recitation, visiting groups and checking on their progress, and assisting students with guiding questions when they ask for help. We are yet unclear on whether GTA-student interactions are quantum phenomena[2], i.e., if observing them changes their behavior, but we hope that is not the case.

[1]The filled-out rubric, with detailed written feedback, is emailed to each GTA within two weeks of each observation.

[2]That was a joke. Come on, this is a *physics* Ph.D. thesis, the word "quantum" should be in here somewhere.

B.3.3 GAP Mentoring Meetings

Starting in 2017, the Graduate Association of Physicists (GAP, `http://gap.physics.gatech.edu`) have conducted peer mentoring sessions with the first-year graduate students. We have incorporated these as part of the GTA prep class since the majority of first-year grad students are GTAs as well. Three mentoring session happen each semester: the first one about academics, the second one about guidance and support, and the third one about career options. The peer mentors are GAP officials at various stages in their grad school careers.

B.3.4 Eliminated Activities: "Peer Observations" and "Experienced TA Observations"

In 2015, the class included an activity of Peer Observations, in which groups of GTAs were assigned to observe each other and give each other feedback. This activity was discontinued after one year due to the lukewarm reception it had from the GTAs. In the following year, 2016, we introduced an activity of Experienced TA Observations. This activity was fraught with logistics issues stemming from the fact that there were too many first-time GTAs and too few Experienced GTAs teaching intro classes that semester. The activity was not well-received, and was thus discontinued after one year.

APPENDIX C

SAMPLE ENTRY SURVEY (2019)

Georgia Tech

Entry Survey

Physics GTA Preparation: JumpStart to Teaching, Fall 2019

Congratulations on being accepted for graduate studies in the School of Physics at Georgia Tech! This Fall 2019 semester you will likely be working as a Graduate Teaching Assistant (GTA), and as a member of the instructional staff you will share in the responsibility to provide our undergraduates with the high quality education they expect from Georgia Tech.

To get you ready for your GTA duties (we don't want to throw you in the deep end without first learning to swim!), the School of Physics requires your enrollment in the Physics GTA Preparation course, **CETL 8000 PH1**. This is a one-credit, pass/fail course designed with the purpose of integrating pedagogical foundations, physics content knowledge, and professional development strategies. Not only will this course help you prepare for your first GTA assignment, but it will also help you develop transferable skills that you can use in your future career, regardless of what it may be (academia, industry, government, etc).

CETL 8000 PH1 starts with the **JumpStart to Teaching**, which is a multi-day GTA development workshop that takes place before the start of your teaching assignments. This year's JumpStart will happen as follows:

What	Day	Time	Location	Additional Notes
JS1: Introduction and Policies	Wednesday, August 14	2 pm - 5 pm	CULC 129	Make sure to bring a pen/pencil
JS2:	Thursday,	2 pm -	CULC 129	Make sure to bring a

Figure C.1: Sample Entry Survey (2019), exported to PDF from Qualtrics.

Teaching Physics	August 15	5 pm		pen/pencil
JS3: Classroom Management	Friday, August 16	9 am - 1 pm	Student Center, Piedmont Room	Lunch with Experienced GTAs goes from 12pm to 1pm (food will be provided)
International TA Orientation ***	Thursday, August 29	6pm - 7:30pm	Student Center, Peachtree Room	*** **International GTAs only** ***

(Note that the August 29 session for international GTAs is run by our Center for Teaching and Learning.)

You all will also need to participate in one **Lab Simulation** practice (Monday, August 19, at 2pm), and one **Microteaching** practice (on either Tuesday the 20th or Wednesday the 21st, at 2pm). More details about the scheduling and content of the LabSim and Microteaching will be given to you in our first meeting on August 14.

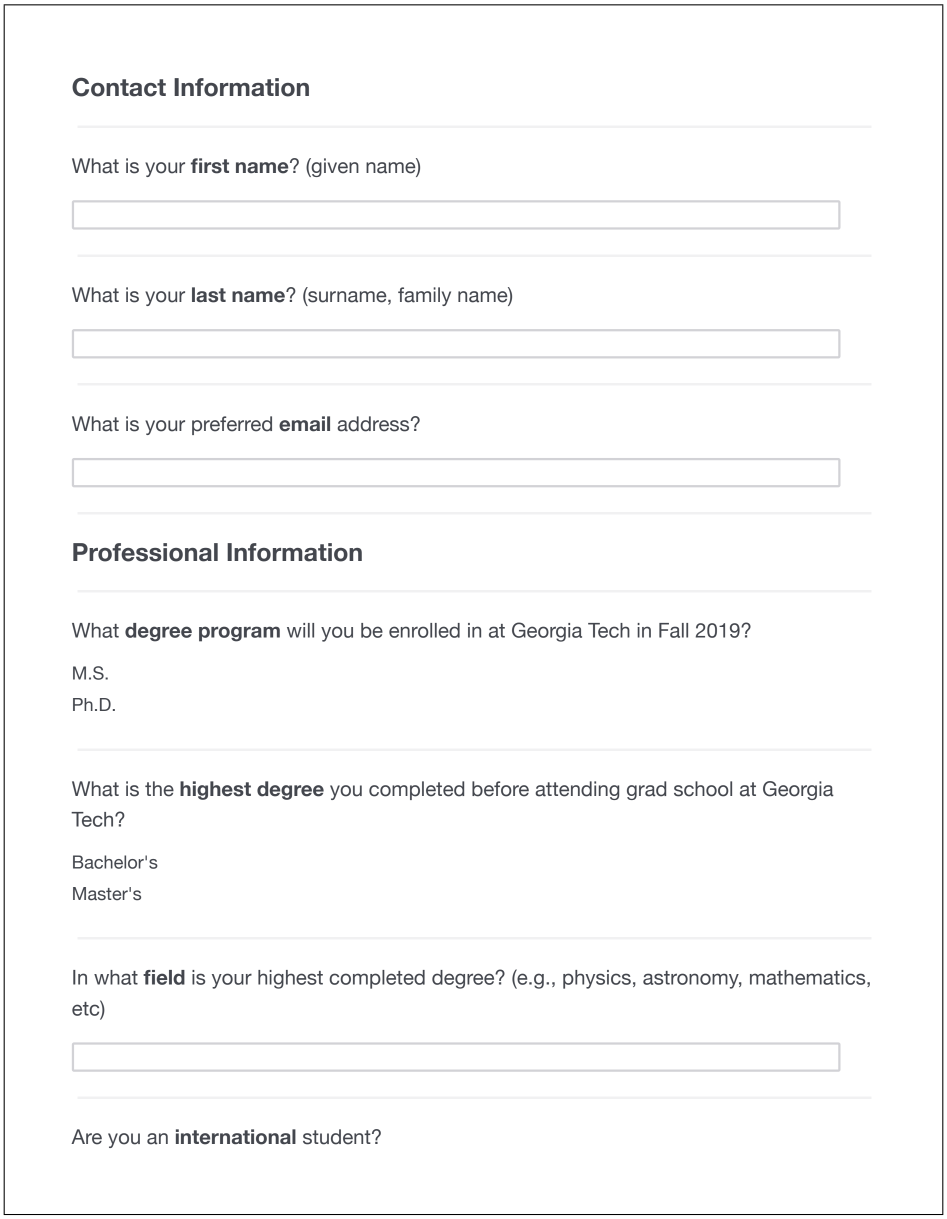
The JumpStart comprises approximately 70% of the course hours for CETL 8000 PH1. The rest of the course is made up of 50-minute **Check-In Meetings**, which happen on (some) Fridays during the semester, at 3pm in Howey S-204. You'll receive the full course schedule in our first meeting.

Now please take a few moments to complete the following survey and registration form for the Fall 2019 Physics JumpStart. **Note that you must still register for the CETL 8000 PH1 class when you register for all your other physics courses.**

Please make sure to complete this survey by **Monday, August 5, 2019**.

See you in a few weeks!

Figure C.1: continued from previous page



Contact Information

What is your **first name**? (given name)

What is your **last name**? (surname, family name)

What is your preferred **email** address?

Professional Information

What **degree program** will you be enrolled in at Georgia Tech in Fall 2019?

M.S.

Ph.D.

What is the **highest degree** you completed before attending grad school at Georgia Tech?

Bachelor's

Master's

In what **field** is your highest completed degree? (e.g., physics, astronomy, mathematics, etc)

Are you an **international** student?

Figure C.1: continued from previous page

Yes
No

International GTAs

In addition to the Physics JumpStart, new International GTAs need to attend the **International TA Orientation**, run by the Georgia Tech Center for Teaching and Learning, on **Thursday, August 29, 2018** from **6pm to 7:30pm** in the Student Center Peachtree Room. This orientation focuses on becoming familiar with the culture of American classrooms and will share strategies for bridging cultural differences and addressing language barriers.

To register for the International TA Orientation, please visit the following URL: http://ctl.gatech.edu/content/fall-2019-international-ta-orientation-registration

Please indicate your understanding and attendance to the international GTAs session below.

I understand and will register and attend the International TA Orientation.
I have some questions and will contact you (Emily Alicea-Muñoz, [redacted] for more information.

Teaching Experience

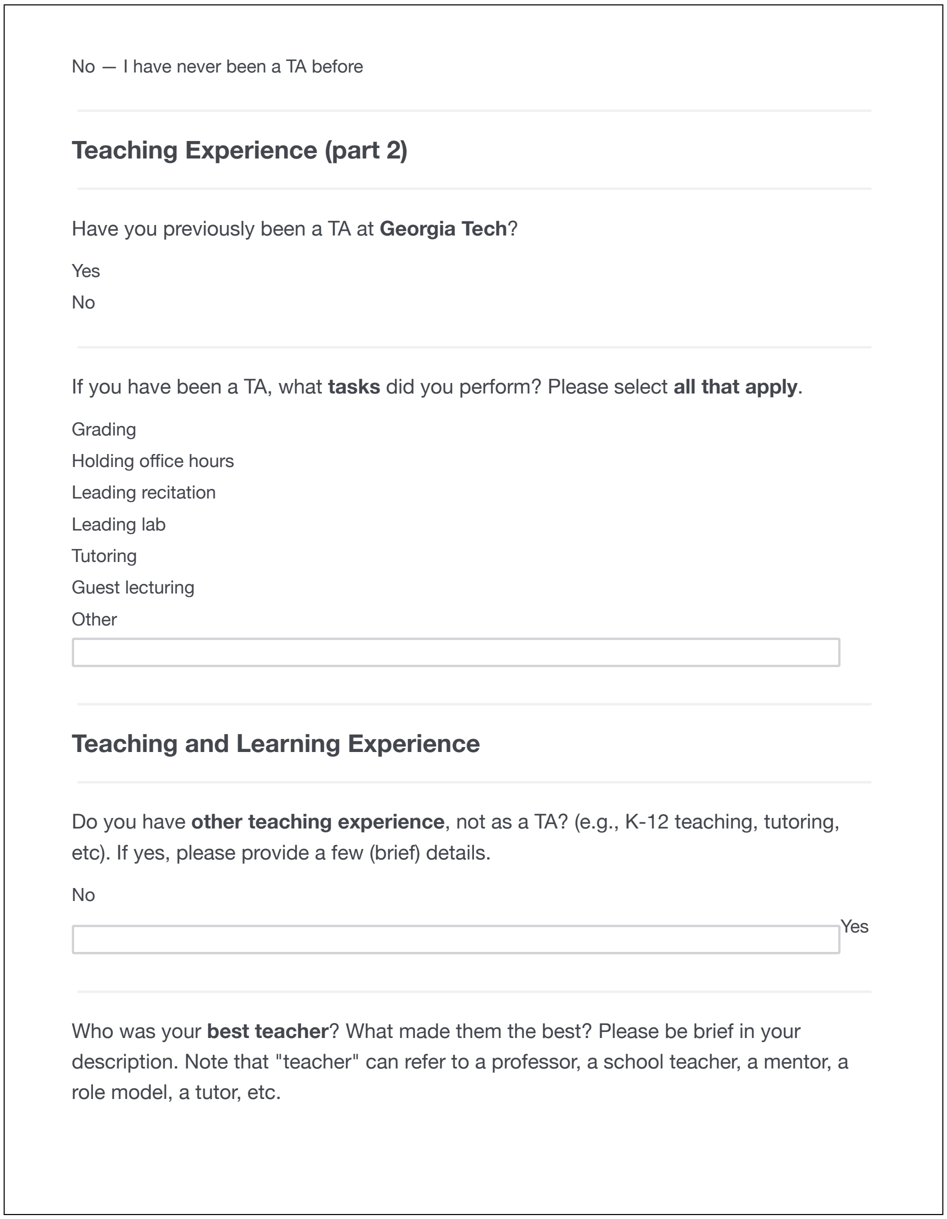
Did you ever take a course as an undergraduate student that was **taught or assisted** by a teaching assistant (TA)?

Yes
No

Have you ever been a **Teaching Assistant** (TA)?

Yes — I have been an undergraduate TA (UTA)
Yes — I have been a graduate TA (GTA)
Yes — I have been both a UTA and a GTA

Figure C.1: continued from previous page



No — I have never been a TA before

Teaching Experience (part 2)

Have you previously been a TA at **Georgia Tech**?

Yes

No

If you have been a TA, what **tasks** did you perform? Please select **all that apply**.

