Transforming the Preparation of Physics Graduate Teaching Assistants

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Michigan State PER Seminar

4 December 2019

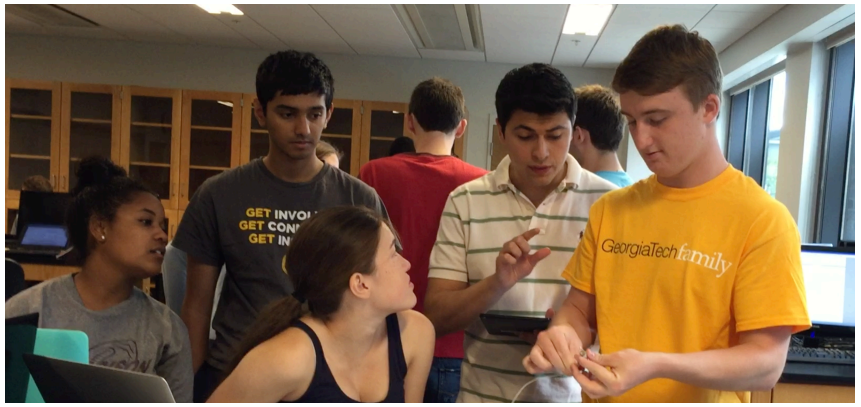
Georgia Tech School of Physics
College of Sciences

Outline

- Background and Motivation
- Developing the “Physics GTA Preparation” Course
- Results from Program Assessment
  - The initial conditions of first-time GTAs in the School of Physics
  - Surveys and Pre/Post Tests
  - End-of-Semester Student Evaluations
- Conclusions and Summary

GTAs are key partners in education of undergrads

- Undergrads spend ~half of their intro physics class time with GTAs
  - At Georgia Tech, these are mostly first-year PhD students
- Potential for **large impact** on student learning
  - At Georgia Tech, ~1800 undergrads/semester take intro physics
- **GTAs need preparation for teaching**



My work: Physics GTA Preparation

- CETL 8000 PH1: Physics GTA Preparation
  - Course design and instruction
  - Curriculum development
  - Program assessment

- Transformed the old “TA training” into a comprehensive GTA professional development program

Tale as old as time…

"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, American Journal of Physics, 25(3), **1957**

1970 and earlier

1980

Logistics for teaching labs, basics of pedagogy, peer observations, video recording

Ohio State
[AmJPhys, 39, 1971]

U Missouri
[AmJPhys, 42, 1974]

Kansas State
[AmJPhys, 42, 1974]

UC Berkeley
[AmJPhys, 43, 1974]

Temple U
[AmJPhys, 46, 1978]

1990

First meta-analyses of GTA prep research; calls for more systematic research

Carroll
[J Higher Ed, 51, 1980]

Abbott et al
[New Directions for Teaching and Learning, 39, 1989]

2000 and beyond

PER, concept inventories, active learning; first long-lasting GTA prep programs

Lawrenz et al
[J College Science Teaching, 22, 1992]

Hestenes et al
[TPT, 30, 1992]

Hake
[AmJPhys, 66, 1998]

Redish & Steinberg
[Physics Today, 51, 1999]

[hundreds of references]

Research shows that…

- Training improves GTAs' teaching **confidence** and **self-efficacy**
  - Prieto & Altmaier, Research in Higher Education, 35(4), 1994
  - Boman, PhD Thesis, 2008
  - Harris et al, International Journal of Mathematical Education in Science and Technology, 40, 2009
  - DeChenne et al, Journal of the Scholarship of Teaching and Learning, 12(4), 2012
  - Reeves et al, CBE-Life Sciences Education, 17, 2018

Research shows that…

- Training improves GTAs' **pedagogical content knowledge (PCK)** and can result in adoption of learner-centered teaching styles
  - Gibbs & Coffey, Active Learning in Higher Education, 5, 2004
  - Lin et al, PhysRev ST-PER, 9, 010120, 2013
  - Wheeler et al, Journal of Chemical Education, 94, 2017

Research shows that…

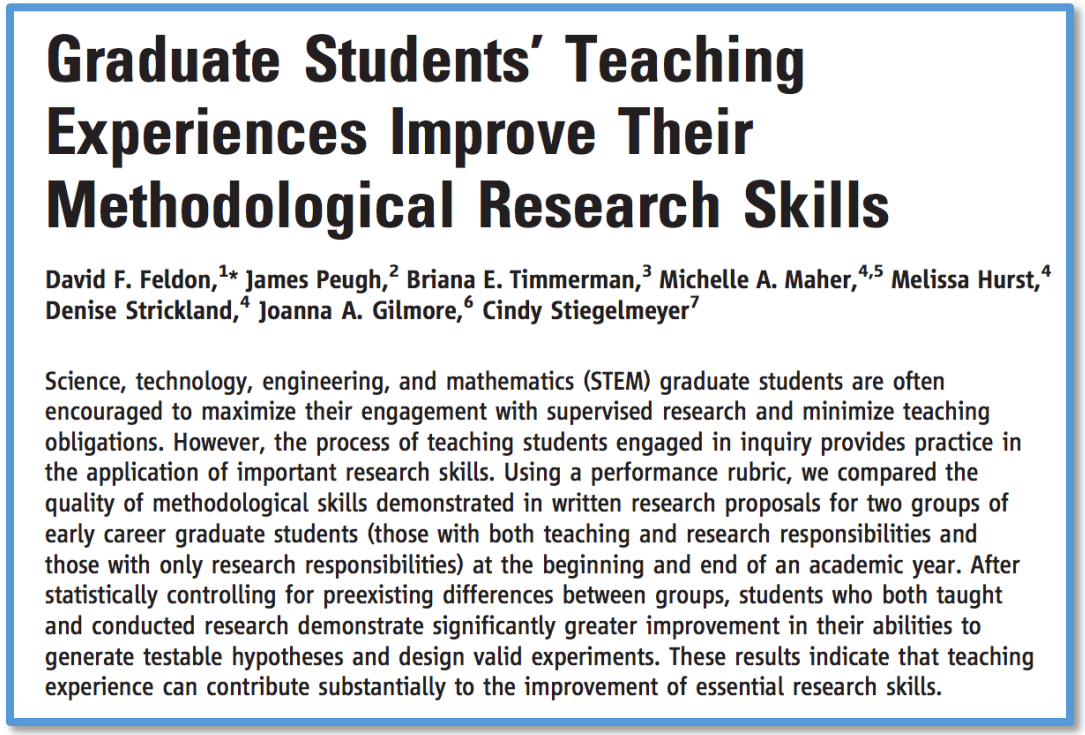
- Science GTAs benefit more from **discipline-specific preparation** than from campus-wide initiatives
  - Luft et al, Journal of Research in Science Teaching, 41(3), 2004
  - Harris & McEwen, Canadian Journal of Higher Education, 39(2), 2009
  - Ellis, PhD Thesis, 2014

Research shows that…

- GTAs need guidance in **logistics** issues such as classroom management and grading
  - Luo et al, Research in Higher Education, 41(3), 2000
  - Henderson et al, PERC 2016
  - Marshman et al, PhysRev PER, 13, 010120, 2017

Research shows that…

- Teaching experience improves graduate students' **research and transferable skills**
  - French & Russel, BioScience, 52(11), 2002
  - Hardré et al, Journal of Faculty Development, 22, 2008
  - Feldon et al, Science, 333(6), 2011



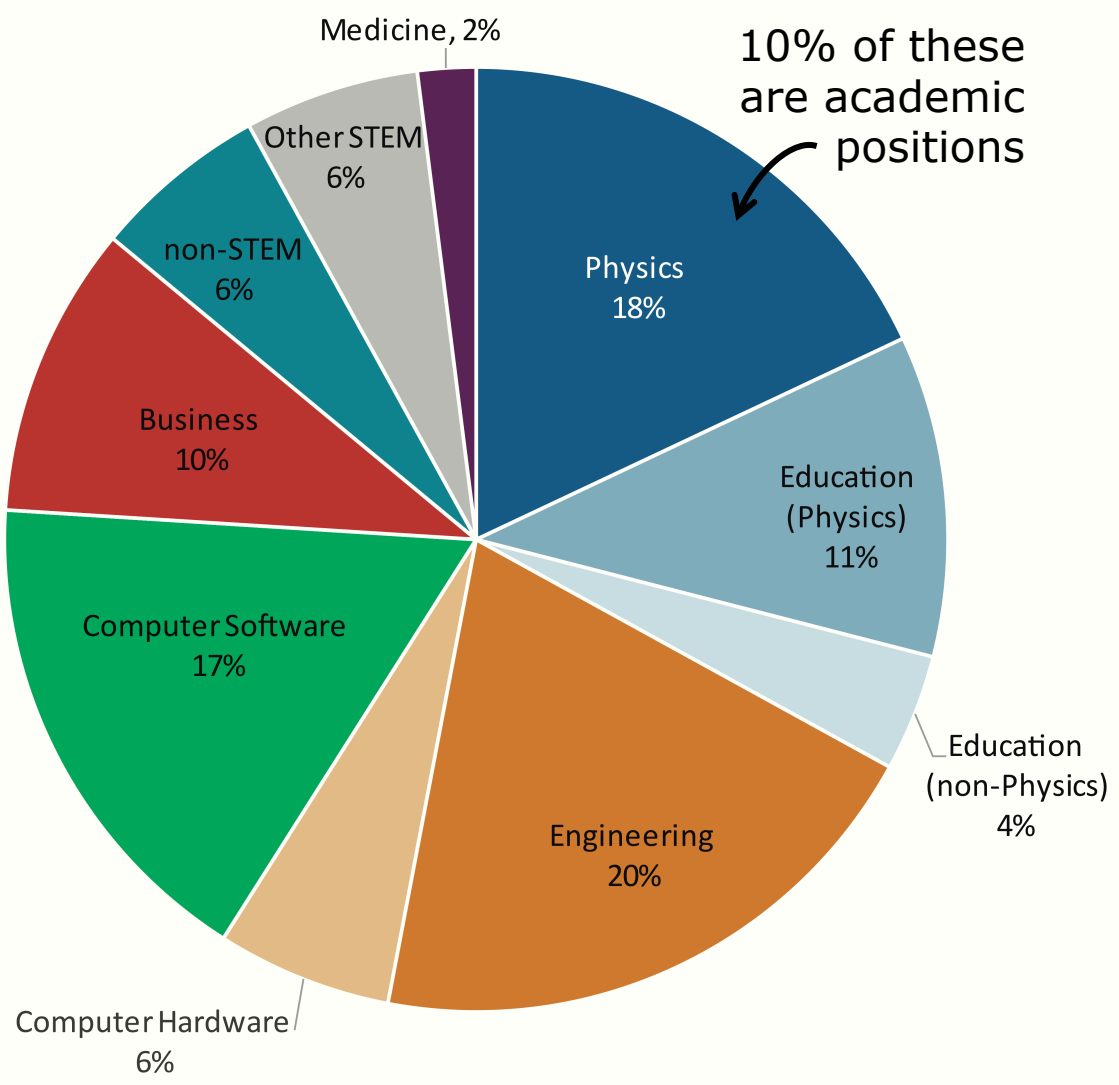
Graduate Students' Teaching Experiences Improve Their Methodological Research Skills

David F. Feldon,[1]* James Peugh,[2] Briana E. Timmerman,[3] Michelle A. Maher,[4,5] Melissa Hurst,[4] Denise Strickland,[4] Joanna A. Gilmore,[6] Cindy Stiegelmeyer[7]

Science, technology, engineering, and mathematics (STEM) graduate students are often encouraged to maximize their engagement with supervised research and minimize teaching obligations. However, the process of teaching students engaged in inquiry provides practice in the application of important research skills. Using a performance rubric, we compared the quality of methodological skills demonstrated in written research proposals for two groups of early career graduate students (those with both teaching and research responsibilities and those with only research responsibilities) at the beginning and end of an academic year. After statistically controlling for preexisting differences between groups, students who both taught and conducted research demonstrate significantly greater improvement in their abilities to generate testable hypotheses and design valid experiments. These results indicate that teaching experience can contribute substantially to the improvement of essential research skills.

A majority of physics PhDs leave academia

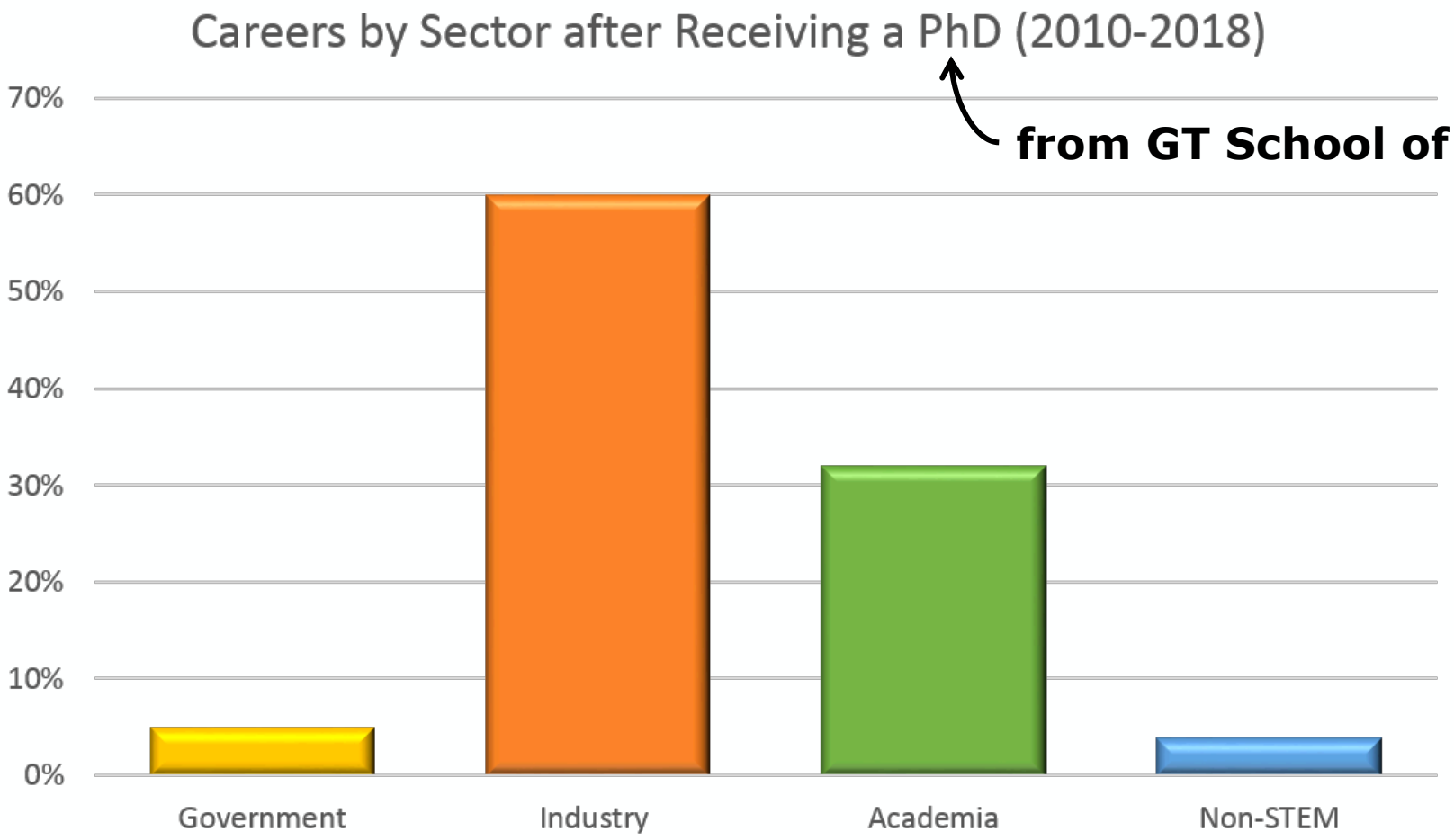
Employment fields for new physics PhDs in potentially permanent positions, classes of 2011-2016