Grading

Holding office hours

Leading recitation

Leading lab

Tutoring

Guest lecturing

Other

Teaching and Learning Experience

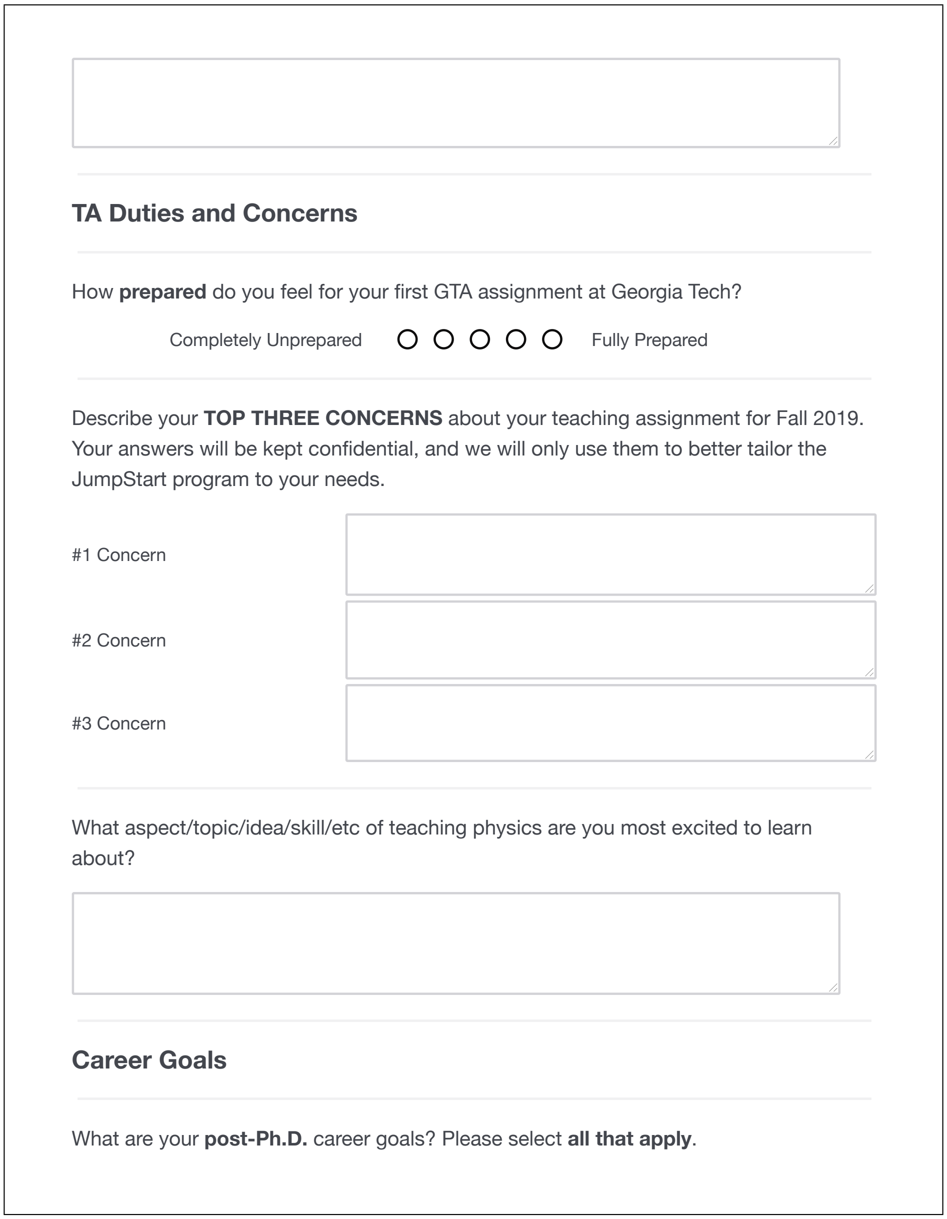
Do you have **other teaching experience**, not as a TA? (e.g., K-12 teaching, tutoring, etc). If yes, please provide a few (brief) details.

No

Yes

Who was your **best teacher**? What made them the best? Please be brief in your description. Note that "teacher" can refer to a professor, a school teacher, a mentor, a role model, a tutor, etc.

Figure C.1: continued from previous page



TA Duties and Concerns

How **prepared** do you feel for your first GTA assignment at Georgia Tech?

Completely Unprepared ○ ○ ○ ○ ○ Fully Prepared

Describe your **TOP THREE CONCERNS** about your teaching assignment for Fall 2019. Your answers will be kept confidential, and we will only use them to better tailor the JumpStart program to your needs.

#1 Concern

#2 Concern

#3 Concern

What aspect/topic/idea/skill/etc of teaching physics are you most excited to learn about?

Career Goals

What are your **post-Ph.D.** career goals? Please select **all that apply**.

Figure C.1: continued from previous page

Academia, professor at a research university
Academia, professor at a liberal arts college
K-12 Teacher
Industry
Data Science
Government
Law
Finance
Undecided
Other

Please indicate your **level of agreement** with the following statement:

"I consider teaching to be an important part of my professional development as a physicist."

Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

JumpStart Registration

By completing this registration form, you acknowledge that you will attend the required **CETL 8000 PH1 Physics JumpStart to Teaching** on:

- Wednesday, August 14, from 2pm to 5pm, in CULC 129
- Thursday, August 15, from 2pm to 5pm, in CULC 129
- Friday, August 16, from 9am to 1pm, in the Student Center, Piedmont Room

You also acknowledge that you will participate in the **LabSim** on Monday, August 19 at 2pm, and one of the **Microteaching** sessions on either Tuesday the 20th or Wednesday the 21st of August, at 2pm. Remember that more details on this will be provided to you once the program begins. And note that **you must still register for the CETL 8000 PH1 class** when you register for all your other physics courses.

Figure C.1: continued from previous page

Failing to attend will result in missing a majority of the contact hours for CETL 8000 PH1, a **required** one-credit pass/fail course. Such an absence will be taken seriously and must be reported immediately to the course instructor.

Please contact the course instructor if you have an unavoidable conflict that will prevent you from attending any part of the JumpStart. The course instructor is **Ms. Emily Alicea-Muñoz**, and she can be reached at: [redacted]

I understand

I understand, but have a conflict and will contact the course instructor

---

The Friday (August 16) meeting includes a **Lunch with Experienced GTAs**, and food will be provided. Do you have any **dietary restrictions**?

None

Vegetarian

Vegan

Gluten free

Other

Final Thoughts

So, do you want to be a good Physics GTA?

Definitely!

Sure...

Meh, it's not like I have a choice.

Not really.

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Figure C.1: continued from previous page

APPENDIX D

FIRST-TIME GTAS' CONCERNS ABOUT TEACHING

One of the questions in the Entry Survey was "Describe your top three concerns about your teaching assignment for [this coming Fall semester]." Between 2014 and 2018, study participants listed 221 concerns which we have coded into 19 categories. This appendix includes the full list of concerns, with the categories arranged alphabetically. The concerns appear exactly as the study participants wrote them, save for a few minor spelling corrections.

Administrative matters

1. Insufficient resources (we should at least have access to the undergrads' textbook or lab assignments and other course materials)
2. Will there be a sense of feedback on job performance from students and/or professors?
3. Procedures
4. What exactly come under the TA duties in the American system?
5. Getting a full grasp on my specific duties as a TA

Class size

1. how many classes/people do I need to take care
2. Single-handedly managing large classes
3. Being single TA for a huge class.

4. I’ve never been a TA for a class larger than 60 students, and the recitation sessions were optional, so maybe 30 students max.

Choosing what to teach

1. Am I allowed to teach and design the lab or class as I see fit or will I be required to stick to a pre-made lesson plan.

2. If I could choose which subject to teach that would be great

3. I do NOT want to be a TA for a lab. I’ve never been comfortable in the lab setting. (I do computational physics.) I’d be much better in a teaching environment, tutoring environment, or grading situation.

4. May I choose the course that I am going to assist?

5. Being relegated to only grading/no contact with students

6. I don’t know when and how shall I choose (or be chosen by) the right courses and teachers to do the job.

7. I would prefer to grade or work in a classroom setting vs. a lab setting.

Content mastery

1. I may not be familiar enough with the material (especially the labs) to help all my students

2. I don’t know if I’d be confident enough to TA for classes other than intro physics or mechanics. Maybe an intro E&M course. (I think that will change as I take own my graduate courses.)

3. Following conventions from textbooks (that I may not own) and lecture (which I may not be able to attend)

4. I suck at basic physics and math. It's hard to teach physics without using Lagrangians, etc.

5. Lastly, I guess I'm nervous about not having seen the material in awhile, so I'm worried that I might not be prepared enough to teach the students efficiently and effectively.

6. I'm afraid of being assigned material that I did not fully understand as an undergraduate, and having to teach it to my students

7. Remembering previously learned knowledge.

8. I feel concerned about being a TA in a subject that I'm not completely confident in myself.

9. Confidence in knowing material

10. How to prepare myself for situations where I'm clueless about how to approach a problem.

11. That I will not have complete enough knowledge to answer all questions

12. What to do if I meet the problem I don't understand too?

13. Being able to answer any question they have.

14. I worry that I won't know the answers to some of their questions

15. Make mistake when teaching.

16. I'm pretty uncomfortable with the idea of teaching physics. My degree in college was in biology, and I didn't take very much physics. I'm worried that students will get a homework problem that I don't know how to solve.

17. Solving the exercises I am supposed to make them understand.

18. Knowledge
19. Tough questions that I cannot solve or figure out immediately.
20. I'm worried that I will tell students something wrong! My biggest fear is completely forgetting an answer to a relatively simple physics problem.
21. Some material from fundamental physics has become rusty in my head. I need to pick them again in order to teach well.
22. My background knowledge in the course that I will be assisting.
23. Me not knowing enough of the subject to clarify the many doubts students will have.
24. Forgetting relevant information
25. Not knowing the material well enough.
26. How to assign the courses to the students? What if I was assigned a course I found difficult to myself?
27. Mixing things up
28. That I will not be able to answer students' questions
29. I've been out of school for two years, and I'm concerned that some of my physics knowledge has become rusty.
30. Being familiar enough with the specific material each professor uses so that I can teach others
31. I do not know enough to be providing correct information to students.
32. Forgetting content
33. I'll have forgotten some of the necessary material from when I took the given class.

Dealing with students

1. Having to deal with disruptive students.
2. That I will have difficult students
3. How to deal with the relationship with students?
4. Overly stressed students
5. Remembering names. I've never been good with this.
6. How to deal with students' requests? For example, asking for permission of late submission of homework.
7. Dealing with problematic students.
8. Sexual harassment situations and how to respond appropriately
9. I cannot handle behavioral situations.

Engaging and motivating students

1. I will be assigned an Intro/101 class (a.k.a. required course for engineers) filled with apathetic engineering students who don't care at all about physics and only care about their grade.
2. Bored students / students that are at a recitation session because it's required, instead of being internally motivated.
3. Being assigned to TA for an intro level physics course and teaching students who are not interested in learning the material (this is inevitable in any course I know, but I still worry).
4. I get way too emotionally involved with how the kiddies are doing.

5. Capturing the student's enthusiasm and engaging them fully.

6. Ability to teach students of varying motivation to succeed

7. Motivating the students to care about the topic they are involved in.

8. I had many recitations during undergrad that were awkward, boring, and unhelpful. I'm worried about that kind of environment

9. How to keep the atmosphere lively and not make tutorials 'a routine thing we've got to attend'

10. That I will be uninspiring

11. I am concerned about not being able to connect with a student who needs help.

12. Making sure every kid is on board and understands what's going on.

13. Ensuring that I seem approachable to others

Explaining concepts and ideas

1. Explaining a key concept during the first 10 minutes of class

2. Being able to explain concepts clearly

3. Communicating my knowledge effectively with less students less experienced in a given topic.

4. I worry that I won't be able to explain the concepts in a way that they understand

5. Not being able to get the point across in a way that everyone can follow. As a teacher/instructor that should be anyone's biggest concern.

6. Students not understanding what I am trying to teach them.

7. Giving answers to questions that clarify, rather than exacerbate, any issue the student has with a particular topic.

8. Sometimes I found it difficult to explain complicated phenomenon in plain words but not by equations

9. I won't be a good TA in that my explanations won't be clear.

Getting respect from students

1. Cachet [edit: being respected?]

2. I'm concerned about being taken seriously. I look kind of like a freshman.

3. I'm not so good at being a hard ass, and the students could probably manipulate me pretty easily.

4. Will students trust me as a Lecturer

5. I'm worried that I won't be respected by my undergraduate students.

6. That students will not take me seriously

7. My students won't respect me.

Grading

1. I'm interested in how to fairly and efficiently grade assignments, especially if the task allows a variety of approaches, with differing levels of thoroughness

2. grading homework/quizzes

3. during final week, do I need to grade final exams

4. My only other concern is adjusting to the grading policies so that all I am consistent with the other TA's.

5. Repetitiveness of grading assignments
6. Will the guidelines for grading (or other areas for that matter) be clearly defined?
7. My grading being too harsh or not harsh enough.
8. Are the labs graded more for completion and attendance, or is the grasp of the material by each student also important?
9. For homework and labs, will we be given any sort of solution set just in case we come up to the wrong conclusion/answer?
10. how to grade
11. Grading
12. Grading consistently
13. Grading problem sets uniformly (not taking a point from the 48th problem set that I gave to the 4th problem set).
14. I want to know about the expectations and how grading is done at Georgia Tech
15. How to grade consistently.
16. grading, and making sure it's fair amongst all TAs. My experience as an undergrad with TAs was that it's very inconsistent.

Labs and technology

1. Facilitating group work in a lab
2. I feel less confident in teaching experimental lab than lectures
3. Leading Lab - During my masters and later, I had kept my focus on topics in theoretical physics and have lesser experience in lab.

4. I am only concerned about my competence in technology.
5. Having to instruct on equipment I have not used before.
6. Lab activities and technical know-how required to properly teach labs
7. Dealing with unfamiliar lab equipment
8. I did the labs in high school but tested out of them in undergrad so I worry that it is possible I won't know how to lead a lab
9. Being able to handle unexpected situations in the classroom/lab (equipment malfunctions, etc)
10. Dealing with unforeseen hang-ups in lab procedure and changing things on the fly
11. Getting students to understand why they are doing things in the lab
12. Leading lab course, I always had a hard time in lab, so helping students with lab seems like a stretch for me.
13. Technical difficulties, I was in West Africa for a year and am pretty out of touch with technology, and I was never very good with technology to begin with.
14. Troubleshooting and solving problems with equipment, setups, materials, etc. in lab courses. Who do I go to if I cannot solve a problem with the lab equipment?
15. Leading a lab course (my training with experimental procedures is not very refined).
16. lab TAing
17. The experiments are too convoluted.
18. Knowing the specific procedures for each lab the students will be doing

Lack of prior teaching experience

1. As a TA it will be my duty to do an excellent job as a teacher (if I get to do it) in which I have limited experience.

2. This is going to be my first time teaching a class, although I have taught students before, so obviously there is a fair amount of anxiety at having to face a class of 100 odd students.

3. I have only had experience with helping students with homework and test preparation. So a concern of mine would be, will this class give me the tools to do the other areas of the job adequately?

4. I have no teaching experience before. (I used to grade homework for undergrads though)

5. I'm worried about my lack of previous tutoring experience. Although I have tutored a little bit, I'm worried that I will feel behind compared to my grad peers.

Language, culture, communication

1. Difference of cultures between students and TA

2. Clarity

3. My English is not fluent as a native English speaker.

4. Communication difficulties between TAs and students due to a language barrier.

5. Not a native English speaker, may be difficult to communicate with the students

6. Since I am an international student, I am concerned that my English accent might be hard for native students to follow and vice versa.

7. I am not as familiar with the classroom atmosphere of American students as native students.
8. Not familiar with the US physics syllabus, there may be area I haven't learned before
9. Accent
10. I am not so sure about my oral English ability.
11. Language problem: I sometimes don't know how to express my idea in English.
12. Culture of classroom in USA.
13. What is the requirement of English level for GTA?
14. Language
15. Having enough English vocabulary to make myself clear
16. My spoken English may not be good enough to interpret everything clearly.
17. Class management. Students from my home country tend to be very quiet and I have to tried to motivate them to participate in class activity. But I am not sure about the culture in America
18. Excessive mumbling and stutters
19. Being an international student, I might not be able to communicate what i want to say in the best possible way.
20. As an international student, English use for teaching is my first concern.
21. How proficient should I be in spoken English?
22. Adapting to the different teaching/classroom atmosphere and the role of a TA in Georgia Tech, as I am an international student.

23. Still little worried about language.
24. Communication
25. Effective communication with the students.

Nervousness and public speaking

1. Appearance
2. Composure
3. I have stage fright, so it's nerve wracking. However, I've performed on stage for the past four years, so obviously it's manageable.
4. Nervous about lecturing
5. I think the first two kind of sum up and there is nothing in general apart from the initial feeling of having butterflies in the tummy.
6. Stage fright.
7. I am too nervous about leading a large group of people on my own.
8. Being nervous
9. Freezing up presenting to a crowd
10. General nerves/anxieties about speaking to groups

Preparing for teaching

1. If I have to lead recitation, I am concerned about what I need to do and how to properly prepare for it (my undergraduate institution was small enough that I haven't been exposed to this type of learning).

2. I might make mistake in tutoring due to occasional carelessness.
3. Will the GTAs create the lab manual? If not, will we be given the labs early so we can go through them before the students' labs?
4. Organization.
5. how to prepare
6. Being completely prepared in a timely manner.
7. How to prepare lessons?
8. Preparing for lessons.

Professors and supervisors

1. My supervisor may be a grouchy person
2. Administrative tasks to assist the instructor of record
3. I will not get along with the professor; I prefer gregarious, casual professors over the more reserved, severe professors.
4. Communication breakdown between course professor and TAs with regards to grading policies or student expectations.
5. Communication with professors on what I am to cover
6. How to deal with the relationship with professors?
7. I want to meet the professors and know who I could be working with/for.

Scheduling

1. Timing. I have a puppy at home (off campus/outside the perimeter) and a husband who works full-time. I will need a schedule that will allow me to leave early in the day.

2. When are we allowed time off? Does it have to align with the time the undergraduate students are on break?

3. Schedule of the TA assignment

4. When do I start

Students' prior knowledge

1. talking at an appropriate level for the students

2. The difference between the level of undergrad courses in India and the US.

3. I not sure about the knowledge background of the students

4. The students are too smart.

Teaching techniques

1. how to teach

2. Not everyone will like my teaching style.

3. If I have questions about the best method to teach a certain type of problem, to whom do I reach out? Will I be working closely with professors to try to maintain consistency across the subjects?

4. Ability to teach material

5. I'm concerned that my teaching style is not sophisticated enough to engage the spectrum of students.

6. Ensuring that I instruct students fluidly and cohesively

7. Not knowing how to teach the content

8. Different teaching techniques for students who might not respond to a classical method

9. That I will not communicate the subject well enough to students

Time management

1. I may not have enough time to complete all of my duties

2. Amount of time to be dedicated to teaching every week

3. Time required outside of class

4. I'm concerned about balancing my assignment and my workload of classes.

5. The TA workload will eclipse the amount of study necessary for 4 concurrent graduate courses, which, due to my lack of TA experience, will lead to poor performance from me as a TA and student.

6. Becoming over busy with studying and learning at the same time

7. balancing coursework and TA responsibilities

8. Cannot balance research, studying, and teaching

9. Work load.

10. I am also a little concerned about the workload (coursework & teaching work) since I have never done this before.

11. Would there be sufficient time to work as a TA and simultaneously studying for my courses?
12. Losing my drive to TA because of my graduate student work load. I want to be upbeat and attentive to any students.
13. I'm worried about time management between TA-ing and my own classes/research.
14. I'm most concerned that I will not have enough time to devote to TAing due to the rigorous course work in the first year of my program and I want to make sure I do a good job.
15. I'm also worried that if I taught a recitation section, or something similar, I'd spend too much time trying to be a good TA and not enough time on my coursework.
16. Time commitment
17. To have overload of work (teaching, homework corrections, my own homework, etc.)
18. Time consuming
19. Spending too much time trying to be a good TA and not having enough time to complete my coursework.
20. I am worried that I may spend too much time on this, and I wonder how much time I am expected to devote on GTA per week.
21. We are supposed to take 4 courses in first semester. I don't know if I have enough time take care of everything
22. How I'll be able to manage my time between TA and my own coursework/research.
23. Being overwhelmed balancing being a TA while being a student myself.
24. Will it take a lot of my time to prepare for the lab

25. Time dedication

26. Time management, specifically how much time to spend preparing/grading

27. I'm concerned about balancing classwork and TA responsibilities.

28. The workload affects coursework and research.

APPENDIX E

SAMPLE ORIENTATION SURVEY (2019)

Georgia Tech Center for Teaching and Learning

Georgia Tech School of Physics

CETL 8000 PH1, Fall 2019 – JumpStart Evaluation

(Introduction and Policies, Teaching Physics, Classroom Management, LabSim, Microteaching)

	Strongly **AGREE**	Agree	Neutral	Disagree	Strongly **Disagree**
The handouts/worksheets have been useful.					
There was a good balance between lecture and activities.					
The pair and group activities were useful.					
The ok/not-ok game was useful for clarifying GT policies.					
I would have preferred more lecturing than activities.					
Going through JumpStart before the TA job begins is helpful to me.					
My worries and concerns about teaching were addressed properly.					
The JumpStart sessions were a waste of time.					
The ok/not-ok game was an entertaining way to learn about GT policies.					
I feel better prepared to be a TA now that I've gone through JumpStart.					
I liked getting to work on real introductory physics problems.					
The Lab Simulation was a valuable practical experience.					
Microteaching was a valuable practical experience.					
I expect the Check-In Meetings during the semester will be useful.					

How prepared do you feel now for your first GTA assignment at Georgia Tech? (please circle only one number)

Completely Unprepared 1 2 3 4 5 Fully Prepared

Do you have any additional comments?

Figure E.1: Sample Orientation Survey (2019).

APPENDIX F

OPEN-ENDED COMMENTS IN THE ORIENTATION SURVEY

At the end of the Orientation Survey, there was an open-ended question, "Do you have any additional comments?" Out of the 109 total Orientation Survey responses, 28 of them included additional comments (26%). Here are all those comments, organized into categories (from most common to least common), and written to appear exactly as the study participants wrote them.

Usefulness / feeling better prepared

1. This was SO much more through than when I'd TA'ed previously! I loved the real, practical advice, and all of the [unreadable] this week

2. I obtained a very good sense of how I will perform in TA scenarios and JumpStart will help me prepare myself for the real duties

3. The GTA preparation course helps me feel conficdence in the following life of being a GTA

4. I loved labsim and microteaching, those were VERY useful

5. The whole evaluation procedure was novel and useful unlike my alma mater. My TAs were unprepared, due to lack of such a training :-)

6. Overall this course REALLY helped me feel ready to TA

7. I feel way more prepared starting to TA now than I did before! I appreciate all the help!

8. This was a good orientation session. All of my fears have been addressed.

9. This was extremely helpful. Thank you Emily.

Suggestions and constructive criticism

1. I would have appreciated more guidance in microteaching. The open-ended nature made the task more difficult.

2. I would have liked more concrete information (The TA videos were GREAT, would have liked more), more "roleplaying" like microteaching, would be useful. FERPA was good, haven't seen it before

3. Maybe LabSim could be combined with microteaching to take less time - split the class, we can still learn from experience

4. Maybe more videos/examples of lab/teaching scenarios

5. Lab simulation may/should be longer than 10 minutes

6. All of the activities were USEFUL, but they were not time-efficient and took longer than they could have.

7. Would have preferred to be better prepared for LabSim than the "students" to better simulate the environment

8. I wish we could receive our assignment faster so that we can prepare

Gratefulness

1. Well done. Effort was apparent and appreciated.

2. Thank you!

3. We really appreciate the amount of effort you put into preparing us for TA roles

4. I am glad we have such an intensive training session to prepare us for TAing. Great job!

Generally negative

1. Group activities are generally difficult for me.

2. I am going to TA labs. Will microteaching be helpful? I do not need to explain stuff in 10 minutes, I guess

3. Much of this could have been covered in a succinct email

Generally positive

1. Excited to get started!

2. Everything is good!

People with extensive prior teaching experience

1. That's an awesome idea [one day, 9am-6pm], maybe as an option for people w/ prior TA experience

2. I think these activities are great for most b/c they don't have experience, but there should be a shorter class for those with experience

APPENDIX G

SAMPLE FINAL SURVEY (2019)

CETL 8000 PH1 (Fall 2019) – Final Survey – Page 1 of 2

1. Interesting

Please indicate how **interesting** you found the course activities, ranking each of them from 1 (uninteresting) to 5 (highly interesting).

	LOW				HIGH
	1	2	3	4	5
JS1 – Intro & Georgia Tech Policies					
JS2 – Teaching Physics					
JS3 – Classroom Management					
JS4 – Lab Simulation					
JS5 – Microteaching					
C1 – Grading – circle one: TRAD / M&I					
C1 – Grading: Gradescope					
C2 – Midterm Evaluations					
C2 – Time Management					
C3 – Teaching Videos					
C4 – Teaching and Research					
C5 – Concluding Remarks					
ICO – Individual Classroom Observations					
WS – Workload Surveys					
GAP – GAP Mentoring Meetings					

2. Useful

Please indicate how **useful** you found the course activities, ranking each of them from 1 (useless) to 5 (highly useful).

	LOW				HIGH
	1	2	3	4	5
JS1 – Intro & Georgia Tech Policies					
JS2 – Teaching Physics					
JS3 – Classroom Management					
JS4 – Lab Simulation					
JS5 – Microteaching					
C1 – Grading – circle one: TRAD / M&I					
C1 – Grading: Gradescope					
C2 – Midterm Evaluations					
C2 – Time Management					
C3 – Teaching Videos					
C4 – Teaching and Research					
C5 – Concluding Remarks					
ICO – Individual Classroom Observations					
WS – Workload Surveys					
GAP – GAP Mentoring Meetings					

3. More

What topics/activities do you wish the class had **more** of?

Figure G.1: Sample Final Survey (2019).

CETL 8000 PH1 (Fall 2019) – Final Survey – Page 2 of 2

4. Less
What topics/activities do you wish the class had **less** of?

5. Missing
What do you think was **missing** from this class, things that should be added to make the class better?

6. Best
What do you think was the **best** thing about this class?

7. Most Need For Improvement
What do you think is the thing in this class that needs the **most improvement**?

8. Emily's Teaching – Please comment on my teaching style/skills:
(a) What did I do that helped you learn? (and other positive feedback in general)
(b) What did I do that hindered your learning? (and other constructive criticism in general)
(c) What can I do to improve as a teacher?

9. Comments
Do you have **any additional comments** about the class and/or about my teaching this semester?

Figure G.1: continued from previous page

APPENDIX H

APPROACHES TO TEACHING INVENTORY (ATI)

Name: ______________________________ **ATI PRE/POST-TEST**

APPENDIX 1: APPROACHES TO TEACHING INVENTORY

This inventory is designed to explore the way that academics go about teaching in a specific context or subject or course. This may mean that your responses to these items in one context may be different to the responses you might make on your teaching in other contexts or subjects. For this reason we ask you to describe your context.

Please describe the subject/year of your response here: ..... Intro Physics .....

For each item please circle one of the numbers (1-5). The numbers stand for the following responses:

1 - this item was **only rarely** true for me in this subject.
2 - this item was **sometimes** true for me in this subject.
3 - this item was true for me **about half the time** in this subject.
4 - this item was **frequently** true for me in this subject.
5 - this item was almost **always** true for me in this subject.

Please answer each item. Do not spend a long time on each: your first reaction is probably the best one.

		Only rarely				Almost always
1	I design my teaching in this subject with the assumption that most of the students have very little useful knowledge of the topics to be covered.	1	2	3	4	5
2	I feel it is important that this subject should be completely described in terms of specific objectives relating to what students have to know for formal assessment items.	1	2	3	4	5
3	In my interactions with students in this subject I try to develop a conversation with them about the topics we are studying.	1	2	3	4	5
4	I feel it is important to present a lot of facts to students so that they know what they have to learn for this subject.	1	2	3	4	5
5	I feel that the assessment in this subject should be an opportunity for students to reveal their changed conceptual understanding of the subject.	1	2	3	4	5
6	I set aside some teaching time so that the students can discuss, among themselves, the difficulties that they encounter studying this subject.	1	2	3	4	5
7	In this subject I concentrate on covering the information that might be available from a good textbook.	1	2	3	4	5
8	I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.	1	2	3	4	5
9	In teaching sessions for this subject, I use difficult or undefined examples to provoke debate.	1	2	3	4	5
10	I structure this subject to help students to pass the formal assessment items.	1	2	3	4	5
11	I think an important reason for running teaching sessions in this subject is to give students a good set of notes.	1	2	3	4	5
12	In this subject, I only provide the students with the information they will need to pass the formal assessments.	1	2	3	4	5
13	I feel that I should know the answers to any questions that students may put to me during this subject.	1	2	3	4	5
14	I make available opportunities for students in this subject to discuss their changing understanding of the subject.	1	2	3	4	5
15	I feel that it is better for students in this subject to generate their own notes rather than always copy mine.	1	2	3	4	5
16	I feel a lot of teaching time in this subject should be used to question students' ideas.	1	2	3	4	5

Thank you

Figure H.1: Approaches to Teaching Inventory (ATI). Originally appearing in [277], with modifications (e.g., line for writing name, subject/year line pre-filled with "Intro Physics") as administered to our students.

APPENDIX I

SAMPLE KNOWLEDGE QUIZ (2019), WITH SOLUTION KEY

Name: ____ CETL 8000 PH1
Knowledge Survey (KS) **PRE/POST TEST KEY**

This knowledge survey is for diagnostic purposes only, to find out how familiar you are with the course material. You will take this diagnostic survey twice: once before the class as a baseline and once again when the class is over to help you and your instructor measure how much you have learned. You will receive full credit for completing the survey to the best of your knowledge. You will not be penalized for incorrect responses. Thank you for cooperation!

Please select only ONE answer for each question unless otherwise specified.

1. The approach to teaching that shifts the role of instructors from givers of information to facilitators of student learning is:
   A. Learner-Centered Teaching
   B. Teacher-Centered Teaching
   C. Online-Based Teaching
   D. Think-Pair-Share
   E. Expectancy-Value Motivation Theory

2. Learner-centered teaching promotes deep learning in all of the following ways, **EXCEPT:**
   A. Engaging students in higher order thinking
   B. Creating opportunities for students to actively process new material
   C. Using examples and analogies that relate to students' prior experiences and knowledge
   D. Making connections to what students value
   E. Lecturing extensively in order to cover all of the material

3. Which of the following would be the most learner-centered way to begin a lesson?
   A. Give a quiz about what was covered last week
   B. Instructor summarizes what was in the assigned readings
   C. Think-Pair-Share
   D. Review quiz grades from homework
   E. Extra Credit

4. As a GTA, I have the authority to introduce some learner-centered teaching approaches into my teaching assignment. [no "right" answer but want to see if feelings change]
   A. Strongly agree
   B. Agree
   C. I'm not sure
   D. Disagree
   E. Strongly Disagree

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Figure I.1: Sample Knowledge Quiz (2019). Correct answers are highlighted in yellow.