Data is based on the responses of 725 new physics PhD recipients in potentially permanent positions when asked "What is your primary field of employment?"

https://www.aip.org/statistics/whos-hiring-physics-phds

A majority of physics PhDs leave academia



from GT School of Physics

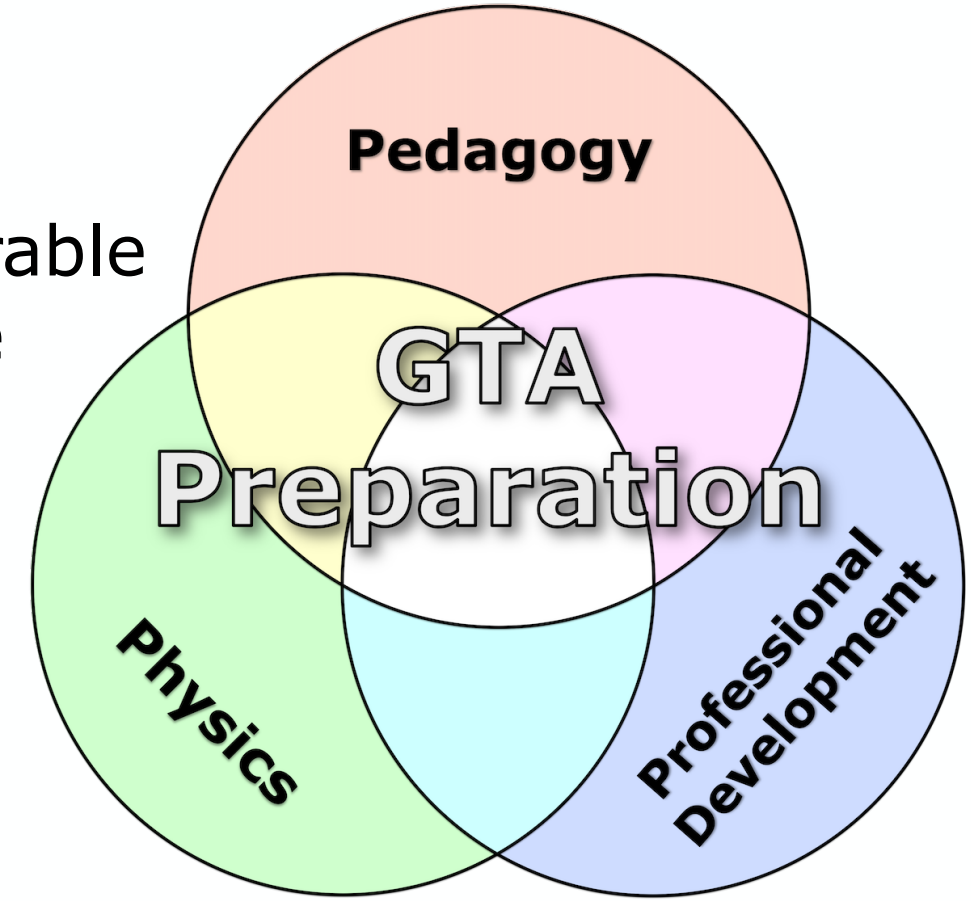
Not necessarily permanent positions (e.g. postdocs)

http://www.physics.gatech.edu/academics/graduate/careers

New Perspective on GTA Preparation

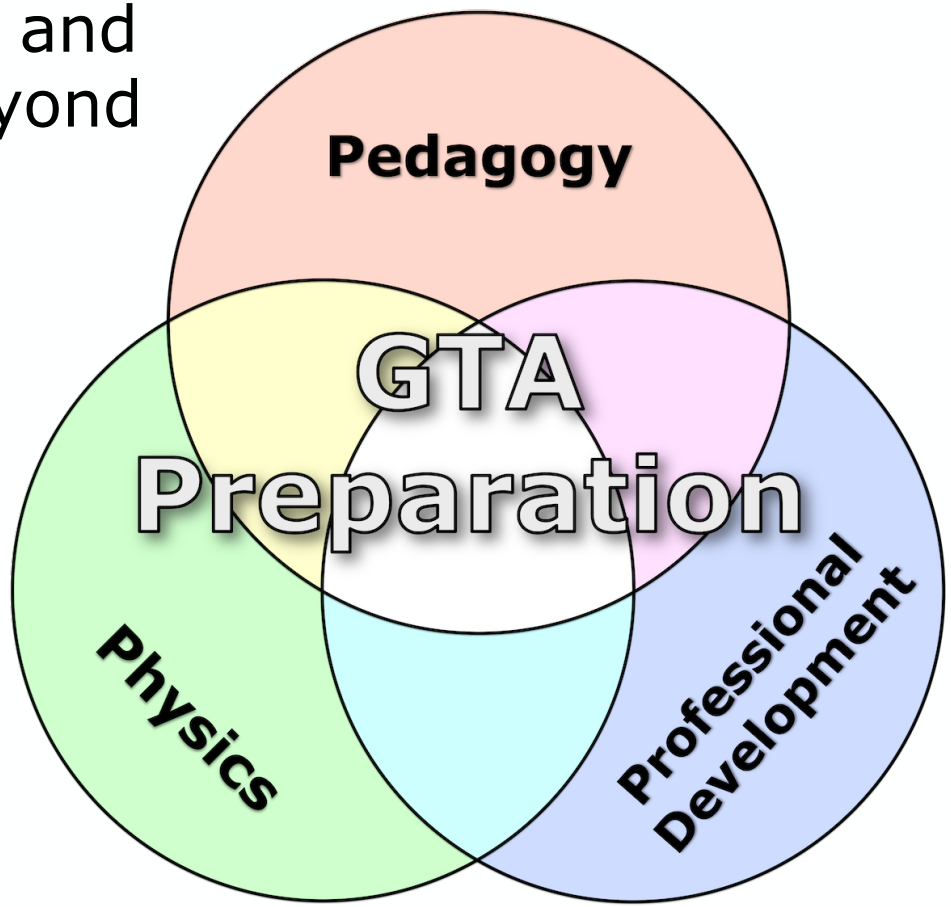
- We want to produce GTAs who are motivated and effective teachers

- We want to help GTAs develop transferable professional skills they can use outside the classroom
  - Especially important for grad students who don't plan on staying in academia



New Perspective on GTA Preparation

- **3P Framework**: 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:
  - **Pedagogy** – the methodology of teaching
  - **Physics** – content and PCK
  - **Professional Development** – transferable skills useful inside and outside academia
- The intersections of the three P's are also important!



Research Questions

- What elements of a formal GTA preparation program do GTAs perceive as the **most useful** or beneficial for their professional development?
- What effect does a formal GTA preparation program have on graduate students' **teaching self-efficacy** and **attitudes** about teaching?
- Does a formal GTA preparation program have an effect on graduate students' **teaching effectiveness**, as determined by end-of-semester student evaluations?

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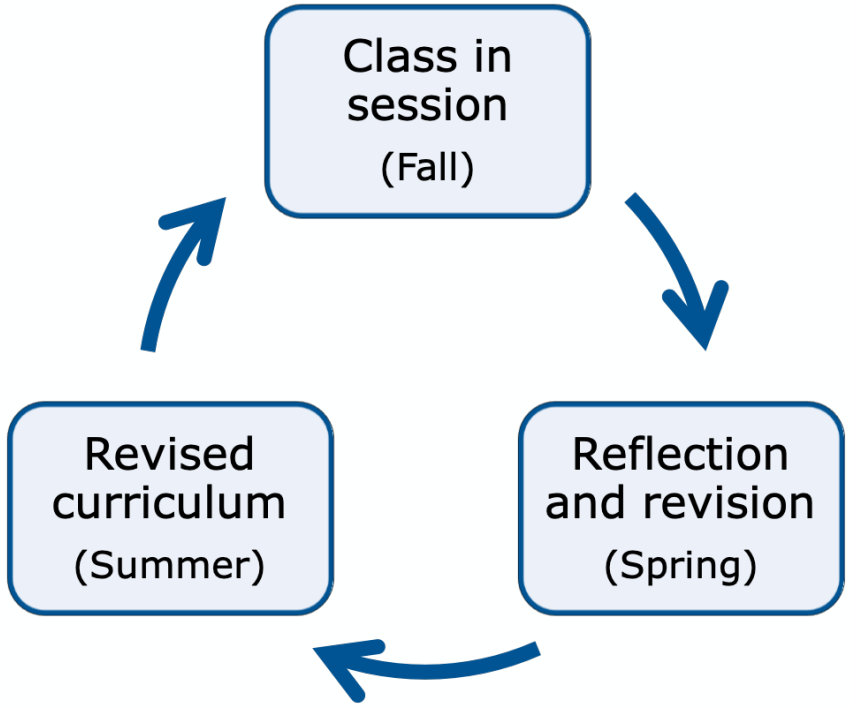
At GT Physics before 2013…

- TA training before semester:
  - General GTA Orientation (policies)
  - Meeting with GTA Supervisors (logistics)
- TA training during semester:
  - Weekly lab meetings and/or communication email (content)
  - Pedagogy seminars (outsourced)

- **Problems!**
  - Disconnect between pedagogy and content
  - Lack of pedagogical reinforcement
  - Lots and lots of complaining
  - GTAs provided with no motivation
  - No apparent relevance for professional goals

CETL 8000 PH1

- Started in 2013 as a collaboration between School of Physics and Center for Teaching and Learning; one credit, pass/fail
- Course design follows best practices for GTA preparation found in research literature
  - Partnership, fosters sense of professional identity
  - Ongoing endeavor, with opportunities for practice, observation, and feedback
  - Grounded in research-based teaching practices
  - Highlights transferable skills
- Curriculum development follows a yearly cycle of implementation and revision, based on assessment data and self-reflection



Course Structure and Content

Orientation
(before semester starts)

1. Introduction & GT Policies
2. Teaching Physics
3. Classroom Management
4. Lab Simulation
5. Microteaching

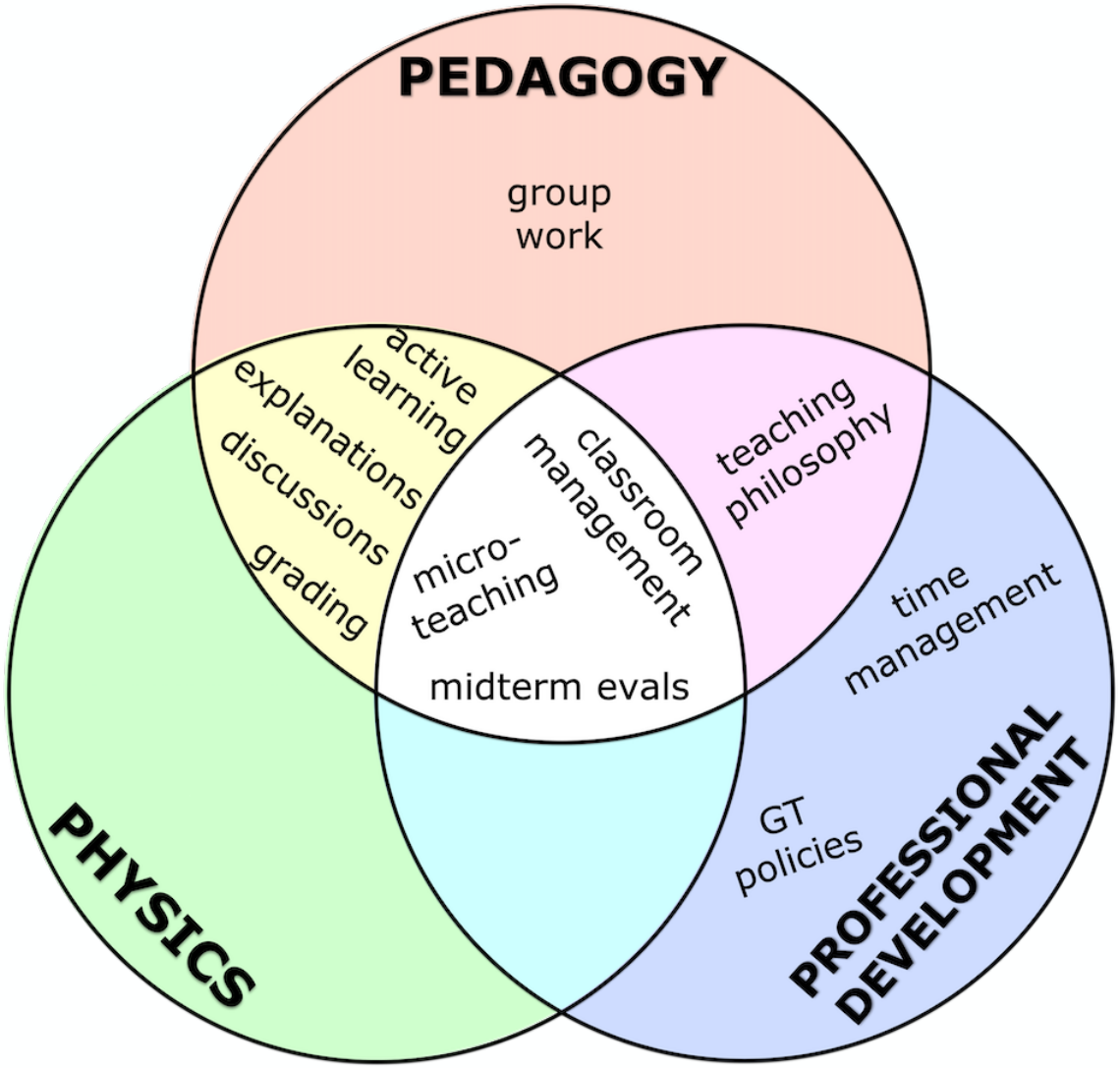
(~15 hrs)