5. The best way to do formative assessment of student learning is:
    A. Ongoing, informal classroom assessments
    B. Frequent quizzes for grades
    C. Several midterms and a final
    D. Provide detailed rubrics in advance
    E. Grade performance based on a combination of tests and projects

6. A group of students tell you they have spent 15 minutes trying to solve a difficult problem, but they are still struggling. What do you do?
    A. Mumble something, quietly excuse yourself, then go help a different group
    B. Tell them which equations they need to use
    C. Ask them probing questions to guide them in the correct path without telling them the answer
    D. Give them the answer so they can move on to the next problem
    E. Tell them they need to figure it out on their own, then turn around and leave

7. Another GTA has asked you to come by his recitation to observe him and then give him feedback so he may improve his teaching. Which of the following is **NOT** an example of useful feedback?
    A. "I noticed that in the first group only one person answered your questions. You should try to get all the students in the group involved and participating."
    B. "You explained [topic] with [example], but I personally would have explained it with [some other different example]. I just really like [the different example] better, no particular reason."
    C. "It was kind of hard to hear you when you were writing at the board, especially from the back of the room, so I think you should speak a little louder."
    D. "I like that you used analogies and real-world examples. That really helps students connect with the material."
    E. "Those students said that they didn't know where to start solving the problems and you told them what equations to use. I think you should ask them first what exactly it is that they don't understand, and then guide them through it instead of just giving them the equation from the start. It will take them longer to get to the answer but I think that will help them learn more."

8. All of these are teaching skills that can be beneficial for your future career as a physicist, **EXCEPT:**
    A. Public speaking
    B. Staying on top of various different responsibilities
    C. Managing groups of people
    D. Making friends with students
    E. Explaining difficult concepts to non-experts

9. Which of the following would guide your response if a student shows up in your office to pick up their roommate's graded homework?
    A. FERPA
    B. ODS
    C. GT Honor Code
    D. Code for the prevention of sexual harassment
    E. The Good Roommate Agreement

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Figure I.1: continued from previous page

10. You find out that several students in your class are holding onto a very common misconception about the relationship between force and motion. What's the best way to correct this problem?
    A. Tell the students they are wrong, and that what you tell them is right because you're the teacher
    B. Do a detailed derivation on the board with lots of math that clearly shows that the correct answer is different from what the students originally thought
    C. Ignore it because the professor will talk about it during lecture
    D. Confront the misconception directly by doing an experiment or demonstration that shows the correct idea
    E. Repeat the correct answer a few times and move on, no sense in wasting class time on something that they'll figure out when doing homework anyway

11. All of the following are ways to make your grading more effective and efficient, **EXCEPT:**
    A. Use a carefully constructed rubric
    B. Make very detailed comments on every error, so students know what exactly they did wrong
    C. Discuss the rubric and the answer key with the other GTAs before you start grading
    D. Limit your comments to just the 1-2 most important issues
    E. Try to predict what the common errors will be so you can spot them quickly and move on

12. A student asks you a question in class and you don't know the answer. What should you **NOT** do?
    A. Clarify the question by restating it to make sure you understand what they are asking
    B. Acknowledge the question and say you will consult with the professor to make sure you have the correct answer
    C. Admit you don't know and say you will think about it and answer later
    D. Offer an educated guess to show students your reasoning process when you don't immediately know the answer
    E. Provide an answer, any answer, so that you don't lose credibility

13. Which of the following is the most effective strategy to use if you have to teach a lesson about a topic you do not know very well?
    A. Learn as much as you can about the entire topic before each class
    B. Focus on learning only those aspects of the topic that relate to the specific learning objectives of the class you'll be teaching
    C. Plan to lecture most of the time so that there a fewer opportunities for questions that you might not know how to answer to
    D. Create lists of the key terms to share with the students
    E. Don't worry, you know more than the students do so you should be able to get by

14. All of the following are effective ways to make an engaging explanation, **EXCEPT:**
    A. Start by explaining the main concept and then provide several examples
    B. Start by asking a question that relates to students' prior experiences before explaining the main concept
    C. Make an analogy to something that students are familiar with
    D. Start with a familiar example, then share a classical example, and then explain the concept
    E. Compare and contrast the concept with similar topics and misconceptions

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Figure I.1: continued from previous page

15. The following are techniques you might use to effectively address classroom incivilities, **EXCEPT:**
    A. Prevention is the best medicine: carefully go over expectations for conduct early in the semester
    B. Periodically remind students about your expectations
    C. Ignore it the first few times because the student will probably stop once she or he realizes that it isn't getting a reaction from you
    D. Immediately respond to the situation; don't let it slide because it will get worse
    E. Pull student aside and warn if the situation doesn't improve you will refer them to the professor

16. All of the following are ways to promote effective group work, **EXCEPT:**
    A. Talk to the spokesperson of the group each time you check in with them
    B. Ask students to each take on a specific role
    C. Make a point of asking a different student each time you check on them
    D. Ask another member of the group to respond to the first person before you respond
    E. Gather feedback from the group about their group dynamics

17. When asked what they want most in an instructor, most undergraduates report valuing when an instructor really cares about them. What is one thing you could do to show students that you care?
    A. Learn their names
    B. Hang out with them after class
    C. Be lenient with the grading
    D. Accept all late work
    E. Give them advice on personal problems

18. ODS is:
    A. The Office of Digital Services, that provides technologically enhanced instructional solutions for all instructors at Georgia Tech
    B. The policy outlining expected conduct and procedure for reporting sexual harassment and racial discrimination
    C. The Office of Disability Services, that provides special accommodations for students with documented disabilities
    D. The policy guiding appropriate responses to requests for information about student records and dealing with academic misconduct
    E. An acronym to help you remember techniques for flexible and responsive teaching

19. What is something you should do if you want to maintain a professional working relationship with your research advisor, your TA coordinator, and university staff?
    A. Arrive late to class
    B. Disregard the rubric/key when grading student work
    C. Communicate at the last minute or not at all about scheduling conflicts or any other problems
    D. Prioritize your teaching assignment at the expense of your coursework and research
    E. Establish a clear and consistent system for completing expected tasks and communicating about progress or unexpected delays

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Figure I.1: continued from previous page

20. What should you do to maximize your time management efficiency before any issues pop up?
    A. Schedule large blocks of time devoted to working through the most complicated tasks
    B. Plan to complete your work close to their deadlines since adrenaline makes most people more efficient
    C. Prioritize work that is “important but not urgent” well in advance of any deadlines
    D. Discipline yourself to do without much entertainment and minimize rest periods
    E. Be flexible and go with the flow of each day as it comes

21. Which of the following programs will enable you to continue your professional development in teaching while you are still a student at Georgia Tech?
    A. Pathway to the Professoriate
    B. Preparing Future Faculty
    C. Tech to Teaching
    D. Near-Peer Mentoring
    E. Future Faculty Teaching Fellowship

22. Who should you talk to if you encounter a difficult situation in your lab or recitation that you don’t know how to handle on your own?
    A. The chair of the School of Physics
    B. Your research advisor
    C. One of the professors who teach the lecture of the class for which you TA
    D. The head TA or any other TA who has taught the class before
    E. The TA coordinator for the class you’re teaching

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Figure I.1: continued from previous page

APPENDIX J
KNOWLEDGE QUIZ QUESTION BANK

The Knowledge Quiz is one of the pre/post assessments that we administer to the students in the GTA preparation class. Here we list all the questions available for asking in the Knowledge Quiz and their answer options, along with the category that each question belongs to, the years in which each question was included in the survey, and any wording changes if applicable. The correct answer for each question is displayed in *italics*.

[K1, General Pedagogy, 2013-2019] The approach to teaching that shifts the role of instructors from givers of information to facilitators of student learning is:

(A) *Learner-Centered Teaching*

(B) Teacher-Centered Teaching

(C) Online-Based Teaching

(D) Think-Pair-Share

(E) Expectancy-Value Motivation Theory

[K2, General Pedagogy, 2013-2019] Learner-centered teaching promotes deep learning in all of the following ways, EXCEPT:

(A) Engaging students in higher order thinking

(B) Creating opportunities for students to actively process new material

(C) Using examples and analogies that relate to students' prior experiences and knowledge

(D) Making connections to what students value

(E) *Lecturing extensively in order to cover all of the material*

[K3, General Pedagogy, 2013-2019] Which of the following would be the most learner-centered way to begin a lesson?

(A) Give a quiz about what was covered last week

(B) Instructor summarizes what was in the assigned readings

(C) *Think-Pair-Share*

(D) Review quiz grades from homework

(E) Extra Credit

[K4, Teaching Practice, 2013-2019] As a TA, I have the authority to introduce some learner-centered teaching approaches into my teaching assignment. [no "right answer" but want to see if feelings change]

(A) Strongly agree

(B) Agree

(C) I'm not sure

(D) Disagree

(E) Strongly Disagree

[K5, General Pedagogy, 2013-2019] The best way to do formative assessment of student learning is:

(A) *Ongoing, informal classroom assessments*

(B) Frequent quizzes for grades

(C) Several midterms and a final

(D) Provide detailed rubrics in advance

(E) Grade performance based on a combination of tests and projects

[K6, General Pedagogy, 2013] You want to find out whether students are holding on to common misconceptions about a particular topic. Which of the following Classroom Assessment Techniques might you use to find out?

(A) Concept map

(B) *Minute papers*

(C) Application cards

(D) Exam wrappers

(E) Midterm exam

[K7a, Professional Development, 2014] What are your primary professional roles, now that you're a graduate student at Georgia Tech? Select all that apply.
[K7b, Professional Development, 2015-2016] What do you think are your primary professional roles, now that you're a graduate student at Georgia Tech? Select all that apply. [no "right" answer, but curious about what they think]

(A) Teacher

(B) Researcher

(C) Working adult

(D) Role model

(E) Student

[K8, General Pedagogy, 2013] You want to find out whether your students find the material relevant to their own goals and interests. Which of the following Classroom Assessment Techniques might you use to find out?

(A) Concept map

(B) Minute papers

(C) *Application cards*

(D) Exam wrappers

(E) Midterm exam

[K9a, Pedagogical Content Knowledge, 2014-2016] You have spent 15 minutes helping a group of four students in trying to solve a very difficult problem, and they still seem to be going in circles. What do you do?

(A) Quietly excuse yourself and go help a different group

(B) Tell them which equation they should use, so they can at least figure out the rest of the way from there

(C) *Ask them probing questions that can guide them towards the correct path without explicitly telling them the answer*

(D) Give them the answer so they can move on to the next problem

(E) Say you're done helping them and now they're on their own, then walk away mumbling about stupid students who don't get even the simplest concepts

[K9b, Pedagogical Content Knowledge, 2017-2019] A group of students tell you they have spent 15 minutes trying to solve a difficult problem, but they are still struggling. What do you do?

(A) Mumble something, quietly excuse yourself, then go help a different group

(B) Tell them which equations they need to use

(C) *Ask them probing questions to guide them in the correct path without telling them the answer*

(D) Give them the answer so they can move on to the next problem

(E) Tell them they need to figure it out on their own, then turn around and leave

[K10, Teaching Practice, 2013-2014] Many of your students did poorly on the last test. You want to find out more about how they are studying so that you can help them the next time. Which of the following Classroom Assessment Techniques might you use to find out?

(A) Concept map

(B) Minute papers

(C) Application cards

(D) *Exam wrappers*

(E) Midterm exam

[K11a, Professional Development, 2015-2016] One of your fellow GTAs has asked you to come by his recitation section and watch him teach. Afterwards, he asks you what you thought about his teaching and if you have any feedback to give him. Which of the following is not an example of useful teaching feedback?
[K11b, Professional Development, 2017-2019] Another GTA has asked you to come by his recitation to observe him and then give him feedback so he may improve his teaching. Which of the following is NOT an example of useful feedback?

(A) "I noticed that in the first group only one person answered your questions. You should try to get all the students in the group involved and participating."

(B) *"You explained [topic] with [example], but I personally would have explained it with [another example] because I like that one better."*

(C) "It was kind of hard to hear you when you were writing at the board, so I think you should speak a little louder."

(D) "I like that you used analogies and real-world examples. That really helps students connect with the material."

(E) "Those students said that they didn't know where to start solving the problems and you told them what equations to use. I think you should ask them first what exactly it is that they don't understand, and then guide them through it instead of just giving them the equation from the start. It will take them longer to get to the answer but I think that will help them learn more."

[K12, Teaching Practice, 2013-2016] You find that your students constantly ask you to justify why they lost points on their assignments. Which of the following would be the most appropriate strategy to apply to this situation?

(A) Give them the extra points back

(B) Don't bend because you will undermine your credibility

(C) *Distribute the rubric in advance and refer to it when answering any questions*

(D) Set a policy that any student who challenges a grade will lose a point.

(E) Refer everything up to the instructor of record.

[K13, General Pedagogy, 2013] After carefully reading through student responses to the CAT, you learn that they do in fact have some misconceptions that are keeping them from fully understanding the material. Which of the following would be the most effective response?

(A) Tell the students that this is how it is and they need to get with the program if they want to be successful in this field.

(B) Explain the technical details one more time.

(C) Point out that this misconception is wrong.

(D) *Ask them to make and test predictions based on the misconception in order to expose contradictions*

(E) Present several more concrete examples that illustrate the accurate information.

[K14, Professional Development, 2015-2019] All of the following are teaching skills that can be beneficial in your future physics research, EXCEPT:

(A) Public speaking

(B) Staying on top of various different responsibilities

(C) Managing groups of people

(D) *Making friends with students*

(E) Explaining difficult concepts to non-experts

[K15, Pedagogical Content Knowledge, 2014-2019] You find out that several students in your class are holding onto a very common misconception about the relationship between force and motion. What's the best way to correct this problem?

(A) Tell the students they are wrong, and that what you tell them is right because you're the teacher

(B) Do a detailed derivation on the board with lots of math that clearly shows that the correct answer is different from what the students originally thought

(C) Ignore it because the professor will talk about it during lecture

(D) *Confront the misconception directly by doing an experiment or demonstration that shows the correct idea*

(E) Repeat the correct answer a few times and move on, no sense in wasting class time on something that they'll figure out when doing homework anyway

[K16a, Teaching Practice, 2013-2016] You find that it takes you hours to grade even the most simple of assignments and that you are often out of sync with the way that other TAs in the course grade. All of the following are ways to make your grading more effective and efficient, EXCEPT:

(A) Use a carefully constructed rubric

(B) *Mark each error so students know what to correct*

(C) Do a norming session with the rubric and a few sample assignments

(D) Limit your comments to just the 1-2 most important issues

(E) Mark exemplars of common grammatical errors and ask students to find and correct the rest

[K16b, Teaching Practice, 2017-2019] All of the following are ways to make your grading more effective and efficient, EXCEPT:

(A) Use a carefully constructed rubric

(B) *Mark each error with very detailed comments, so students know what exactly they did wrong*

(C) Discuss the rubric and the answer key with the other GTAs before you start grading

(D) Limit your comments to just the 1-2 most important issues

(E) Identify what the common errors will be so you can spot them quickly and move on

[K17a, General Pedagogy, 2013-2016] All of the following are effective responses to a question you do not know the answer to, except:

[K17b, General Pedagogy, 2017-2019] A student asks you a question in class and you don't know the answer. What should you NOT do?