Follow-Up Meetings
(during Fall semester)

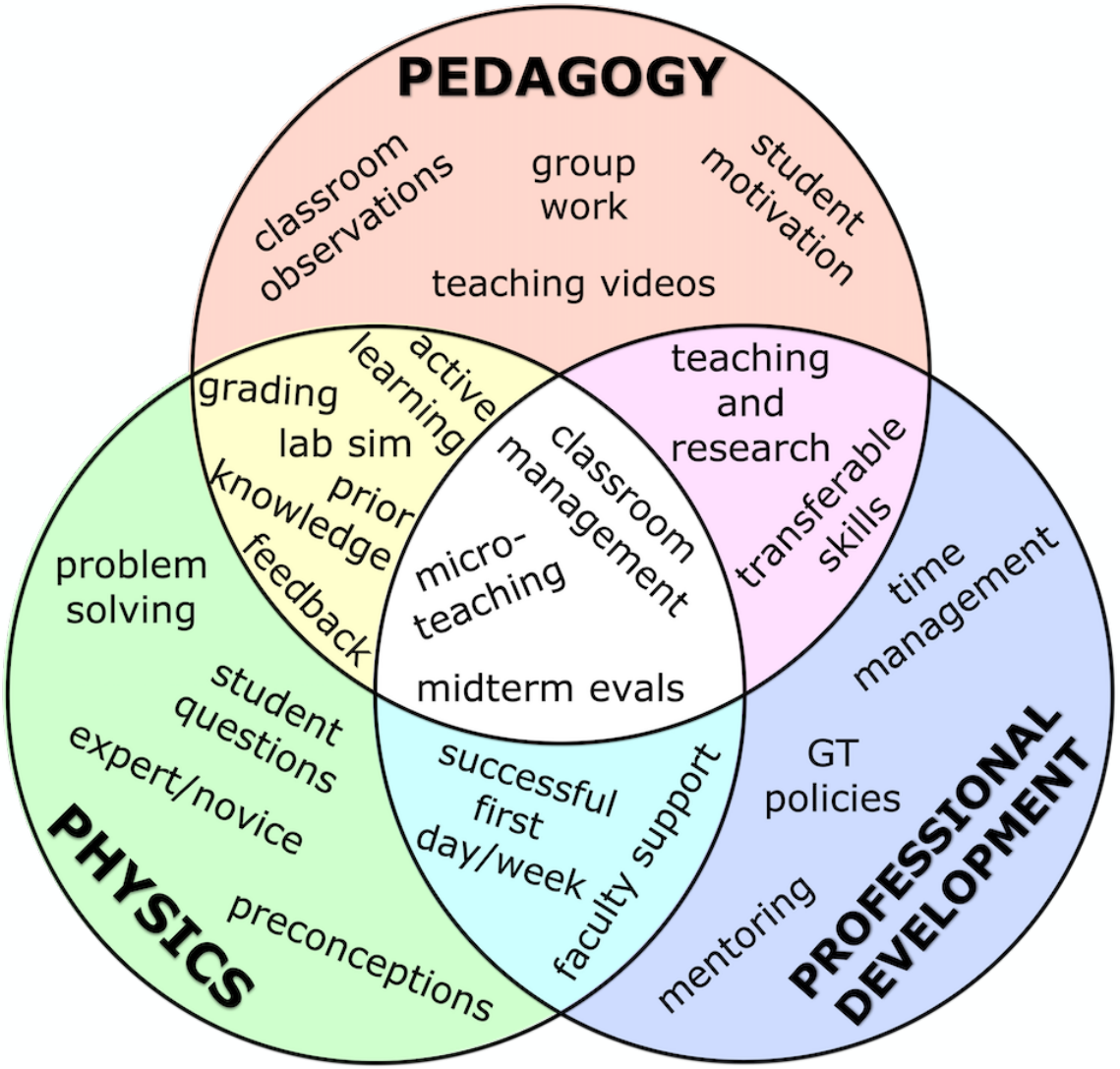
1. Grading
2. Midterm Evaluations & Time Management
3. Teaching Videos
4. Teaching and Research
5. Concluding Remarks

(~5 hrs)

Out of class activities: Classroom Observations, Workload Surveys, GAP Meetings


PEDAGOGY
group work
active learning
explanations
discussions
grading
classroom management
micro-teaching
midterm evals
teaching philosophy
time management
GT policies
PROFESSIONAL DEVELOPMENT
PHYSICS

2013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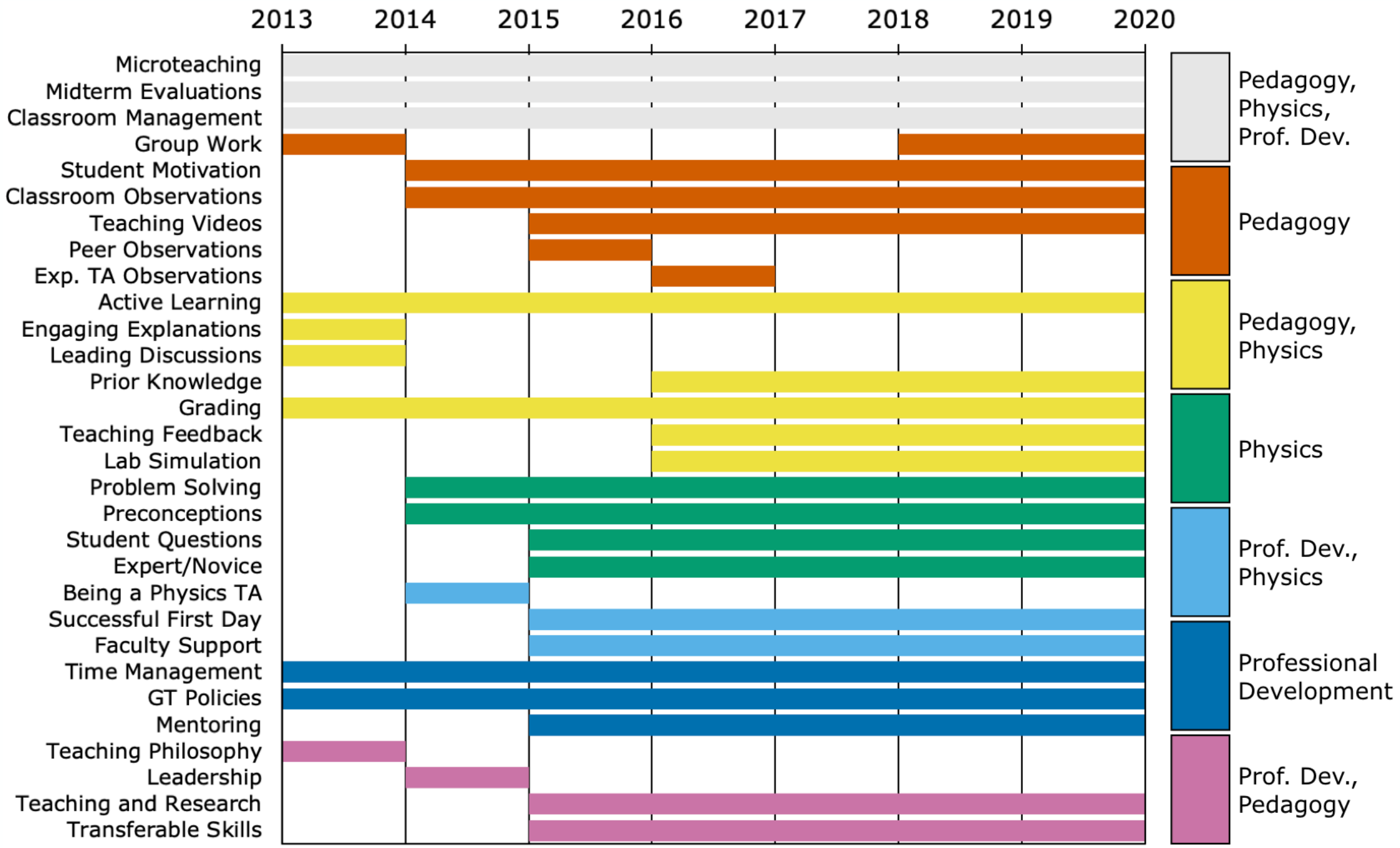
classroom observations
group work
student motivation
teaching videos
active learning
grading
lab sim
prior knowledge
feedback
classroom management
micro-teaching
midterm evals
teaching and research
transferable skills
time management
problem solving
student questions
expert/novice
preconceptions
PHYSICS
successful first day/week
faculty support
GT policies
mentoring
PROFESSIONAL DEVELOPMENT

2019


2013
2014
2015
2016
2017
2018
2019
2020
Microteaching
Midterm Evaluations
Classroom Management
Group Work
Student Motivation
Classroom Observations
Teaching Videos
Peer Observations
Exp. TA Observations
Active Learning
Engaging Explanations
Leading Discussions
Prior Knowledge
Grading
Teaching Feedback
Lab Simulation
Problem Solving
Preconceptions
Student Questions
Expert/Novice
Being a Physics TA
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Faculty Support
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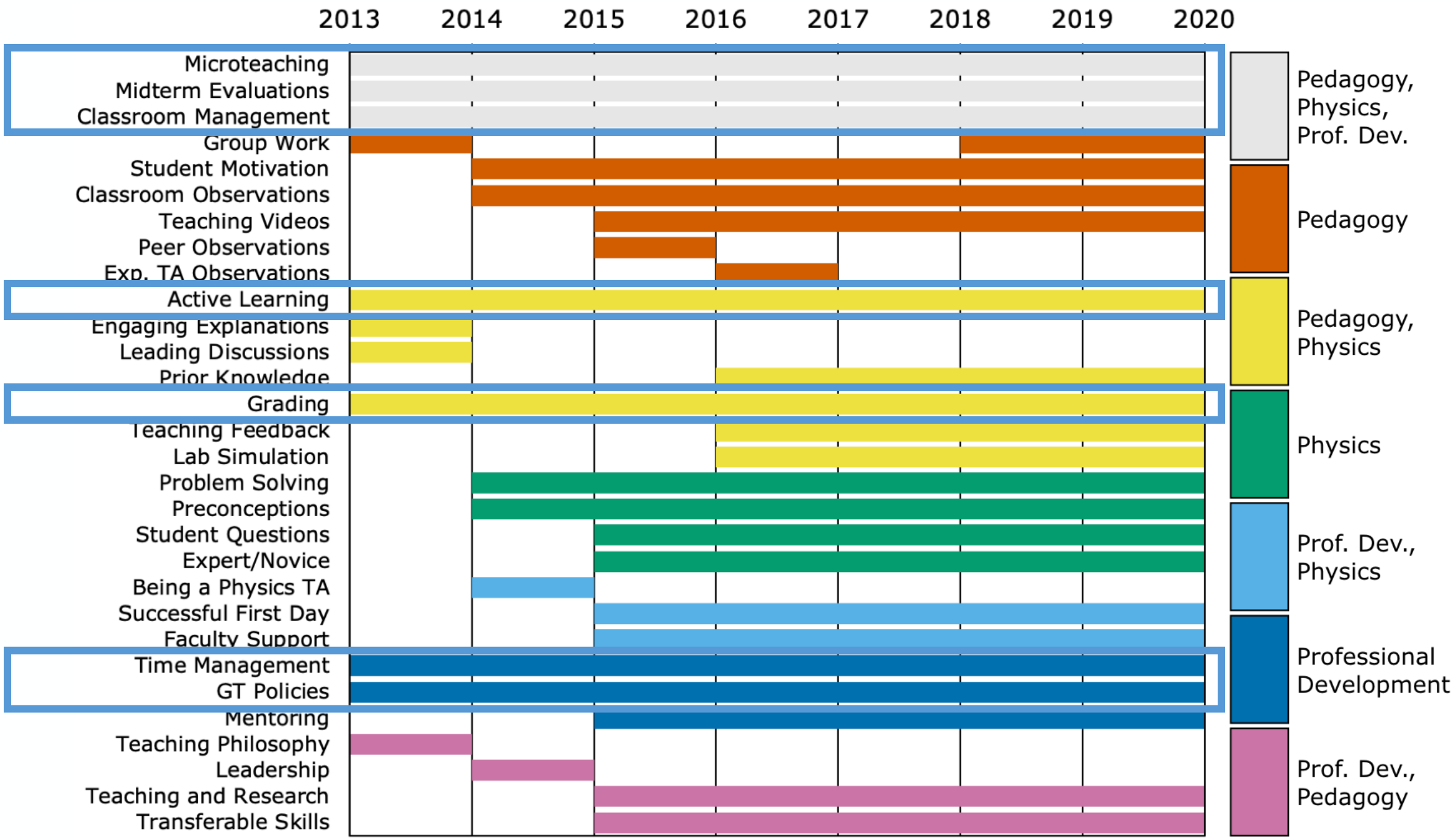
Physics
Prof. Dev., Physics
Professional Development
Prof. Dev., Pedagogy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Persistent over the years

- Microteaching
- Midterm Evaluations
- Classroom Management
- Active Learning
- Grading
- Time Management
- Georgia Tech Policies

Started as mostly pedagogy with some physics sprinkles, now it's fully integrated within physics content and examples

Persistent over the years

- Microteaching
- Midterm Evaluations
- Classroom Management
- Active Learning
- Grading
- Time Management
- Georgia Tech Policies

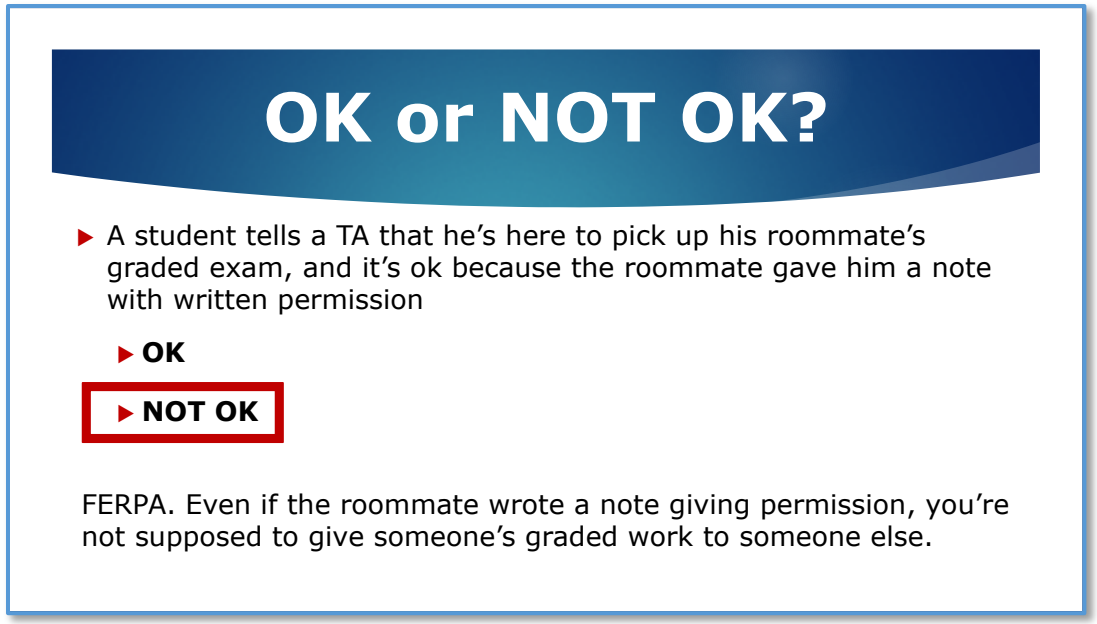
Separate sessions for the different GTA assignments

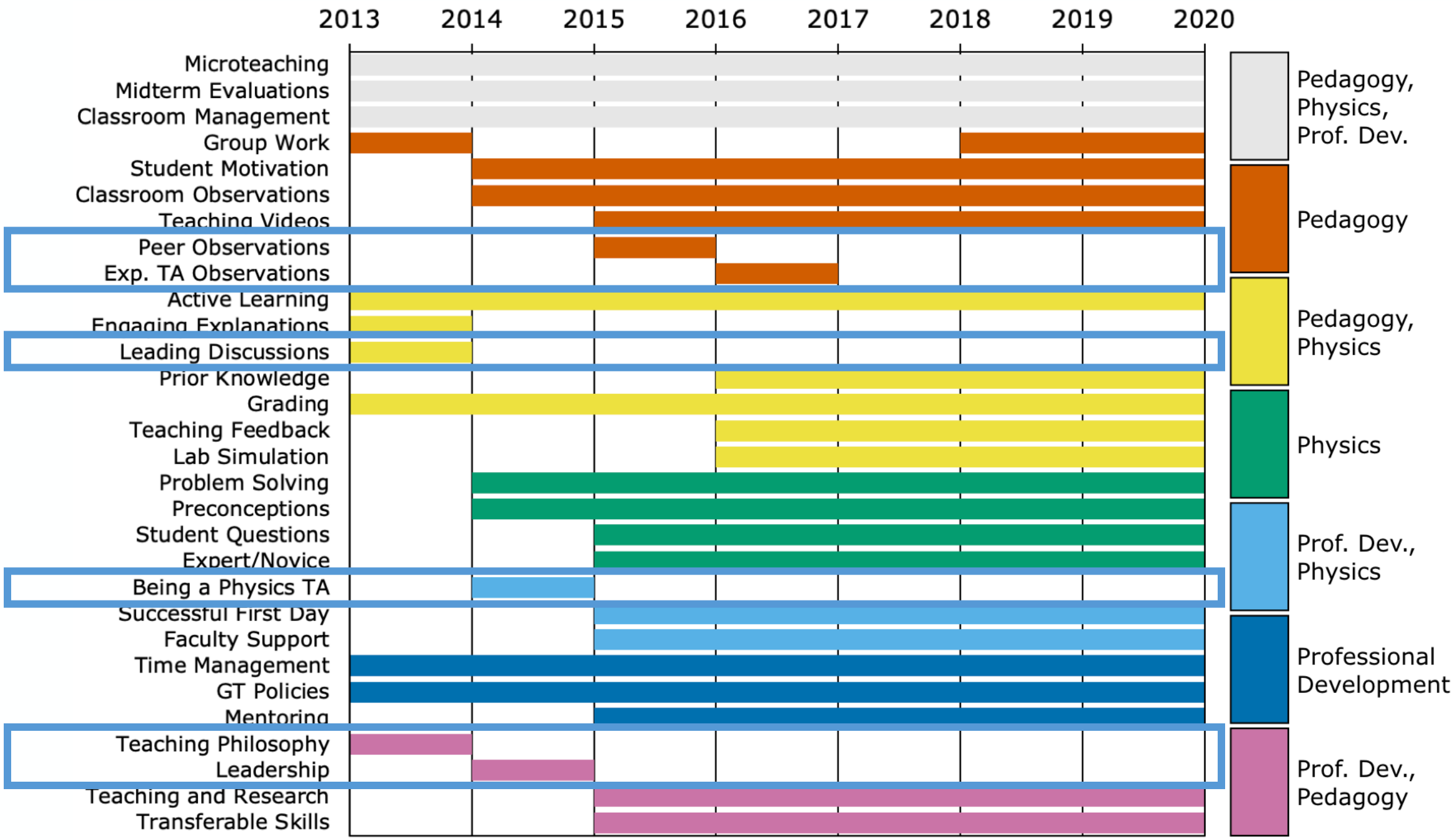
New in 2019: separate session on Gradescope (online grading)

Persistent over the years

- Microteaching
- Midterm Evaluations
- Classroom Management
- Active Learning
- Grading
- Time Management
- Georgia Tech Policies

Introduced OK/NOT-OK game in 2017, so now learning about policies is actively engaging

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Physics
Prof. Dev., Physics
Professional Development
Prof. Dev., Pedagogy

False Starts

- Peer Observations
- Experienced TA Observations
- Leading Discussions
- Being a Physics TA
- Teaching Philosophy
- Leadership

Love/hate, not well received

Some GTAs felt unqualified to give useful feedback

Some GTAs felt their peers were unqualified to give them useful feedback

False Starts

- Peer Observations
- Experienced TA Observations
- Leading Discussions
- Being a Physics TA
- Teaching Philosophy
- Leadership

Complete disaster mostly due to logistics issues

Only attempted once, never again!

False Starts

- Peer Observations
- Experienced TA Observations
- Leading Discussions
- Being a Physics TA
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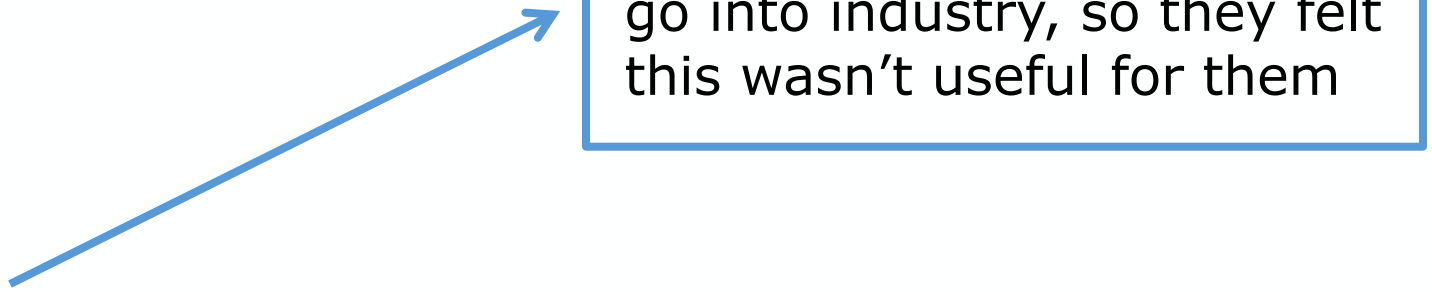
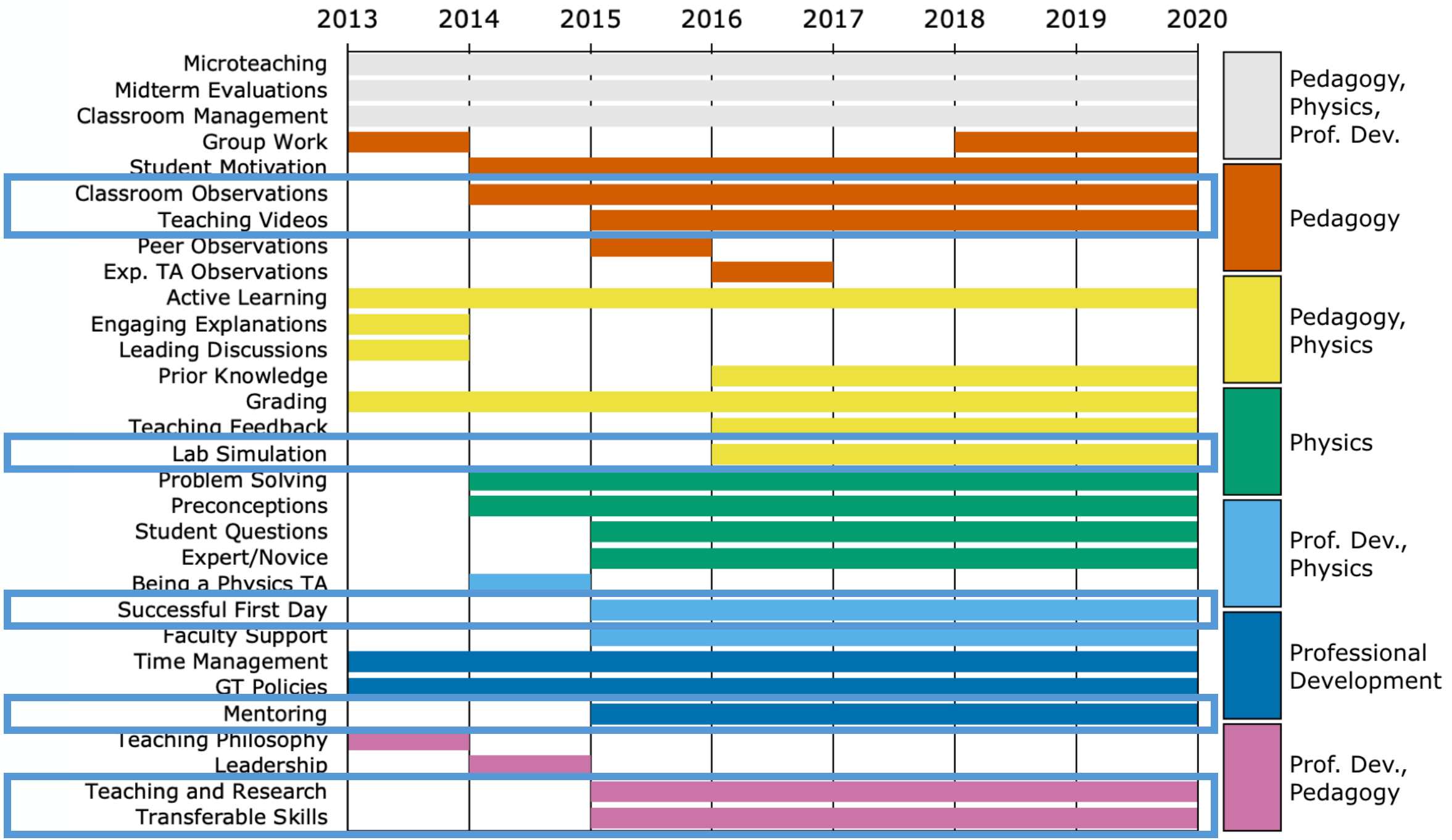
- Leadership

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Newer and Successful

- Classroom Observations
- Teaching Videos
- Lab Simulation
- Successful First Day/Week
- Mentoring
- Teaching and Research/ Transferable Skills

Started with once per semester, now it's twice per semester (early September, late October)

Newer and Successful

- Classroom Observations
- Teaching Videos
- Lab Simulation
- Successful First Day/Week
- Mentoring
- Teaching and Research/ Transferable Skills

Like Microteaching, but for labs

GTAs take turn facilitating in a lab environment

Roleplay: secretly planted bad behaviors are a HUGE hit

Newer and Successful

- Classroom Observations
- Teaching Videos
- Lab Simulation
- Successful First Day/Week
- Mentoring
- Teaching and Research/ Transferable Skills

First attempt was a disaster (2015 Follow-Up Meeting titled "How's it going?")