(A) Clarify the question by restating it to make sure you understand what they are asking

(B) Acknowledge the question and say you will consult with the professor to make sure you have the correct answer

(C) Admit you don't know and say you will think about it and answer later

(D) Offer an educated guess to show students your reasoning process when you don't immediately know the answer

(E) *Provide an answer, any answer, so that you don't lose credibility*

[K18, General Pedagogy, 2013-2019] Which of the following is the most effective strategy to use if you have to teach a lesson about a topic you do not know very well?

(A) Learn as much as you can about the topic before each class.

(B) *Focus on learning only those aspects of the topic that relate to the specific learning objectives.*

(C) Plan to lecture most of the time so that there a fewer opportunities for questions that you might not know how to answer to.

(D) Create lists of the key terms to share with the students

(E) Don't worry – you know more than the students do so you should be able to get by.

[K19, General Pedagogy, 2013-2019] All of the following are effective ways to make an engaging explanation, EXCEPT:

(A) *Start by explaining the main concept and then provide several examples*

(B) Start by asking a question that relates to students' prior experiences before explaining the main concept.

(C) Make an analogy to something that students are familiar with.

(D) Start with a familiar example, then share a classical example, and then explain the concept

(E) Compare and contrast the concept with similar topics and misconceptions.

[K20, General Pedagogy, 2013-2016] Which of the following is not generally considered an active learning technique?

(A) Think-Pair-Share

(B) *Lecture*

(C) Jigsaw

(D) Gallery Walk

(E) Case Studies

[K21, General Pedagogy, 2013-2014] Which of the following is a higher order learning goal?

(A) Identify five active learning techniques

(B) Explain a learner-centered teaching

(C) Know techniques to check for student understanding

(D) *Solve this classroom management problem*

(E) Understand why doing leads to learning

[K22, General Pedagogy, 2013-2016] You spend half of a class period showing examples about a particular issue in your field. You know this is one subject to common misconceptions by most new students. Students compliment you afterwards and say that the explanation was very clear. You feel pretty confident that you have been able to reach them! And indeed, when you quiz them on definitions and the specific examples, the students get the answers right. But when you ask them to solve more involved problems that require critical thinking, they fall back on the misconceptions. What to do?

(A) Blame the students for not paying enough attention or studying enough.

(B) Bond with your fellow TAs over how terrible your students are

(C) Add even more information and examples in your lecture next time

(D) *Give feedback on more difficult questions in class before the test.*

(E) Accept that you have no talent for teaching and should think of a different career

[K23, Teaching Practice, 2013-2019] All of the following are techniques you might use to effectively address classroom incivilities, EXCEPT:

(A) Prevention is the best medicine: carefully go over expectations for conduct early in the semester.

(B) Periodically remind students about your expectations.

(C) *Ignore it the first few times because the student will probably stop once she or he realizes that it isn't getting a reaction from you.*

(D) Immediately respond to the situation; don't let it slide because it will get worse.

(E) Pull student aside and warn if the situation doesn't improve you will refer them to the professor.

[K24, Teaching Practice, 2013-2019] All of the following are ways to promote effective group work, EXCEPT:

(A) *Talk to the spokesperson of the group each time you check in with them.*

(B) Ask students to each take on a specific role

(C) Make a point of asking a different student each time you check on them

(D) Ask another member of the group to respond to the first person before you respond

(E) Gather feedback from the group about their group dynamics.

[K25, Teaching Practice, 2013-2016] Imagine that you are in front of your recitation section and explaining to them that they will be working in groups this semester to solve problems. One student groans loudly and says that he hates group work. All of the following are effective ways to respond except:

(A) Acknowledge that group work is not always easy, but explain that this is a required part of the class and that you will work with them to make it a productive experience.

(B) Engage that student and the class in a discussion about their experience with group work and outline how you will work with them to avoid the common problems.

(C) *Reassure the student that anyone not wanting to work in groups can complete the work individually instead.*

(D) Explain that the problems are so complex that they are more than what just one student can solve alone.

(E) Point out that working in groups is important for their professional development and employers will be looking to make sure they have these skills once they complete college.

[K26, Teaching Practice, 2013-2019] When asked what they want most in an instructor, most undergraduate students report valuing when an instructor really cares about them. What is one thing you could do to show students that you care?

(A) *Learn their names*

(B) Hang out with them after class

(C) Be lenient with the grading

(D) Accept all late work

(E) Give them advice on personal problems

[K27, Teaching Practice, 2013-2016] You got through a very difficult situation where a student was constantly trying to undermine you and other students in the class. Even though sometimes it felt like you were limping towards the finish line, you made it to the end of the semester and feel that you did your best to minimize the damage to the other students' learning and your own credibility. But you can't help but wonder if there might have been another way to handle it. All of the following would be productive ways to move forward except:

(A) Attend a workshop on working with difficult students and establishing a positive classroom environment.

(B) Participate in brown bag discussions with other TAs and/or faculty to talk about common experiences and share strategies for how to handle them

(C) Find and read literature about similar situations and best practices for how to address them.

(D) Journal about your experience to identify opportunities to improve next time.

(E) *Brush off the self-doubt and feel confident that you will do fine if it happens again in the future*

[K28a, Administrative, 2013-2015] ADAPTS is:
[K28b, Administrative, 2016-2019] ODS is:

(A) **[2013-2015]** The Applied Design and Professional Technical Services lab, providing technologically enhanced instructional solutions for all instructors at Georgia Tech
[2016] The academic unit that provides technologically enhanced instructional solutions for all instructors at Georgia Tech
[2017-2019] The Office of Digital Services, that provides technologically enhanced instructional solutions for all instructors at Georgia Tech

(B) The policy outlining expected conduct and procedure for reporting sexual harassment and racial discrimination

(C) *The Office of Disability Services, that provides special accommodations for students with documented disabilities*

(D) The policy guiding appropriate responses to requests for information about student records and dealing with academic misconduct.

(E) An acronym to help you remember techniques for flexible and responsive teaching

[K29a, Administrative, 2013-2016] Which of the following policies would guide your response if a parent calls you to discuss his or her childs grade in your class?
[K29b, Administrative, 2017-2019] Which of the following would guide your response if a student shows up in your office to pick up their roommate's graded homework?

(A) *FERPA*

(B) ADAPTS

(C) GT Honor Code

(D) Code for the prevention of sexual harassment

(E) **[2013-2016]** Helicopter Operation Safety Protocol
[2017-2019] The Good Roommate Agreement

[K30a, Professional Development, 2013-2016] If you want to maintain a professional working relationship with your faculty supervisor, co-TAs (if any) and university staff, please avoid all of the following, except:
[K30b, Professional Development, 2017-2019] What is something you should do if you want to maintain a professional working relationship with your research advisor, your TA coordinator, and university staff?

(A) Arrive late to class

(B) Disregard the rubric/key when grading student work

(C) Communicate at the last minute or not at all about scheduling conflicts or any other problems.

(D) Prioritize your teaching assignment at the expense of your coursework and research.

(E) *Establish a clear and consistent system for completing expected tasks and communicating about progress or unexpected delays.*

[K31a, Professional Development, 2013-2016] What should you do to maximize your time management efficiency before the semester gets away from you?
[K31b, Professional Development, 2017-2019] What should you do to maximize your time management efficiency before any issues pop up?

(A) Schedule large blocks of time devoted to working through the most complicated tasks

(B) Plan to complete your work close to their deadlines since adrenaline makes most people more efficient

(C) *Prioritize work in the "Important but not Urgent" category*

(D) Discipline yourself to do without much entertainment and minimize rest periods

(E) Be flexible and go with the flow of each day as it comes

[K32, Administrative, 2013-2016] Which of the following programs will enable you to continue your professional development in teaching while you are still a student at Georgia Tech?

(A) Pathway to the Professoriate

(B) Preparing Future Faculty

(C) *Tech to Teaching*

(D) Near-Peer Mentoring

(E) Future Faculty Teaching Fellowship

[K33, Administrative, 2013-2016] To which of the following publications might you turn when looking for campus services to support some aspect of your teaching?

(A) *"Teaching at Georgia Tech"*

(B) "Research Horizons"

(C) "The Whistle"

(D) "The Daily Digest"

(E) "The Technique"

[K34, Administrative, 2013-2016] What campus resource should you contact if you would like someone to observe and give you feedback about your teaching?

(A) CEISMC

(B) GOSTEM

(C) TAOS

(D) *CTL*

(E) MOOCs

[K35], Administrative, 2014-2019] Who should you talk to if you encounter a difficult situation in your lab or recitation that you don't know how to handle on your own?

(A) The chair of the School of Physics

(B) Your research advisor

(C) One of the professors who teach the lecture of the class for which you TA

(D) The head TA or any other TA who has taught the class before

(E) *The TA coordinator for the class you're teaching*

APPENDIX K

END-OF-SEMESTER STUDENT EVALUATION QUESTIONS

TAOS Core Questions

Item	**Scale**
Role of TA: Select All Applicable • Lab Assistant • Recitation Assistant • Grading/Testing • Office Hours • Other (Please Specify)	N/A
Quality of Teaching	**5 Point Scale**
1. TA's oral communication skills	Very Poor ? Exceptional
2. TA's written communication skills	Very Poor ? Exceptional
3. TA explained course concepts clearly	Strongly Disagree ? Strongly Agree
4. TA's familiarity with course concepts	Very Poor ? Exceptional
5. TA's respect for students	Very Poor ? Exceptional
6. TA's attitude about their teaching role in this course	Detached ? Extremely Enthusiastic
7. TA stimulated my interest in the subject matter	Ruined My Interest ? Made Me Eager to Learn More
8. TA was approachable for assistance in this course	Strongly Disagree ? Strongly Agree
9. TA's level of preparedness	Completely Unprepared ? Extremely Well Prepared
10. TA's management of classroom/lab environment	Very Poor ? Exceptional
11. TA actively engaged students (*i.e.*, participation, group work, questions, etc.)	Very Poor ? Exceptional
12. Considering everything, the TA was an effective TA	Strongly Disagree ? Strongly Agree
13. Regarding this TA's overall performance	
What was the greatest strength?	Free-form Response (No character limit)
What is the most needed improvement?	Free-form Response (No character limit)
14. General comments regarding TA	Free-form Response (No character limit)

Figure K.1: End-of-semester student evaluation questions. Note that "TAOS" stands for "Teaching Assistant Opinion Survey." From [311].

APPENDIX L

SAMPLE COURSE SYLLABUS (2019)

Georgia Tech Center for Teaching and Learning — Georgia Tech School of Physics

CETL 8000 PH1
Physics GTA Preparation, Fall 2019

Instructor: Ms. Emily Alicea-Muñoz
Email: ealicea@gatech.edu
Phone:[redacted] (texting preferred)
Slack: @ealicea (gtphysics.slack.com)

Office: Howey E-201
Office Hours:
by email appointment

Assisting with Classroom Observations:
Ms. Elaine Rhoades ([redacted]), Ms. Danelle Skinner ([redacted])

COURSE DESCRIPTION AND RESOURCES

This course is designed to support your responsibility to provide our undergraduates with the high quality education that we desire in the School of Physics. In addition, your teaching experience will hone transferable skills that enhance your professional development whatever your intended career path. During this course, you will build a foundation for learner-centered teaching. By the end of the semester, you will have the foundation you need to be a great teacher and to continue your career development beyond the classroom.

This course is a required accompaniment to your first semester as a member of the School of Physics teaching staff. We ask that you take part in the ownership of your education as a co-educator, rather than being a "student" in the more traditional passive sense. It is our expectation that as a co-educator you will:

- Participate actively and thoughtfully at all times.
- Have the conviction to ask and answer difficult questions, take what may seem to be unpopular positions, and admit when you do not know.
- Have patience to listen to and respect others.
- Think, write, and engage with your peers in a scholarly manner; foster a collegial learning environment that is purposeful, open, disciplined, caring, and celebrative.

All necessary course materials will be provided to you in person (e.g., handouts) or in the class **Canvas** site, CETL-8000-PH1 (https://gatech.instructure.com/courses/54618, requires gatech login). All announcements and reminders will be posted there, so please **set your Canvas preferences to receive email notifications** to your [name]@gatech.edu email address.

Additional information about the specifics of the Intro Physics GTA assignments (M&I and Traditional) can be found in the **Physics GTA Resources** website (http://gta.physics.gatech.edu/). If at any point you find anything incorrect in the resources site, please let me know so I can fix it!

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Figure L.1: Sample course syllabus (2019).

Course Objectives

1. Reflect on your professional identity and your roles and responsibilities as a Graduate Teaching Assistant (GTA) in the School of Physics at Georgia Tech.
2. Create a valuable student-centered learning experience, using active learning techniques to explain concepts, anticipate and address student preconceptions, and facilitate problem-solving in any physics classes you teach.
3. Apply teaching principles to giving and receiving feedback, and revise your teaching practice based on feedback received from your instructors, peers, and students.
4. Manage classroom dynamics, including any potential problems that may arise.
5. Assess the level of student understanding using rubrics, and develop strategies for efficiency in grading.
6. Identify transferable skills utilized in teaching that can be useful outside the classroom and valuable towards achieving your career goals.

Course Structure and Content

The class is structured in two parts. The first part is the **JumpStart**, and it consists of a series of workshops to introduce you to life as a GTA and help you develop the skills you need before entering the classroom. Topics covered include:

JS1. **Introduction and Policies** – Welcome, overview, and introductions; GTA duties and expectations; Georgia Tech policies.

JS2. **Teaching Physics** – Brief introduction to active learning; explaining concepts and addressing student preconceptions; the novice/expert divide and anticipating student questions; facilitating problem-solving in physics.

JS3. **Classroom Management** – Strategies for classroom management; facilitation of group work in labs or recitations; how to keep students motivated; introduction to classroom observations.

JS4. **Lab Simulation** – Practice teaching in a lab environment, using real introductory physics lab experiments, while your peers play the parts of students.

JS5. **Microteaching** – Practice teaching problem-solving, and receive feedback from your peers and instructor; practice giving teaching feedback to your peers.

The second part of the course consists of the **Check-In Meetings**, which are 50-minute Friday afternoon class sessions that serve as pedagogical reinforcement during the semester. Topics include:

C1. **Grading** – Strategies for fair and efficient grading, including rubrics; grading practice of real student solutions to old exam problems. There will be separate meetings for the different teaching assignments.