Peer mentoring by senior grad students is now included and is much better received

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Enrollment in GTA Preparation

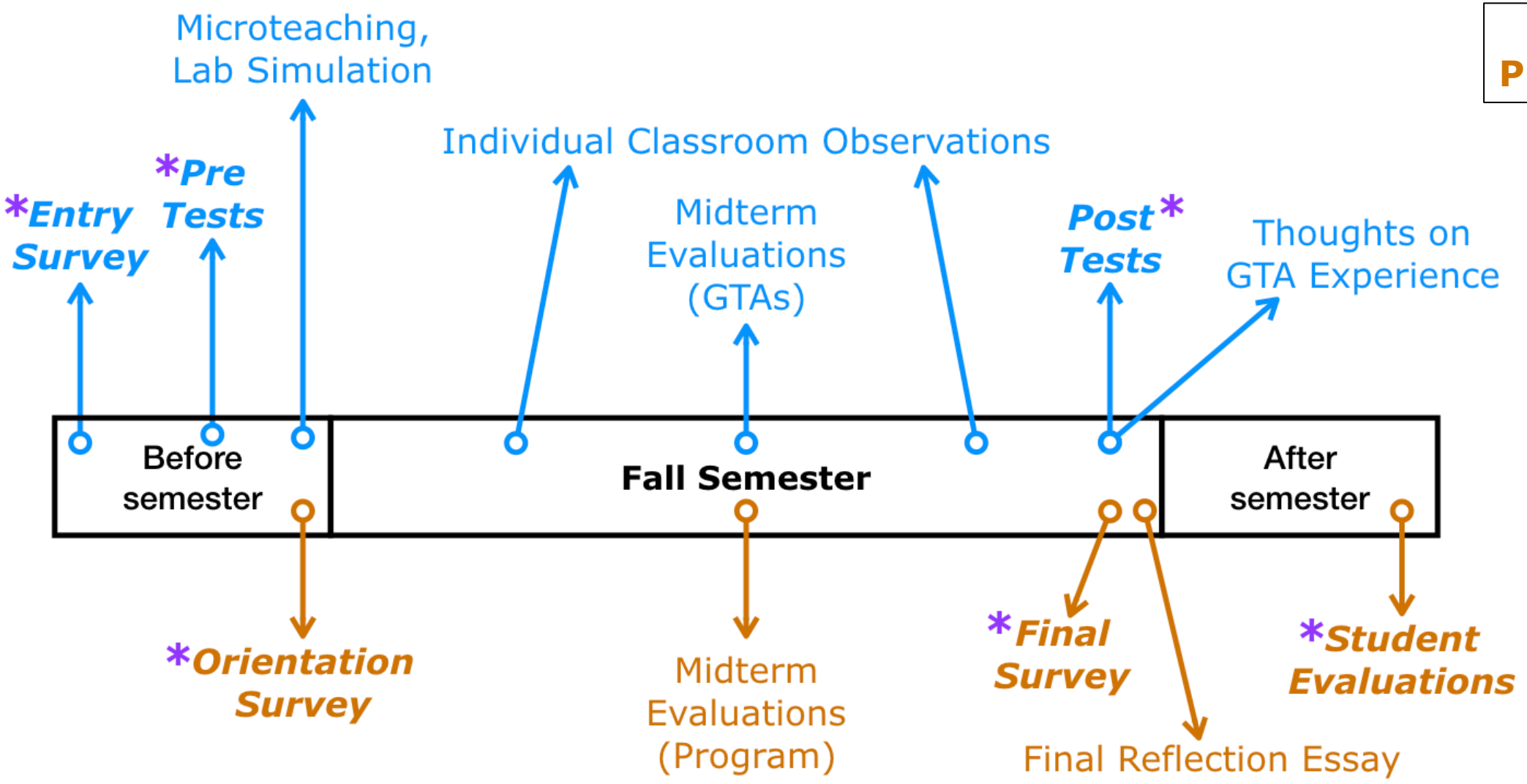
Total enrollment 2013-2019: 152

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%)

Demographics (with consent)

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%

Program and GTA Assessment



Program and GTA Assessment

- Assessments selected for current analysis give us a broad idea of how effective the GTA prep class has been (the forest); future work will focus on finer details (the trees)
- Modified Kirkpatrick Model*
  - Reaction – Orientation Survey, Final Survey
  - Learning – Pre/Post ATI and Knowledge Quiz
  - Behavior – Classroom Observations (future analysis)
  - Results – End-of-semester student evaluations (as proxy)
- Mixed methods approach (quantitative and qualitative data)

* Kirkpatrick, *Evaluating Training Programs: The Four Levels*, 1994
* Wyse et al, CBE-Life Sciences Education, 13, 2014

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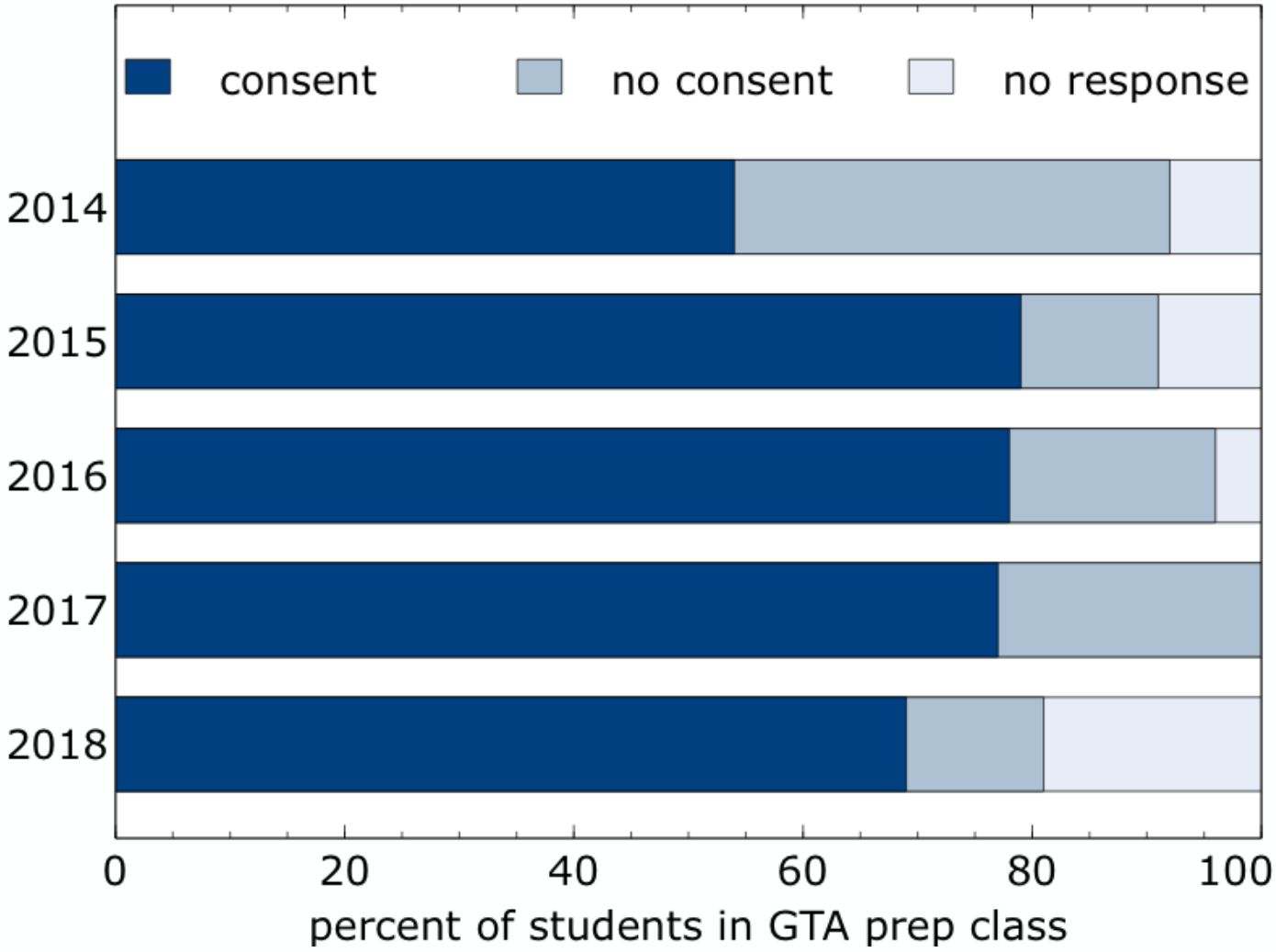
The initial conditions of first-time GTAs

- Entry Survey (every July), not anonymous
- 83/103 responses with informed consent
- Sample is representative of full population
- **Prior TA experience:**
  - **No = 59%**
  - **Yes = 41%**

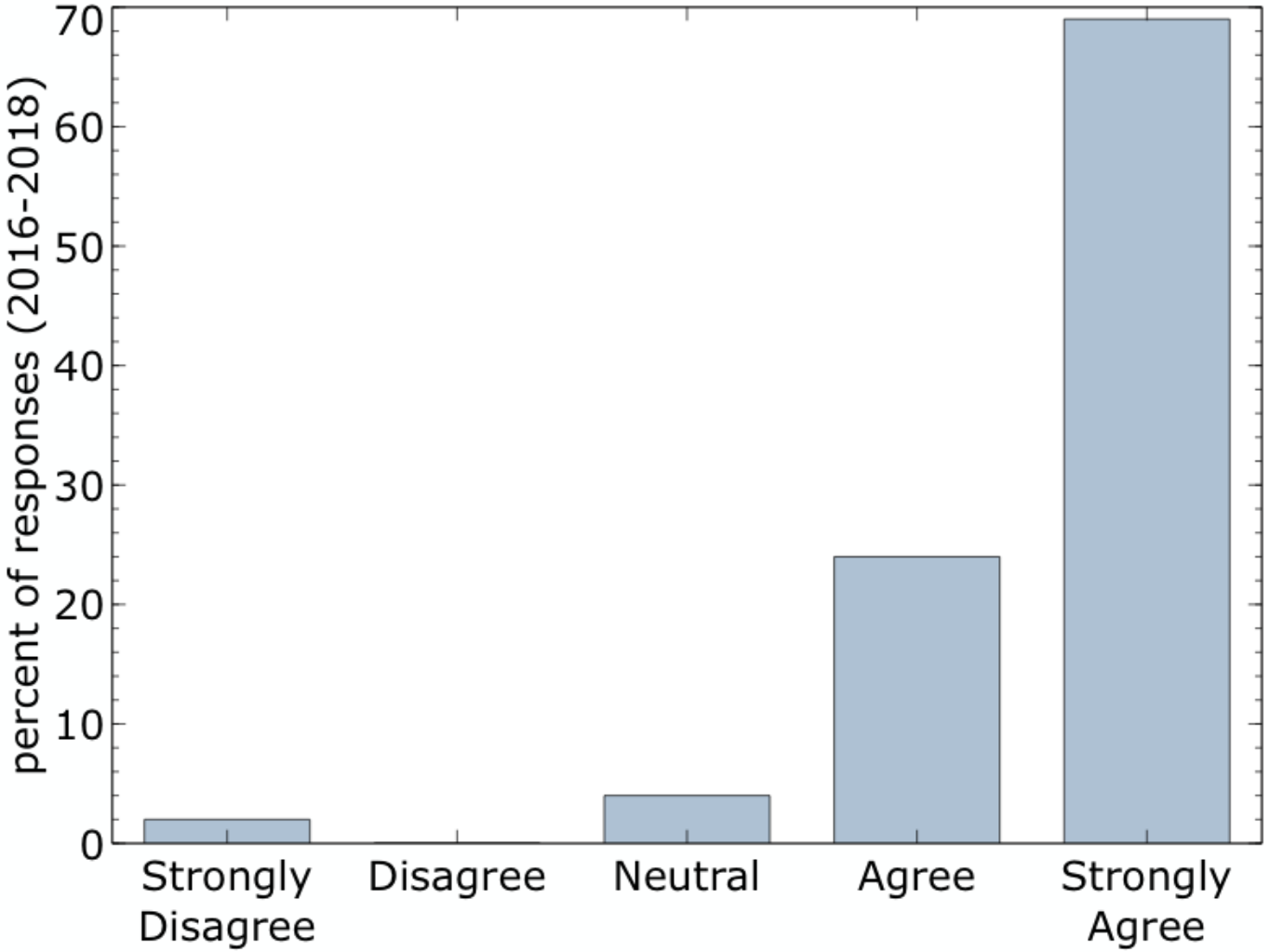


The initial conditions of first-time GTAs

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

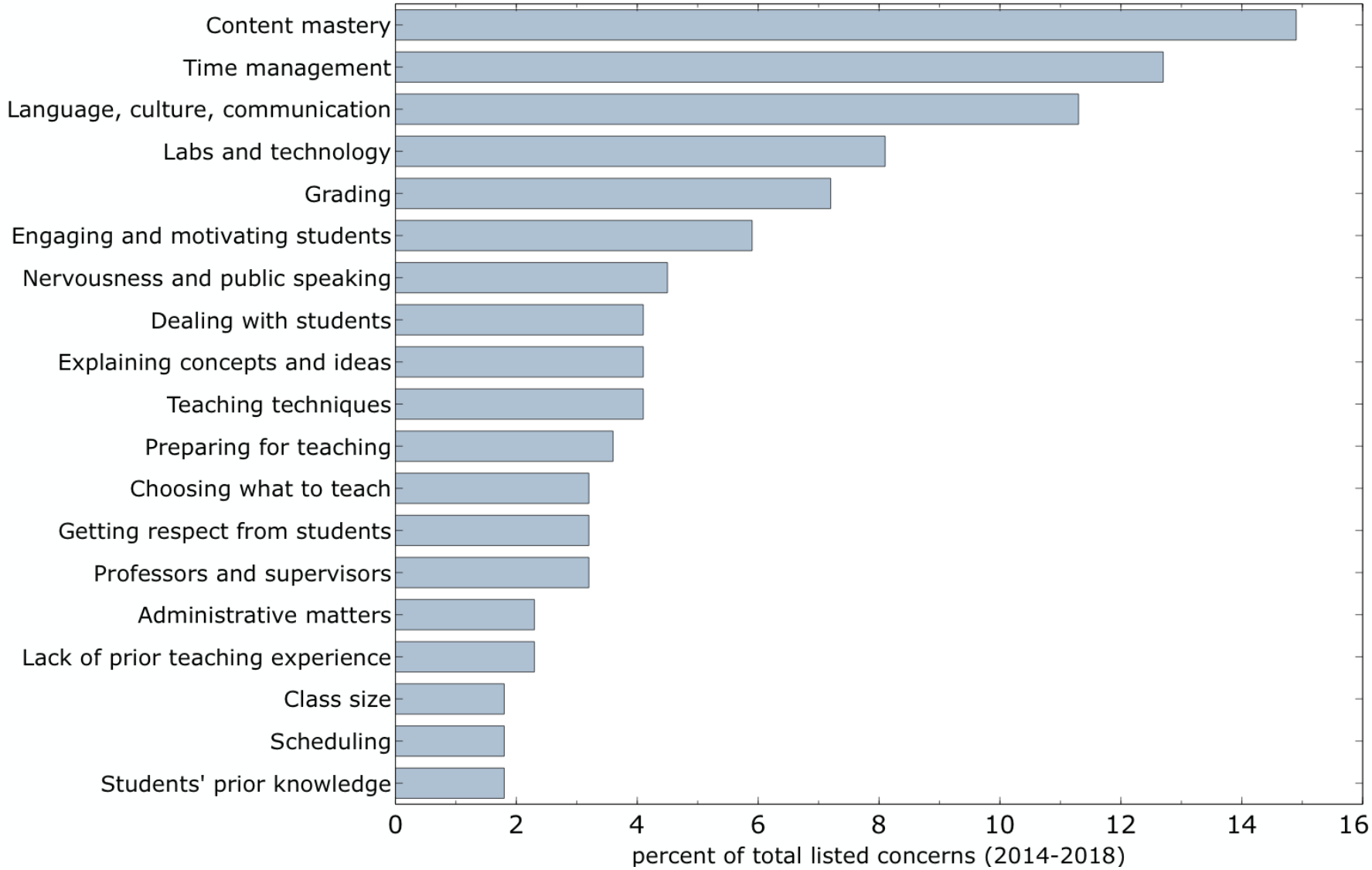
  "I consider teaching to be an important part of my professional development as a physicist."

- **An overwhelming majority of first-time GTAs consider teaching important for their professional development**



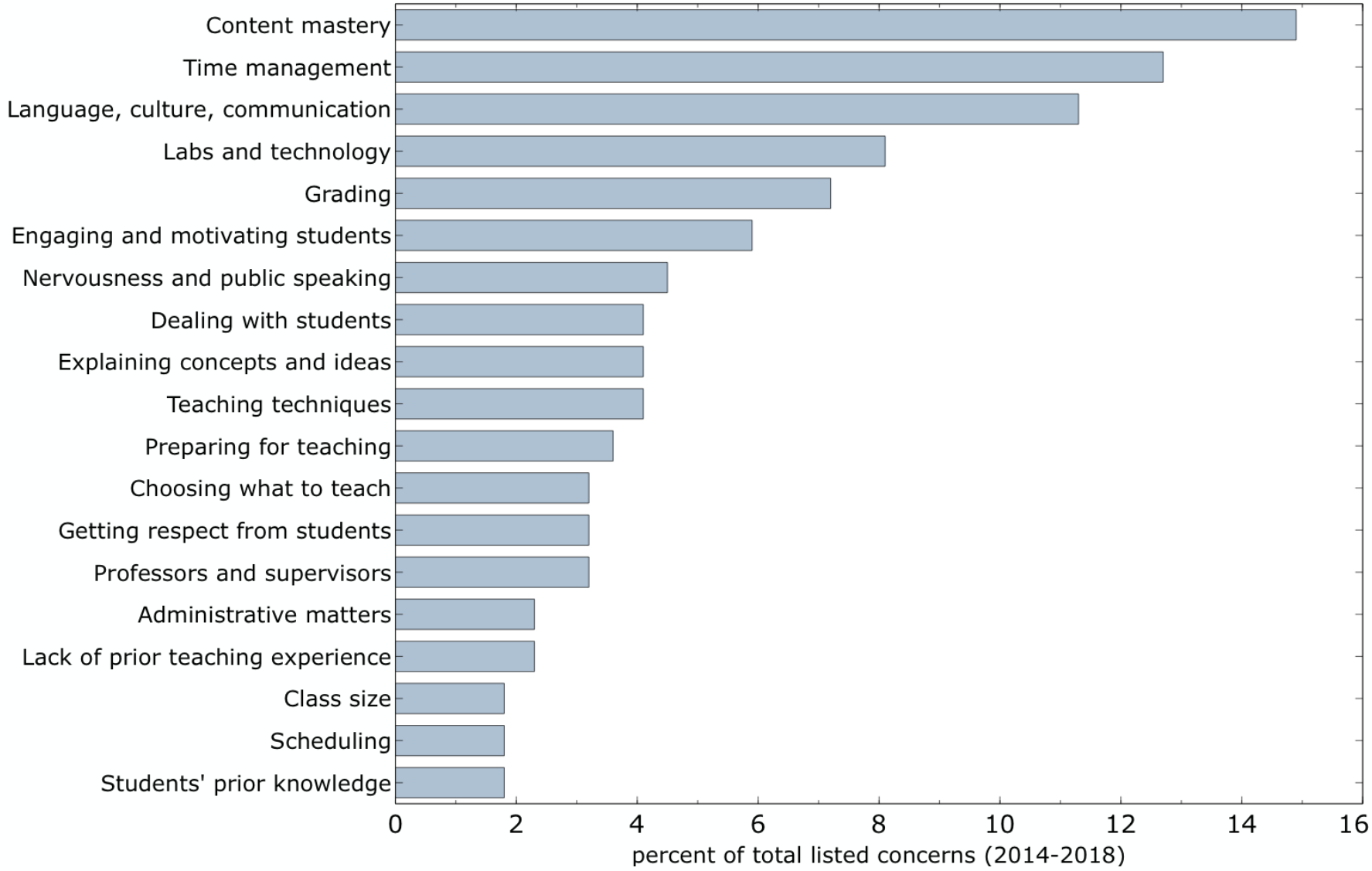
The initial conditions of first-time GTAs

- Asked to indicate top 3 concerns about teaching
- 221 total concerns (2014-2018)
- Coded into 19 categories



The initial conditions of first-time GTAs

- **First-time GTAs are worried about their physics knowledge and time management**
- **First-time GTAs who are non-native English-speakers are also worried about language and culture issues**



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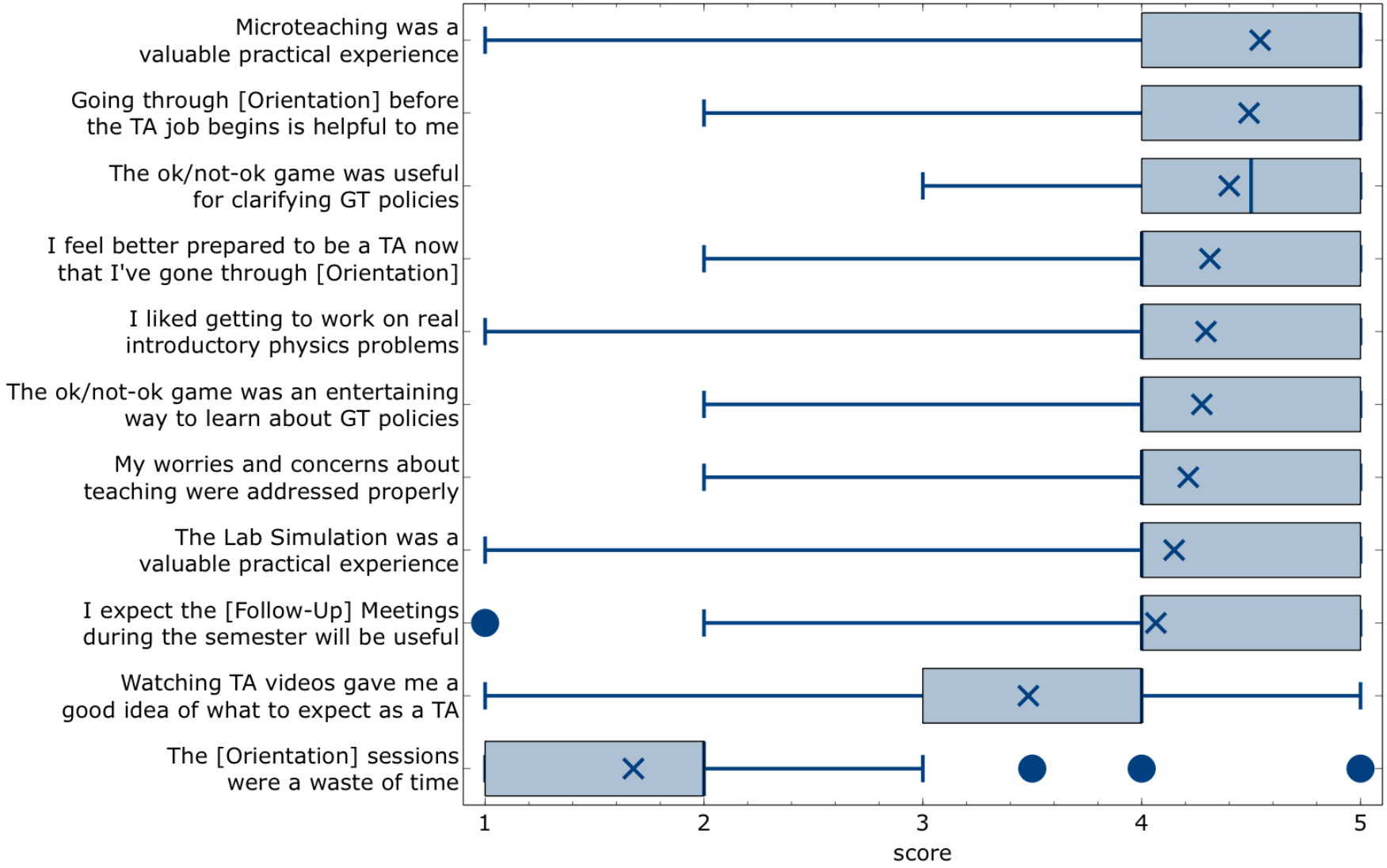
Orientation Survey

- Anonymous, Likert-type statements to assess five categories: Class Activities, Guests, Materials, Timing, Usefulness
- Open-ended comments indicated GTAs felt better prepared for teaching
- Statements about class activities indicate that GTAs enjoy the interactive nature of the class and find the activities useful

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

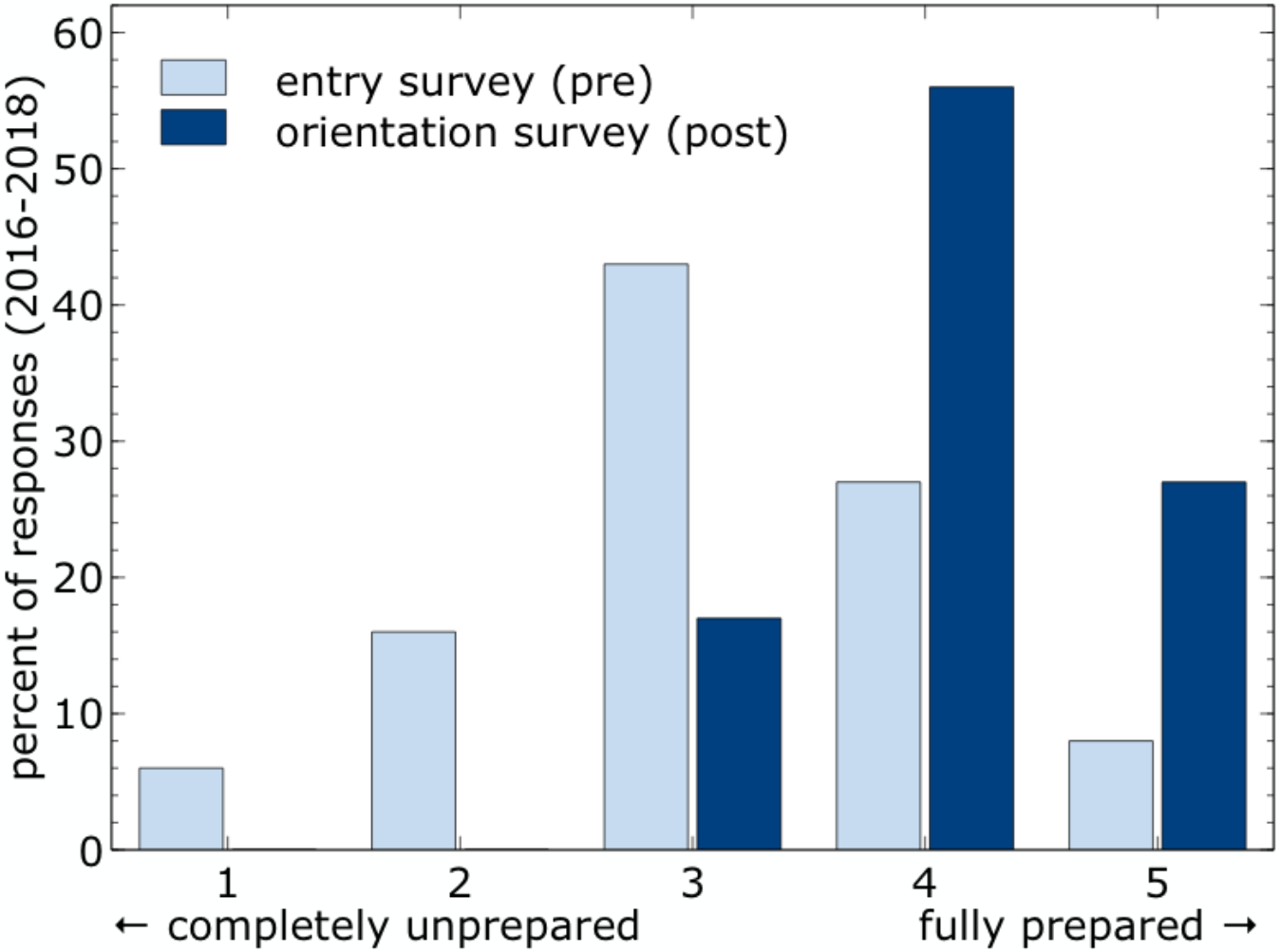
Orientation Survey

- Usefulness statements scored very high
- Top 3 highest scored Usefulness statements were the three best scored statements overall in the survey
- **GTAs enjoy the interactive nature of the class and consider the Orientation useful**



Orientation Survey: Preparedness

- "How prepared do you feel for your first GTA assignment at Georgia Tech?"
- **Pre:** Entry Survey ($N = 49$, not anonymous)
- **Post:** Orientation Survey ($N = 64$, anonymous)