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Figure L.1: continued from previous page

C2. **Midterm Evaluations and Time Management** – Strategies for collecting teaching feedback from students; strategies for effectively managing the time you spend on your different tasks.

C3. **Teaching Videos** – Watch video recordings of physics GTAs at Georgia Tech and critique their use of the teaching strategies you've learned about in this class.

C4. **Teaching and Research** – Identifying transferrable skills in teaching that can help in your career beyond the classroom.

C5. **Concluding Remarks** – Final thoughts and reflection at the end of your first semester of graduate school.

GAP MENTORING MEETINGS

The Graduate Association of Physicists (GAP) will host three mentoring meetings for you during the semester. Attendance to these meetings is strongly encouraged, as they will count towards your Attendance and Participation grade. Also, there will be food!

GAP1. **Academics** – Introduction to GAP; information about the graduate classes and best practices; MS/PhD requirements; what do you need to do to be successful in the program.

GAP2. **Guidance and Support** – What to do when you're starting to feel stressed out; mental health, campus resources; talking with your advisor.

GAP3. **Career Options** – Discussion of the different paths you can take after grad school; what do you need to do, and when do you need to start doing it.

COURSE REQUIREMENTS AND GRADING SCALE

Your performance in this class will be measured via five assessment categories: (1) Attendance and Participation; (2) Pre/Post Tests; (3) Workload Surveys; (4) Teaching Activities and Projects; and (5) Reflections. This class is **PASS/FAIL**, with a 75% cutoff. Earning **75% or above means you pass**, earning **below 75% means you fail**.

1) **Attendance and Participation (AP) – 10pts each – 5% of final grade**
This class is taught with practical exercises that you can apply directly to your teaching. You must be present AND engaged in participation in order to benefit from them and earn AP points.

2) **Pre/Post Tests – 10pts each – 5% of final grade**
These are two diagnostic tools – the *Knowledge Survey (KS)* and the *Approaches to Teaching Inventory (ATI)* – designed to measure your knowledge and opinions about teaching before and after you take this course. You will take the two pre-tests on or before the JS1 class meeting, and the two post-tests during the C5 meeting.

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Figure L.1: continued from previous page

3) Workload Surveys (WS) – 10pts each – 5% of final grade
I will send you a very short survey at the end of each week, from Week 2 to Week 15, for you to list how many hours you have spent working as a GTA that week. This will help you identify time-sinks, and it will allow me to check that you are not being overworked (GTA duties should take no more than 12-13 hours per week on average). Note that statistically aggregated results may be shared with the GTA supervisors but individually identifiable answers will <u>NOT</u> be shared.

4) Teaching Activities and Projects – 50% of final grade
Detailed instructions for each of these will be provided separately.

4a. **Lab Simulation (LabSim) – 100pts**
This happens during the JS4 class meeting. You will facilitate a simulated introductory physics lab experience where your peers will be the students doing the lab experiments, and you'll give feedback to your peers when they do the same. At the end, after everyone has acted as facilitator, you'll answer a short set of review questions about the experience.

4b. **Microteaching – 200pts**
This happens during the JS5 class meetings. You will facilitate solving a physics problem for your peers and receive feedback on your teaching, and you will also provide feedback on your peers' teaching as well. After the activity, you'll answer a set of debrief questions (in short essay format) about the activity and the feedback you received.

4c. **Midterm Evaluations – 200pts**
This is introduced in the C2 class meeting. About halfway into the semester, you will collect feedback from your students, and then you'll write a one-page report on the results you obtained.

4d. **Individual Classroom Observations (ICO) – 100pts**
An instructor will stop by your classroom on a pre-arranged date and time to observe your teaching and give you feedback. The first observation will be during Week 4 (September 9-13), and the second observation will be during Week 10 (October 21-25). After you've gone through both ICOs, you will answer a short debrief about the feedback you received from your instructors.

5) Reflections – 35% of final grade

5a. **My First Week as a GTA – 50pts**
At the end of your first week of teaching duties, you will write a short reflection about how things went during that first week.

5b. **Final Reflection – 150pts**
At the end of the semester, after all the class meetings are over and all other assignments have been turned in, you will write an essay summarizing your experiences in this class and in teaching. Instructions will be provided separately, later in the semester.

Essay assignments will be graded according to the **Essay Rubric**, which is posted on Canvas.

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Figure L.1: continued from previous page

Course Policies

Please read carefully through this section, as these policies are important.

- **Attendance** – You **MUST** attend every class meeting. If you need to be absent due to a reasonable excuse (e.g., illness, professional travel, or similar), then you need to notify me about your absence via email as soon as possible, preferably before the absence happens. I will then provide you with a way to make up for the missed materials and points. If you miss a class meeting without notifying me of the reason for your absence, then you will lose the AP points for the missed session and you'll miss out on the class content.

- **Learning Accommodations** – Accommodations can be made for students with disabilities. The accommodations should be arranged in advance and in accordance with the Office of Disability Services, http://disabilityservices.gatech.edu/

- **Academic Integrity** – Please always keep in mind the obligations and expectations associated with the Academic Honor Code and the Academic Misconduct policies, available at:
  http://www.policylibrary.gatech.edu/academic-affairs/academic-honor-code
  http://www.policylibrary.gatech.edu/student-life/academic-misconduct

- **Late Work** – Assignments are submitted on Canvas. Each assignment has a clearly defined deadline (date and time), which is always a Sunday night at 11:59pm. Late work will be accepted only until **one day** past the deadline (meaning, Monday night at 11:59pm), and will incur a 20% penalty when graded. **Assignments that have not been submitted by the late deadline will not be accepted and will earn a score of zero.**

Course Schedule and Assignment Due Dates

The attached page shows the full semester schedule, including class meeting dates/times, GAP meetings dates/times, and assignment due dates. Please make sure to **put these dates in your calendar** so you don't forget them!

I'll usually send reminders through Canvas, but you're still responsible for keeping track of the course schedule yourself.

Suggestion: don't wait until the last minute to start working on the assignments.

Note that during the semester, we have room Howey S-204 reserved for every Friday at 3pm, but we will not be meeting on every single Friday.

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Figure L.1: continued from previous page

CETL 8000 PH1 – COURSE SCHEDULE AND ASSIGNMENT DUE DATES (FALL 2019)

Title	Date	Time	Location
JS1: Introduction and Policies	Wednesday, August 14	2:00pm – 5:00pm	CULC 129
JS2: Teaching Physics	Thursday, August 15	2:00pm – 5:00pm	CULC 129
JS3: Classroom Management	Friday, August 16	9:00am – 12:00pm	Student Center Piedmont Room
Lunch with Experienced GTAs	Friday, August 16	12:00pm – 1:00pm	Student Center Piedmont Room
JS4: Lab Simulation	Monday, August 19	3:00pm – 5:00pm	CULC 372
JS5: Microteaching #1	Tuesday, August 20	2:00pm – 4:00pm	CULC 375
JS5: Microteaching #2	Wednesday, August 21	2:00pm – 4:00pm	CULC 375
International TA Orientation (International GTAs only)	Thursday, August 29	6:00pm – 7:30pm	Student Center Peachtree Room
C1: Grading (M&I only)	Friday, August 23	3:00pm – 3:50pm	Howey S-204
Microteaching Debrief	Sunday, August 25	11:59pm	Canvas
C1: Grading (Trad and IPLS only)	Friday, August 30	3:00pm – 3:50pm	Howey S-204
My First Week as a GTA	Sunday, September 1	11:59pm	Canvas
C1: Grading (Gradescope – everyone)	Friday, September 6	3:00pm – 3:50pm	Howey S-204
GAP1: Academics	Friday, September 13	3:00pm – 3:50pm	Howey S-204
C2: Midterm Evaluations and Time Management	Friday, September 20	3:00pm – 3:50pm	Howey S-204
GAP2: Guidance and Support	Friday, October 4	3:00pm – 3:50pm	Howey S-204
Midterm Evaluations Report	Sunday, October 13	11:59pm	Canvas
C3: Teaching Videos	Friday, October 18	3:00pm – 3:50pm	Howey S-204
C4: Teaching and Research	Friday, November 1	3:00pm – 3:50pm	Howey S-204
GAP3: Career Options	Friday, November 8	3:00pm – 3:50pm	Howey S-204
C5: Concluding Remarks	Friday, November 15	3:00pm – 3:50pm	Howey S-204
ICO Debrief	Sunday, November 17	11:59pm	Canvas
Final Reflection	Sunday, November 25	11:59pm	Canvas

Clear background: JumpStart and Check-In Meetings; Blue background: GAP meetings; Yellow background: Assignment due dates

Figure L.1: continued from previous page

APPENDIX M
SAMPLE CLASS MATERIALS (2019)

The following pages reproduce some of the class materials from the most recent version of the Physics GTA Preparation course (Fall 2019). In the interest of brevity (we would really prefer this dissertation not turn into a massive thousand-page doorstopper), we do not include all the materials (slides, handouts) from all the lessons. Instead, we only include:

- Handouts for *Teaching Physics*, the second session of the Orientation. The instructions for the Microteaching activity are included in this handout packet.
- A new handout for the *Grading* module, "Intro Physics Grading Flowchart," designed to help GTAs streamline their grading workflow.
- The rubric/evaluation sheet for the Individual Classroom Observations. It should be noted that the definitions and expectations for each rubric item are discussed with the GTAs during the *Classroom Management* lesson, which is the third meeting in the Orientation.

The brave reader who has made it all the way to here should know that if they would like to learn more about the class materials, they can contact the author of this dissertation via email[1]. Additionally, all course materials can be accessed in this Drobox folder:

`https://tinyurl.com/ealiceaGTAPD`

The contents of this folder will be kept updated with the current course materials. At the time of this writing, that would be Fall 2019.

[1] `ealicea@gatech.edu`

Georgia Tech Center for Teaching and Learning

Georgia Tech School of Physics

CETL 8000 PH1
Physics GTA Preparation
Fall 2019

JumpStart Day 2

Teaching Physics

Thursday, 15 August 2019
2:00pm - 5:00pm
CULC 129

Figure M.1: Sample handouts for *Teaching Physics* (2019).

Expert-Novice Comparison

Adapted from "A New TA's Guide to Teaching Introductory Physics" by Kathleen Harper and Sandra Doty (2008)

Experts	Novices
Organize knowledge hierarchically and around basic principles (e.g., kinematics, conservation of energy)	Organize knowledge randomly and around surface features (e.g., inclined planes, pulleys)
Can mentally connect related pieces of knowledge	Haven't yet realized that some topics are interconnected
Tend to draw diagrams before attempting math when problem-solving	Tend to jump straight into equations and numbers when problem-solving
May spend more time thinking about a problem	May try to dive into a problem without thinking about it first
Break complex problems into more manageable pieces	Try to tackle complex problems as a whole
Monitor themselves more frequently	Don't monitor or check their progress
Are guided by the underlying principles of the situation	Often rely on memorized algorithms
Feel comfortable with symbolic problems	Feel more comfortable with problems that have numbers
Check their answers (e.g., units are correct, numbers are physically realistic)	Don't check their answers
Work forward, meaning that they look at the information given and begin figuring out what they can from it	Use means-ends analysis, meaning that they look at the "gap" between start and finish and try to do something to reduce the gap
View problem-solving as a process	View problem-solving as a pure recall task

Some important things to remember:

- All experts were novices at some point
- No one is an expert at everything
- A lot of the novice behaviors are rather logical things to do when you take into account their inexperienced knowledge organization
- Problem-solving is a multidimensional process, so it's possible for a given student to exhibit novice behaviors in some cases and expert behaviors in others

Figure M.1: continued from previous page

Tips for Making Engaging Explanations

Georgia Tech Center for Teaching and Learning (2013)

The goal of an engaging explanation is to make an unfamiliar concept or process meaningful to your students. In order to do this, it is not enough to simply state the concept and its definition. This is unlikely to make a lasting impact or help students to experience a change in their understanding of the topic. Here are some guidelines to help you along.

1. **Make the concept relevant to students.**
   What important question does the concept help to answer? What important problem does the process solve? Activate student's prior knowledge by relating the new concept to what students have already learned in this class or in other classes. How will it relate to concepts or skills students will need in future classes and beyond?

2. **Give an example from a context that is familiar to the students.**
   You might tell a compelling personal story or draw upon common student experiences.

3. **Make an analogy to a context that has been classically studied in your discipline.**
   This is probably the example that is featured in every classical textbook. Explicitly make connections between the more familiar example to the classic example.

4. **Define and describe the concept.**
   Do this only after you have helped the student connect it to prior knowledge and familiar contexts.

5. **Compare/Contrast or Cause/Effect**
   The more students can connect concepts and processes with larger contexts, the more likely it is they will be able to recall and, more importantly, use this concept or process in the future. It is especially important to contrast the concept with any misconceptions your students may have about it.

6. **Find striking visuals that students can associate with the concept.**
   Visuals can provide a powerful mnemonic to trigger student associations later on.

7. **Check for student understanding.**
   Never just assume that your students "got it." Seek feedback about what students have grasped and what still did not make sense.

NOTE: You should always try to limit your explanations to 5-7 minutes at a time. You will not be able to use all of the above strategies in every explanation. Be selective and use only the approach that is most appropriate for the topic you are teaching.

Figure M.1: continued from previous page

Summary of Findings from Physics Education Research

From "Five Easy Lessons: Strategies for Successful Physics Teaching" by Randall D. Knight (2002)

In brief summary, Physics Education Research (PER) has revealed that:

- **Students enter our classroom not as "blank slates,"** ***tabula rasa*****, but filled with many prior concepts.** These are called, by various researchers, misconceptions, preconceptions, alternative conceptions, or common-sense conceptions. Students' concepts are rather muddled, not well differentiated, and contain unrecognized inconsistencies. By the standards of physics, their concepts are mostly wrong. Even so, they are the concepts by which students make decisions about physical processes.

- **Students' prior concepts are remarkably resistant to change.** Conventional instruction – lecture classes, homework, and exams that are predominantly or exclusively quantitative – makes almost no change in a students' conceptual beliefs.

- **Students' knowledge is not organized in any coherent framework.** At the end of instruction, their knowledge of physics consists of many discrete facts and formulas only loosely connected to each other. This is in contrast to a physicist's knowledge, which is organized in terms of physical principles. Whereas a physicist sees "a Newton's second law problem," then retrieves specific knowledge as needed, most students see "a falling body problem," or "an inclined plane problem," or "a pulley problem," with little or no recognition of the similarities. Their organization of knowledge (or lack thereof) is largely responsible for their formula-seeking problem-solving strategies. Our typical admonition that "Newton's laws are all you need to remember" is meaningless to students who lack the knowledge organization that we have.

As a result, most students don't develop a functional understanding of physics, they can't apply their knowledge to problems or situations not previously encountered, and they can't reason correctly about physical processes.