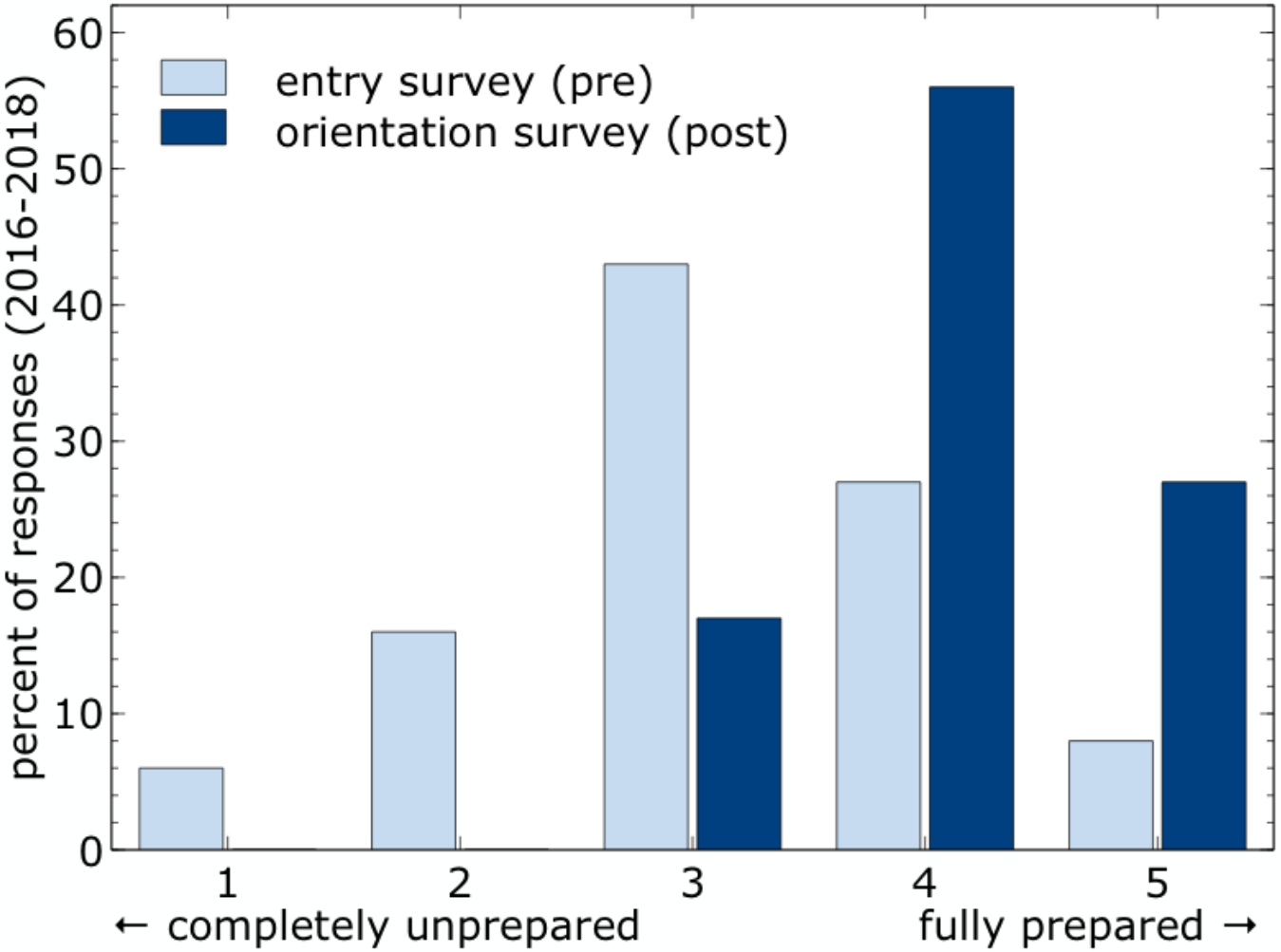
Orientation Survey: Preparedness

- Statistically significant pre/post difference (KS test, $p < 0.001$)
- Very large effect size (Cohen's $d = 1.333$)

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

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

- **GTAs feel better prepared for teaching after the Orientation**



Final Survey

- At end of semester, asked GTAs to rate usefulness of lessons

- **Overall top 3** most useful:
  1. Microteaching (4.40 ± 0.95)
  2. Lab Simulation (4.30 ± 1.09)
  3. Teaching Physics (4.10 ± 1.05)

- **Yearly top 3** most useful are more nuanced →

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

Final Survey: Utility Scores

- Utility score:

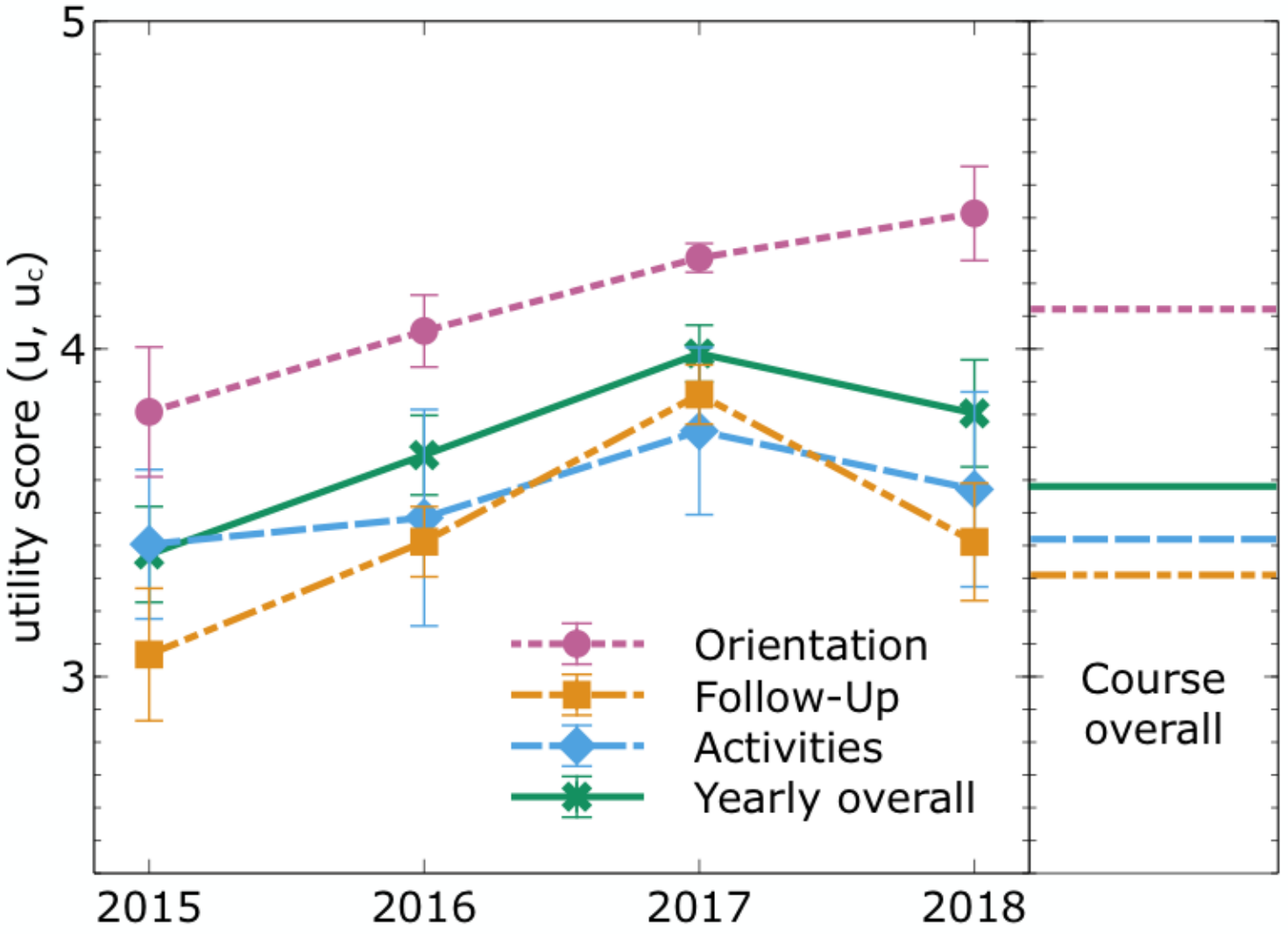
$$u = \frac{1}{N} \sum_i M_i$$

- Course overall: all items, all years
- Category overall: all items within each separate category, all years
- Yearly overall: all items, for each year
- Yearly categories: all items within each separate category, for each year

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

Final Survey: Utility Scores

- Course overall: 3.58 ± 0.12 (mean ± standard error)
- Category overall best: Orientation (4.12 ± 0.10)
- Follow-Up Meetings ranked lowest, need improvement
- 2015 and 2016 have some specific items that were very lowly rated
- **Most useful: Orientation** (and its usefulness increases every year)



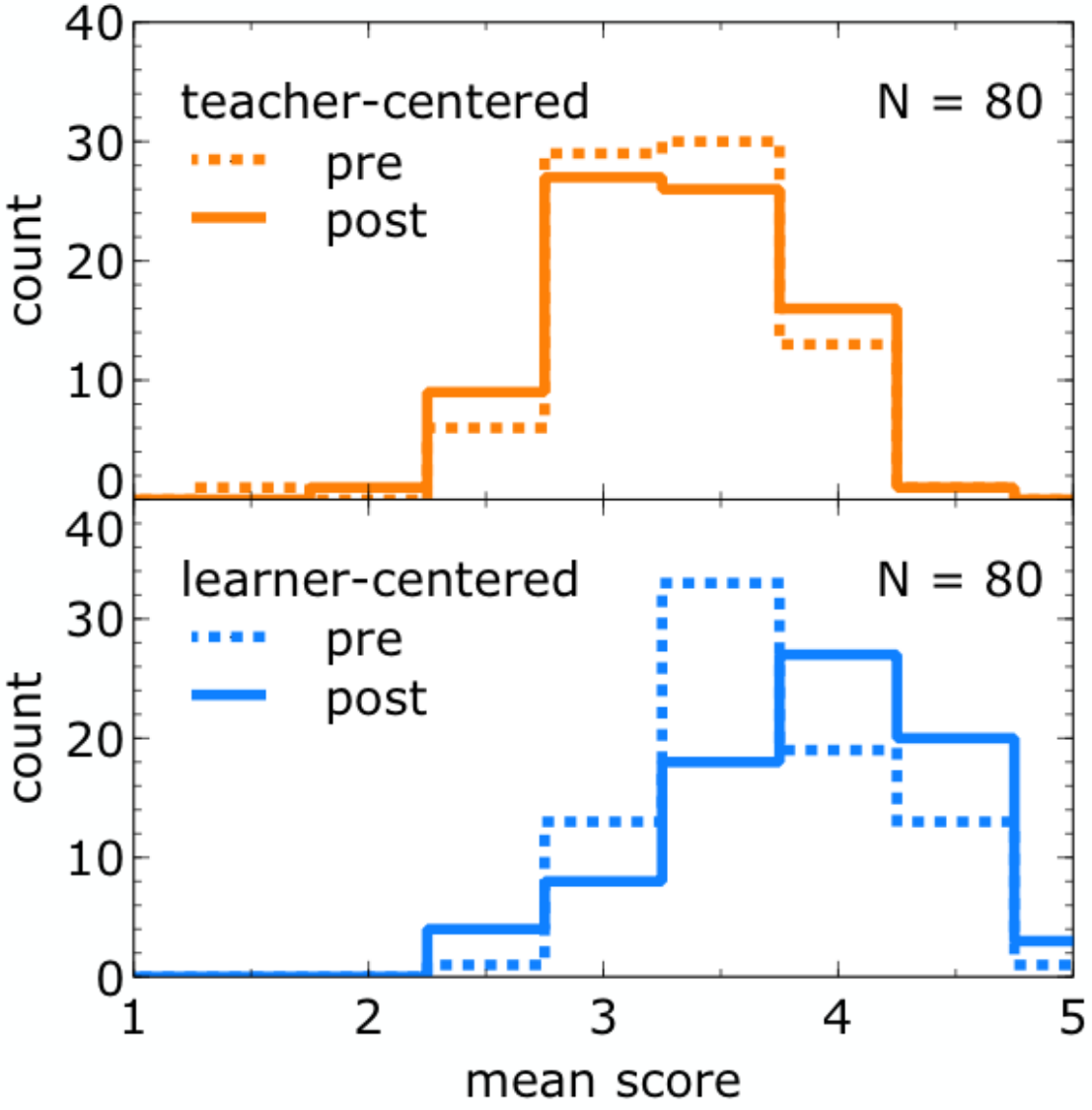
Pre/Post Tests: ATI

- Approaches to Teaching Inventory*
- 16 Likert-type items in 2 scales to measure:
  - Information Transmission (teacher-centered approaches)
    - e.g., "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."
  - Conceptual Change (learner-centered approaches)
    - e.g., "I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop."
- Complete case analysis: matched pre/post pairs with responses to every item
- For each student: teacher-centered mean, learner-centered mean (in pre-test and again in post-test)

* Trigwell & Prosser, Educational Psychology Review, 16, 2004

Pre/Post Tests: ATI

- No statistical difference in pre/post teacher-centered distributions (KS test, $p = 0.304$)
- Statistical difference in pre/post learner-centered distributions (KS test, $p = 0.046$) and means (t-test, $p = 0.037$); small effect size ($d = 0.254$)
- **GTAs adopt more learner-centered approaches to teaching after one semester of GTA preparation**



Pre/Post Tests: Knowledge Quiz

- Multiple choice test measuring five categories of knowledge (Administrative, Pedagogical Content Knowledge, General Pedagogy, Professional Development, Teaching Practice)
- Analysis of matched pre/post pairs; each question is either correct or incorrect; a student's score is percentage of correct responses
- Full test scores have consistently had **higher post-test** yearly class averages
- Effect size measured with Cohen's d and normalized gains measured as:

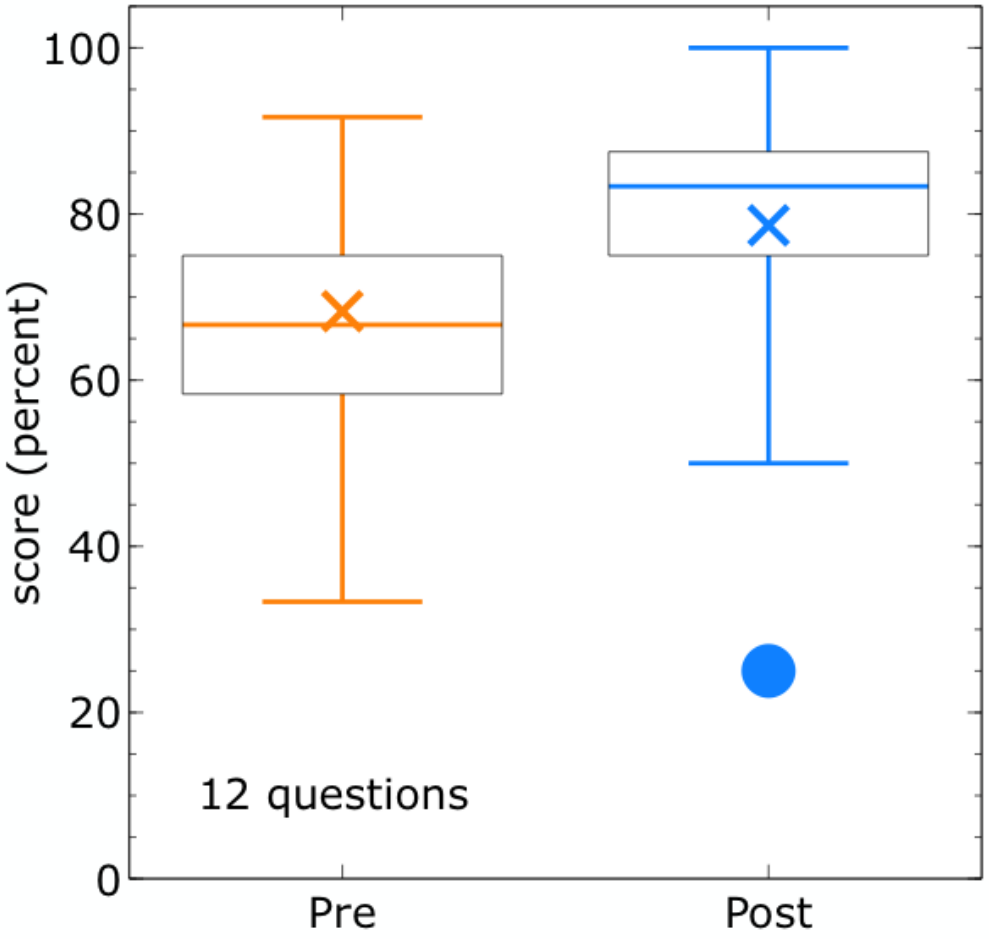
$$\langle g \rangle = \frac{M_{\text{post}} - M_{\text{pre}}}{100 - M_{\text{pre}}}$$

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

Pre/Post Tests: Knowledge Quiz

- **Detailed analysis:** focus on 12 questions that repeat every year with same wording
  - Post-tests always higher than pre-tests (all statistically significant t-tests)

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



- **GTAs' pedagogical knowledge increases after one semester of GTA preparation**

Outline

- Background and Motivation
- Developing the “Physics GTA Preparation” Course
- Results from Program Assessment
  - The initial conditions of first-time GTAs in the School of Physics
  - Surveys and Pre/Post Tests
  - **End-of-Semester Student Evaluations**
- Conclusions and Summary

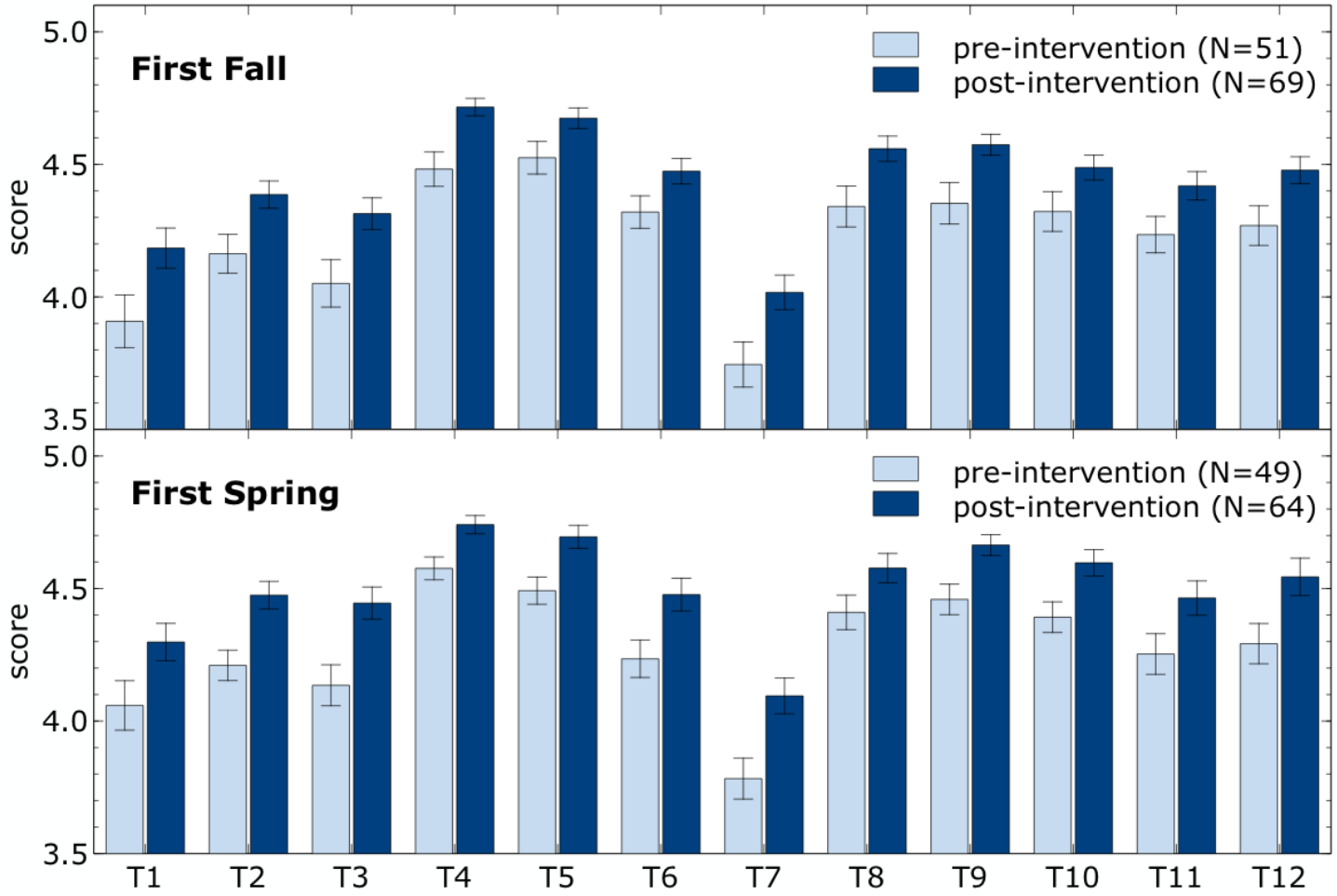
End-of-Semester Student Evaluations

- **Caveat:** student evaluations alone cannot measure teaching effectiveness
- **Pre-intervention:** GTAs with first teaching experience in 2011-2012
- **Post-intervention:** GTAs with first teaching experience in 2013-2015 (first three years of GTA prep course)
- Analysis of student evaluation scores for only **first Fall** and **first Spring** semester of teaching (when each grad student was a first-time GTA)

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

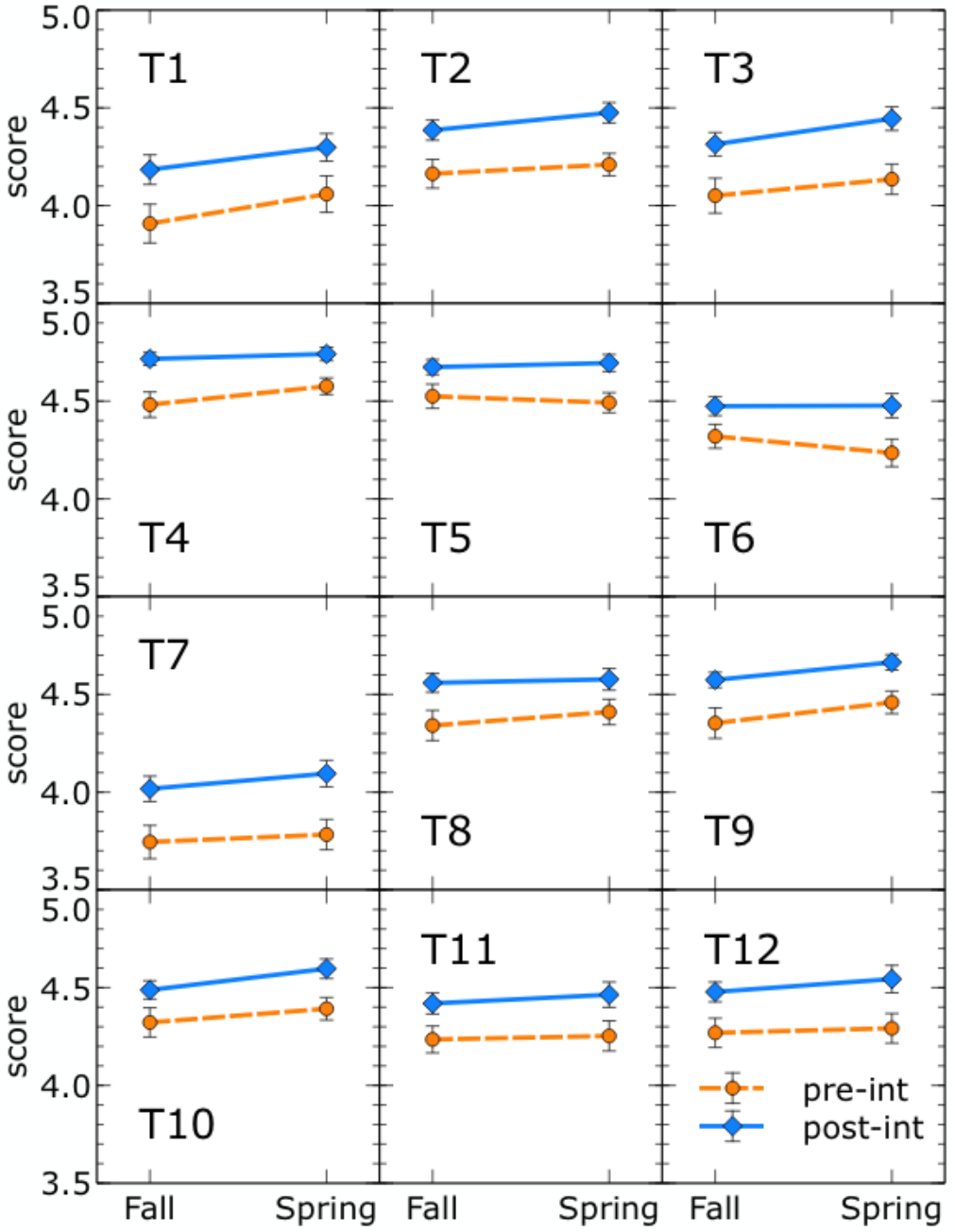
End-of-Semester Student Evaluations

- Post-intervention group was **always rated higher** than pre-intervention group (most differences are statistically significant)
- Skewed ratings suggest that Georgia Tech undergrads are reluctant to give a low (1, 2) rating unless something is egregiously wrong



End-of-Semester Student Evaluations

- **Highest rated:** familiarity with concepts, respect for students, approachability, level of preparedness
- **Lowest rated:** stimulated interest in subject
- For most items, rating in first Spring is higher than rating in first Fall
- **Participating in GTA prep leads to higher student evaluations**



Outline

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- **Conclusions and Summary**

Answering the Research Questions

- What elements of a formal GTA preparation program do GTAs perceive as the **most useful** or beneficial for their professional development?
  - *Microteaching, Lab Simulation, Teaching Physics*
  - *GTAs appreciate hands-on activities in which they get to practice teaching and receiving feedback on their performance*
  - *GTAs are interested in developing the pedagogical content knowledge necessary for teaching physics*

Answering the Research Questions

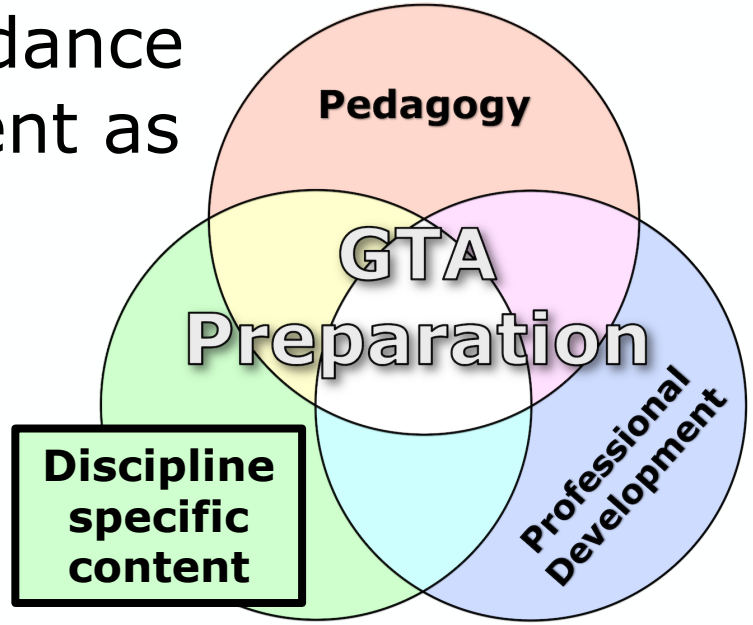
- What effect does a formal GTA preparation program have on graduate students' **teaching self-efficacy** and **attitudes** about teaching?
  - *GTAs report feeling better prepared for teaching after participating in the Orientation*
  - *GTAs adopt more learner-centered approaches to teaching after participating in the GTA prep course*

Answering the Research Questions

- 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 the GTA prep course are rated consistently higher in end-of-semester student evaluations than GTAs who predated the course*

Significance to PER

- There is no "one-size-fits-all" approach to GTA preparation
- Lots of work has been done, but most of it focuses on GTAs as future faculty – we shouldn't ignore the ones who leave academia
- The 3P Framework can provide universal guidance that ensures broader professional development as an integral part of GTA preparation
- Generalized to other fields: 3P → PDP (pedagogy, discipline-specific content, professional development)



Summary

- The Physics GTA Preparation course successfully **integrates** pedagogy, physics, and professional development
- Our GTA prep course satisfies the principles for **best practices** in GTA preparation, and is effective at preparing GTAs for their teaching roles
- 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
- Curriculum materials at: **https://tinyurl.com/ealiceaGTAPD**

Thank you!