A few PER References (some, but not all, are cited in the "Five Easy Lessons" book)

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S. Freeman, et al., PNAS, 111, 23 (2014)
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A. Van Heuvelen, Am. J. Phys, 59, 891 (1991)

Figure M.1: continued from previous page

Engaging Students: Characteristics of Successful Active Learning

From "Five Easy Lessons: Strategies for Successful Physics Teaching" by Randall D. Knight (2002)

The main idea behind active learning is to get students to construct their own knowledge. The students do activities that keep them engaged, thinking, and learning, instead of sitting passively and taking notes. The following are a few characteristics of successful active learning in the physics classroom:

- Students spend much of class time actively engaged in doing/thinking/talking physics – not listening to someone else talk about physics
- Students interact with their peers
- Students receive immediate feedback on their work
- The instructor is more of a facilitator, less a conveyor of knowledge. "A guide on the side, not a sage on the stage" is a simpleminded but memorable cliché that makes the point
- Students take responsibility for their knowledge. This includes participating in activities, studying the text, and completing the assignments. "You didn't talk about this in class" is not an acceptable excuse for missing an exam question – assuming that the question was based on material that was well described in the textbook

Note that lecture classes that encourage student questions and discussion are –with some exceptions– not active learning environments. Only a small fraction of students ask questions or participate in open discussions. The majority of the class are still passive watchers and listeners. In fact, most students probably listen to their peers even less closely than to the instructor. Questions and discussion can be important *components* of an active learning environment, particularly in smaller classes, but they don't constitute active learning in and of themselves.

"Active learning" does not connote a single type of teaching. There are a variety of approaches to active learning, and an instructor needs to select what will work best in his or her local situation. Some approaches work well in large lecture halls, others really are dependent on smaller groups. Some require TAs, some can be done by an instructor alone. Some can be effective with small changes in teaching style, others require a significant overhaul. The point though is that they all work! Interactive engagement in any form is more effective than conventional lecture instruction.

Figure M.1: continued from previous page

Dealing with Students' Misconceptions

From "Five Easy Lessons: Strategies for Successful Physics Teaching" by Randall D. Knight (2002)

Before students can absorb new knowledge they need to be rid of the incorrect information that is already in their minds. One of our most important tasks as teachers is to persuade them to erase the incorrect information, then to provide them with reasons to build better mental models. It is important to note, however, that simply *telling* them what's wrong with their preconceptions and *telling* them the right ideas will have little to no effect.

Many researchers have found that the most effective learning cycle appears to be:

- **Confront student misconceptions directly.** This is most often done through experiments or lecture demonstrations known to elicit common misconceptions. Students are asked to make a prediction, and the instructor or assignment usually asks them to be explicit about their reasoning (this forces them to use their mental model, rather than just guess). Then the experiment or demonstration is performed.

- **Explore the fact that many predictions were wrong.** This can't be glossed over quickly. Students have to recognize and accept that there really is a conflict between their prediction and reality. Left to themselves, many students will brush the conflict aside as of no relevance.

- **Consider alternative models.** This must include not only the hypotheses of the model (such as $F=ma$), but clarifying and differentiating the terms of the model (such as distinguishing velocity and acceleration, rather than the students' undifferentiated idea of *motion*). Be explicit about the reasoning steps from the hypotheses of the model to the prediction of a specific experimental outcome.

- **Reiterate.** Students' alternative conceptions are highly resistant to change, and one example of a conflict is unlikely to have much effect. They need to see repeatedly that their conceptual model fails, when put to the test, but that an alternative model succeeds.

There's a delicate balance here for the instructor. You need to challenge students' misconceptions, but you don't want to put students down or make them feel dumb for holding such views. Emphasizing two items can help. First, nearly everyone holds these misconceptions, including many very smart people in other disciplines. They're not alone. Second, the concepts of physics *are* difficult and aren't obvious. Galileo couldn't figure them all out, and even Newton struggled with them for many years. But everything's easier in hindsight than it was to discover, so they *can* learn these ideas if they keep practicing.

Figure M.1: continued from previous page

Teaching Physics Problem Solving Skills

From "Five Easy Lessons: Strategies for Successful Physics Teaching" by Randall D. Knight (2002)

Many students have breezed through high school science classes by being skilled equation hunters. Although such a simple strategy fails when facing the increasingly complex problems of college courses, students have no other alternative strategy at their disposal. Exhortations to "just remember a few general principles" are meaningless to students because they don't know –unless they' re taught—how to reason this way.

A major goal of the introductory physics course is for students to learn more sophisticated problem-solving skills. But such an outcome does not happen automatically for many students. To succeed, we must:

- Teach students the specific skills needed to solve complex problems. These include interpretation skills, pictorial skills, graphical skills, and reasoning skills.
- Show students how those skills are assembled into a powerful problem-solving strategy and demonstrate their use, in detail, in the example problems we work in class.
- Make explicit the assumptions, decisions, and reasoning that are part of an expert's problem-solving strategy but which usually go unsaid.
- Help students organize their knowledge in a more coherent, hierarchical, easily searched structure.

A coherent knowledge structure is essential if students are to follow a more sophisticated problem-solving strategy, but how is such a knowledge structure built? This is a bit of a chicken-and-egg problem. One way is to ask students for significant qualitative reasoning and explanations, activities that promote learning the logical connections between ideas rather than the memorization of formulas. Another is to require the students to follow the specific steps of a problem-solving strategy, either instructor-provided or given in the text. This forces the students to consider other issues besides "find the right formula" and with practice this technique aids them in building a coherent knowledge structure.

Figure M.1: continued from previous page

Intro Physics Problem Solving Tips for Students

Alec Lindman, Fall 2014

The key to helping students with problem-solving is to **coach** them, never give them the answer (but this doesn't mean that you should never show students how to work out sample problems!). When coaching, try to get students to explain their thought process. Prompt them with questions like "what is the underlying physical principle?" or "what have you tried so far?" This way you can identify where they're going wrong, and you avoid having them accidentally lucking into a correct solution.

The following is a little "recipe" for problem-solving that Alec Lindman, a former GTA, wrote for his students in a flipped lab in Fall 2014. I'm reproducing his recipe here with his permission, as I thought it was a good starting point for students when learning problem-solving.

~ * ~ * ~ * ~ * ~ * ~ * ~

Of course I won't just give you the answers to everything. However, here's the answer to almost everything, or rather how to solve almost every problem this semester:

- Determine what's happening in the question and draw a diagram, if appropriate.
- Identify the physical principle you'll use to understand the event.
- List the information you have and what you need:
    - Things you know that are relevant and useful
    - Things you know (or that the problem told you) that are irrelevant
    - Things you want to find
- Figure out what your answer should look like:
    - Roughly what size should it be? For example, if someone throws a ball, it probably shouldn't come out going faster than the speed of sound.
    - What units should it have? It's reasonable to conclude that the weight of a book probably shouldn't be measured in centimeters.
    - Should the answer grow or shrink in particular ways if you change the initial conditions? Finding a light bulb gets brighter when you turn off the switch isn't very logical.
- Use the physical principle you identified earlier to build the equation or equations that you'll use to relate the information you know and find what you want to find.
- Work with the equations algebraically until you find an expression that tells you precisely the answer you want. Notice that you have **NOT** used any numbers thus far. If you do all your work symbolically, you can check the units, you can check many of your previous ideas – are the units correct, and does it grow or shrink correctly when you change the values that make it up? If you have a page full of numbers and no equations, I'm not going to be able to help you much, since numbers are all anonymous.
- Plug in your values and check that the size of your answer makes sense.
- Make sure to include your units with your answer – you should know them from the units of the algebraic expression into which you substituted your values.

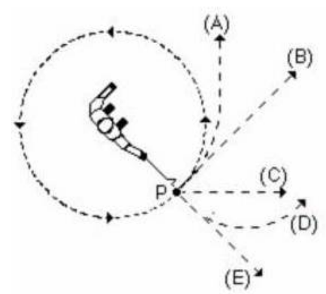
If you follow these steps, you'll have done exactly what I would have done to solve the problem, and most likely you'll have the right answer. If not, the form of your work should allow myself or one of your groupmates to look through and find where you went wrong, without drowning in a sea of numbers.

Figure M.1: continued from previous page

Identifying Misconceptions, or "Why did they get it wrong?"

Example 1

A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure. At the point **P** indicated in the figure, the string suddenly breaks near the ball. If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?



Correct Answer: B

Why would a student choose the incorrect answers?
How would you address these misconceptions and correct them?

Option A	**Option C**
Option D	**Option E**

Figure M.1: continued from previous page

Example 2

A truck and a car are in a head-on collision.
The truck is much heavier than the car.

Case 1: The car and the truck are moving at the same speed when they collide.
Case 2: The car is moving much faster than the truck when they collide.
Case 3: The truck is parked when the moving car collides head-on with it.

Consider each case separately. Which of the following possibilities, A through D, best describes the forces between the car and the truck in each individual case?

A. The truck exerts more force on the car than the car does on the truck
B. The truck exerts the same amount of force on the car as the car does on the truck
C. The truck exerts a force on the car but the car doesn't exert a force on the truck
D. The car exerts more force on the truck than the truck does on the car

Correct answer is B in all three cases.
Why would a student pick any of the incorrect answers?
How would you fix these misconceptions?

Case 1

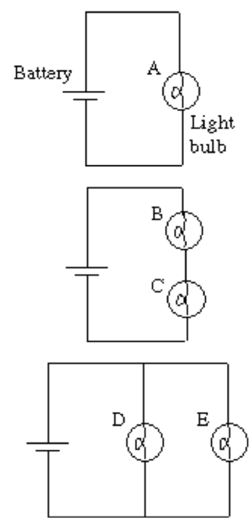
Case 2

Case 3

Figure M.1: continued from previous page

Example 3

In these three circuits, all three batteries are identical and have negligible internal resistance, and all the light bulbs are identical.



Rank all the light bulbs (A, B, C, D, E) in order of brightness, from brightest to dimmest.

1) A = B = C > D = E

2) A > B = C = D = E

3) A > B = C > D = E

4) A > B > C > D = E

5) A = D = E > B = C

6) A = D = E > B > C

7) A > D = E > B = C

8) D = E > A > B = C

Correct order is 5 (in BOLD).

Why would a student pick any of the incorrect orders?
How would you help them understand what is correct?

Figure M.1: continued from previous page

Problem-Solving Class Activity

The purpose of this activity is to give you some practice and familiarity with intro-level problem-solving. We're doing this not only to show you the type of problems a PHYS 2211 or 2212 student might get in an exam, but also to give you an opportunity to think of ways to help students solve such problems.

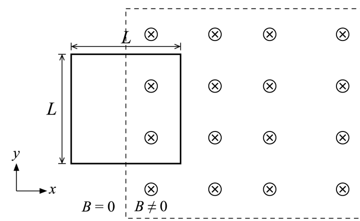
In the following pages you'll find four introductory physics problems.

- Split up into **groups of 5 people**. Each group will work on only one problem, which I will assign.
- Each person should briefly read through their assigned problem and think of how solve it, using introductory level physics and math – no Lagrangians here please!
- Each group will spend **10 minutes** working on their problem. You should use that time to:
    - Discuss the problem as a group (talk about the physical principles involved, the knowns and unknowns, steps needed to solve it, etc)
    - Solve the problem (writing stuff out and boxing the solution)
    - Discuss (and write down) the sorts of issues you anticipate an intro student would have with working through this problem, and how you would help them
- Afterwards, we'll have a full class discussion about problem-solving facilitation strategies.

Figure M.1: continued from previous page

Problem 1

A square loop of side-length L and total resistance R is located halfway inside a region with uniform magnetic field B_0. The magnitude of the magnetic field suddenly begins to increase linearly with time, eventually quadrupling in a time T.



(a) What is the magnitude and direction of the current induced in the loop at time T?

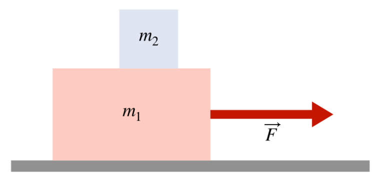
(b) What is the magnitude and direction of the net force on the loop at time T?

What issues do you expect intro students to have with this problem? How would you help them?

Figure M.1: continued from previous page

Problem 2

A block with $m_2 = 12$ kg is placed on top of another block with $m_1 = 29$ kg. A force of $F = 361$ N is applied to the right (+ x direction) on the lower block, and the upper block slips on the lower block (accelerating less than the lower block). The coefficient of kinetic friction between the upper block and the lower block is $\mu_{1,2} = 0.2$ and the coefficient of kinetic friction between the lower block and the floor is $\mu_{1,f} = 0.4$.



(a) What is the acceleration of the upper block? (magnitude and direction)

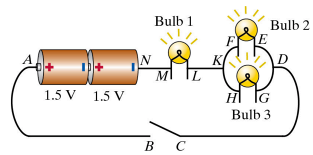
(b) What is the acceleration of the lower block? (magnitude and direction)

What issues do you expect intro students to have with this problem? How would you help them?

Figure M.1: continued from previous page

Problem 3

A circuit is made of two 1.5 volt batteries and three light bulbs as shown in the figure. When the switch is closed and the bulbs are glowing, Bulb 1 has a resistance of 14 ohms, Bulb 2 has a resistance of 35 ohms, and Bulb 3 has a resistance of 28 ohms (the wires and batteries have negligible resistance).



(a) In steady-state, the currents through bulbs 1, 2, and 3 are I_1, I_2, and I_3, respectively. Write down the loop and node rules for this circuit.

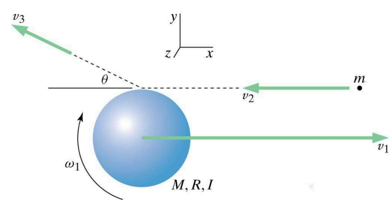
(b) Determine the magnitudes of the three currents.

What issues do you expect intro students to have with this problem? How would you help them?

Figure M.1: continued from previous page

Problem 4

A spherical satellite of radius R and mass M is originally moving with a speed v_1 and rotating with angular speed ω_1 in the directions shown in the diagram. A small piece of space junk of mass m is initially moving towards the satellite with speed v_2. The space junk hits the edge of the satellite at the location shown in the diagram, and moves off with a new velocity v_3 at an angle θ as indicated in the diagram. Before and after the collision, the rotation of the space junk is negligible.



(a) What is the magnitude and direction of the new angular velocity of the satellite after the collision?

What issues do you expect intro students to have with this problem? How would you help them?

Figure M.1: continued from previous page

Georgia Tech Center for Teaching and Learning

Georgia Tech School of Physics

Microteaching Instructions

Microteaching is an opportunity for you to practice teaching/facilitating (for problem-solving specifically) in front of an audience of your peers, who will give you feedback on your teaching. You'll also have the opportunity to give your peers feedback on their teaching. This practice will be useful to both recitation and lab GTAs, since regardless of your TA assignment, you'll need to help students solve problems.

Logistics

- There will be two Microteaching Practice sessions, in **CULC 375** starting at **2:00pm**
    - Microteaching 1 – Monday, August 20
    - Microteaching 2 – Wednesday, August 21
    - Note that each grad student only needs to attend **ONE** session. This means half of you does microteaching on Monday, and the other half does it on Wednesday.

- In the JS2: Teaching Physics class meeting you were presented with some introductory physics problems to choose from. You pick whichever problem you prefer, and that is the problem that you will be microteaching about.

- Each problem has a sign-up sheet. A maximum of **two people** may sign up to teach each of the problems.

- When you sign up, you collect a copy of the problem, but **you will not be given a solution** at first – the solutions will be available on Canvas after Microteaching is over.

- At some point before your assigned microteaching session you will need to sit down and solve your problem, keeping in mind that these are INTRODUCTORY physics problems and therefore you shouldn't be using any advanced physics or math in the solution.
    - For reference, intro physics students should know trigonometry and how to differentiate and integrate (though some may have trouble with integration).
    - Don't freak out if you can't solve the problem by just looking at it. And please don't be afraid to ask for help if you need it!

- When you're preparing to microteach, **don't plan on just standing at the board** to solve the problem. You will be facilitating, not lecturing.

Figure M.1: continued from previous page

The Activity

- The instructor will indicate one person to be the **Teacher**. This will be the person going up to microteach their problem. The rest of the people in the room will be the **Peers** (i.e., the students taking the class), and they will be split into two groups of ~4 people each.

- Each Teacher will have a maximum of **10 minutes** to microteach their selected problem. As mentioned earlier, please note that **you shouldn't plan to just stand at the board**, solve the problem, and display the solution. Although you will of course need to use the board, you will need to guide the two groups of Peers into solving the problem on their own. You will be, essentially, **facilitating** a problem-solving session for your Peers, not just showing them how to do a problem at the board.
  - For an example of what facilitating problem-solving looks like, please refer to the **Microteaching Sample video on Canvas**. But do keep in mind that you don't have to microteach exactly the same way as in the sample video. The video is just a guideline, showing how you can guide people in solving a problem without straight-up lecturing.
  - It's ok if you run out of time without finishing the entire problem!

- After the 10 minutes are over, the instructor will give the Teacher feedback on their teaching, while the two Peer groups write down their own feedback as well.

- Each Peer group will be given a **Microteaching Feedback Form** with two items to fill out together, as a group:
  - **Positive feedback** – what did the Teacher do well?
  - **Areas for improvement** – what does the Teacher need to work on?
  - Please make sure that what's written is legible, as you will be giving this feedback form to the Teacher once it's filled out.

- When giving feedback, focus primarily on **teaching technique**. If you give the Teacher any physics feedback, make sure to explain your reasoning. Meaning, don't just say that you prefer some other alternative method of explaining a concept, but rather **explain** why you think said alternative method is better.

- The feedback session for each Teacher should last no more than **5 minutes**. The instructor will call on Peers at random for them to say some of their group's feedback out loud to the Teacher.

- After the first Teacher has finished microteaching, and has received (written and oral) feedback from both the instructor and the two Peer groups, then the instructor will call on the next person who will microteach. Teacher #2 will then get up, and Teacher #1 will take their former place, becoming part of one of the Peer groups.

- The process will be repeated until all the grad students in the room have microtaught, with a five-minute break after half of the microteachings have happened.

Figure M.1: continued from previous page

Microteaching Debrief Essay

After the microteaching sessions, every person in the class will have received three Microteaching Feedback forms: one from the instructor and one from each of their two Peer groups. You will use the feedback you received, as well as your thoughts about the experience, to answer the questions in the Microteaching Debrief, in the format of a short essay.

These are the debrief questions:

1. What problem did you select, and why? How did you prepare for teaching?

2. What feedback fid you receive from your peers and instructor? Do you agree, or was it surprising? Include at least one item of positive feedback and one area for improvement.

3. What do you think about your peers' approaches to teaching? Did anything good or bad stand out? Don't mention names when answering this question!

4. What effect will this activity have on your teaching this semester? In other words, how do you think your teaching will improve after going through the Microteaching Practice?

Your short essay should have **no more than one paragraph per question** (1 page max). The essay will be graded according to the Essay Rubric (available on Canvas).

The deadline for this assignment is **Sunday, August 25, at 11:59pm**, on Canvas.

Preferred file formats: **.pdf** or **.docx**
Also acceptable: **.doc**, **.txt**, **.rtf**, **.pages**,

Figure M.1: continued from previous page

Georgia Tech Center for Teaching and Learning

Georgia Tech School of Physics

Microteaching Feedback Form

Teacher: ______________________________ Problem: ______________________

Peers: ____

Tips for giving feedback:

- Be specific; don't just say "you did good" or "that was bad"
- Prioritize the most significant feedback; avoid nitpicking
- Focus your feedback on teaching technique; if giving specific physics feedback, then explain your reasoning for it (don't just say X, Y, or Z is better, but rather explain why you think that)
- Refer to behavior that can be changed (e.g., don't tell someone to lose their accent, but rather ask them to speak louder or slower if necessary)
- Describe what you have seen or heard instead of interpreting (e.g., "the speaker made eye contact with most of the class" instead of "there was good eye contact")

Positive feedback: what did the Teacher do well?

Areas for improvement: what does the Teacher need to work on?

Figure M.1: continued from previous page

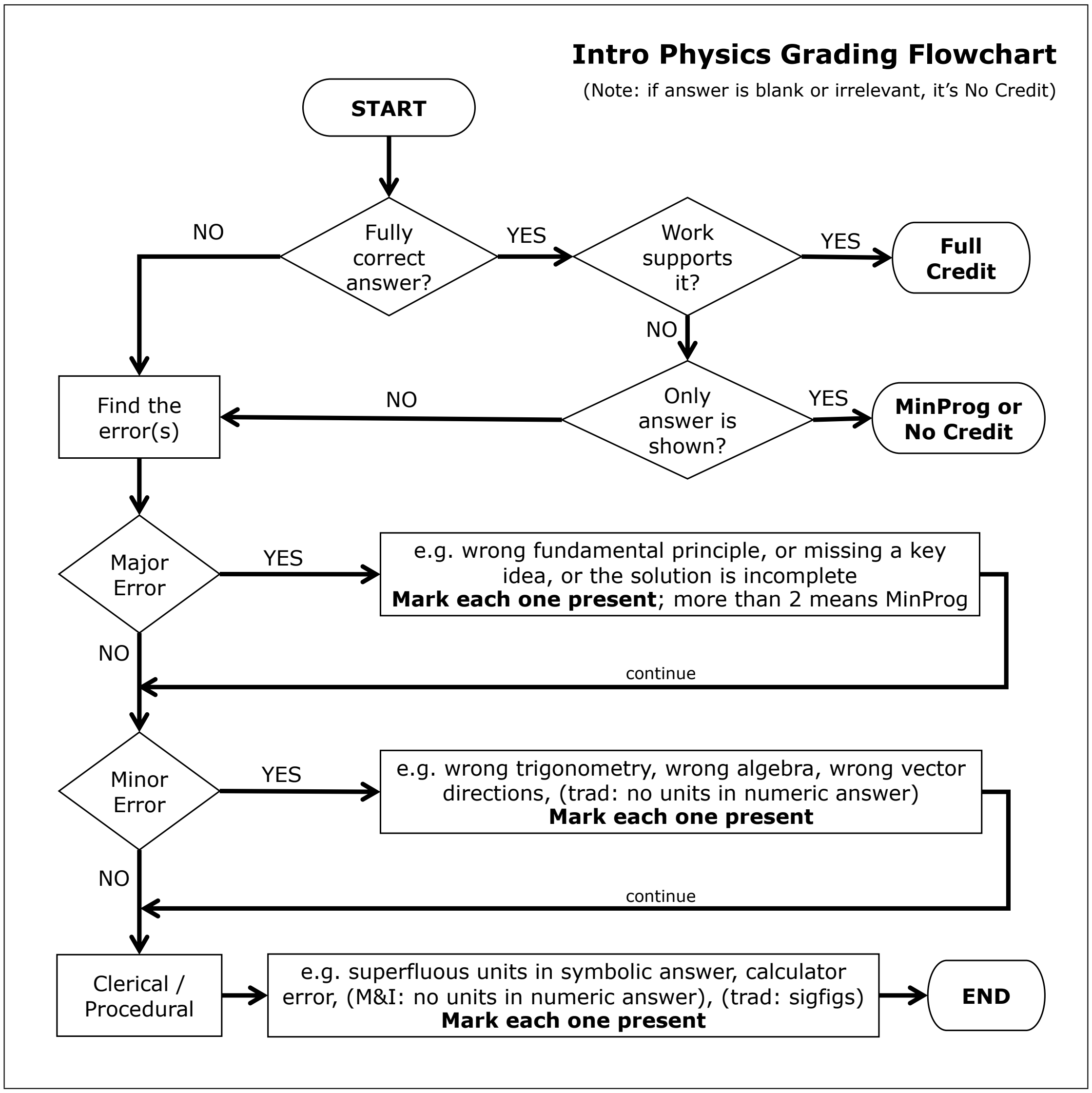


Figure M.2: Grading flowchart (2019).

Individual Classroom Observations (**ICO**) Evaluation Sheet

GTA Name: ___________________________ [Traditional / M&I / IPLS] **Date:** ____________________

PHYS 2211 / 2212 / Other: ___________________ [Recitation / Lab] **Observer:** ____________________

GTA wants instructor feedback about: ____

GTA Evaluation Criteria (ICO)	Excellent	Good	Just OK	Need to improve	N/A
Uses the first 10 minutes of recitation/lab effectively					
Speaks with a clear, audible, and well-modulated voice					
At the board, the GTA's handwriting is legible					
Shows enthusiasm for physics and tries to motivate students					
Checks for student understanding by asking probing questions (without sounding condescending)					
Helps students develop the necessary problem-solving skills and coaches them without giving away the answers					
When students are working in groups, the GTA makes sure that all group members are actively participating					
Spreads his/her time reasonably among the various groups of students in the lab/classroom					
Comes to the lab/recitation prepared and can think on his/her feet if there's a need for troubleshooting					

Additional comments and observations:

Figure M.3: Rubric/evaluation sheet for Individual Classroom Observations (2019).

APPENDIX N

IRB CONSENT FORM

Georgia Institute of Technology

Project Title: Improving Teaching Assistant Development in the Sciences

Investigators: Carol Subino Sullivan, Ph.D., Cara Gormally, Ph.D. Emily Alicea-Muñoz, Donna Llewellen, Ph.D. Michael Schatz, Ph.D. Tris Utschig, Ph.D.

Protocol and Consent Title: “Improving Teaching Assistant Development in the Sciences”

You are being asked to be a volunteer in a research study.

Purpose: The purpose of this study is to evaluate whether our new Teaching Assistant (TA) development program for the sciences is effective at improving TA’s teaching effectiveness. We expect to enroll up to 50 people in the study per year.

Exclusion/Inclusion Criteria: Participants in this study must be TAs at Georgia Tech.

Procedures:
If you volunteer to participate in the research study, you may be asked to do the following: if you are enrolled in CETL 2000/8000, allow researchers to analyze the work done to satisfy the normal requirements of the course including some or all of the following; a diagnostic pre-test and post-test, up to two practice teaching exercises (called “microteaching”), a learning portfolio, one or more classroom observations and writing weekly reflections on your teaching experiences. However, your participation in this study is not required for this course, and your course instructor(s) will not know whether or not you have consented until after the semester is complete and your grades have been submitted.

In addition to typical class requirements, you may be asked to do some or all of the following: a video recorded teaching observation of a single session of your normal teaching responsibilities (up to three hours) once during your first term as a TA and once again during a subsequent term, participate in an audio recorded interview of no more than 120 minutes, allow your mid-semester and final teaching evaluations (TAOS) from your teaching assignments to be analyzed, participate in one video recorded focus group (up to one hour), and/or complete a survey to determine how helpful the TA development program was in your preparation for teaching.

Risks or Discomforts: There are no risks or discomforts expected to be associated with this research study any greater than those involved in daily activities.

APPROVED *Consent Form Approved by Georgia Tech IRB: September 18, 2014 - Indefinite*

Figure N.1: IRB Consent Form.

Benefits: You will directly benefit from participating in this study by becoming better prepared for your teaching assignments through increased feedback and analysis of your teaching practices. You will also develop teaching skills that are transferable to your future career whether it is in academia or industry. In addition, future TAs in all the sciences will benefit from the improved curriculum developed as a result of the assessment study. The indirect benefit of the study is that undergraduate student learning will improve as a result of the more effective instruction they get from their TAs.

Compensation to You: There is no compensation for participation.

Confidentiality: The following procedures will be followed to protect your privacy in this study: The data collected about you will be kept private to the extent allowed by law. Your records will be kept under a code number rather than by name. Your records, including documents, audio and video recordings, will be kept in secure files and only study staff will be allowed to look at them. The course instructor will not learn the identity of those students who have agreed to participate until after course grades have been submitted. Although your confidentiality cannot be guaranteed because of the nature of the focus group, every effort will be made to protect your privacy. Video recordings made of the focus groups are for the sole purpose of determining speakers during the transcription process and will be deleted after said transcription. Your records will be stored appropriately and your name and any other fact that might point to you will not appear when results of this study are presented or published. The researcher will use pseudonyms to protect identifiers in reporting. Your privacy will be protected to the extent allowed by law. To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB may review study records. The Office of Human Research Protections and/or the Food and Drug Administration may also look over study records during required reviews.

Costs to You: There are no costs to you, other than your time, for being in this study.

In Case of Injury/Harm: If you are injured as a result of being in this study, please contact Carol Subino Sullivan, Ph.D., at telephone (404) 894-1355. Neither the Principal Investigator nor Georgia Institute of Technology has made provision for payment of costs associated with any injury resulting from participation in this study.

Participant Rights:

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason and without penalty.

APPROVED *Consent Form Approved by Georgia Tech IRB: September 18, 2014 - Indefinite*

Figure N.1: continued from previous page

- Any new information that may make you change your mind about being in this study will be given to you.
- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

Questions about the Study: If you have any questions about the study, you may contact Dr. Subino Sullivan at telephone (404) 894-1355 or csubino@cetl.gatech.edu.

Questions about Your Rights as a Research Participant:
If you have any questions about your rights as a research participant, you may contact

Ms. Melanie Clark, Georgia Institute of Technology
Office of Research Integrity Assurance, at (404) 894-6942.
[or]
Ms. Kelly Winn, Georgia Institute of Technology
Office of Research Integrity Assurance, at (404) 385- 2175.

If you sign below, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this study.

____
Participant Name (printed)

____ ____________
Participant Signature Date

____ ____________
Signature of Person Obtaining Consent Date

APPROVED *Consent Form Approved by Georgia Tech IRB: September 18, 2014 - Indefinite*

Figure N.1: continued from previous page

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VITA

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