The Impact of a Graduate Teaching and Leadership Course on Engineering Graduate Teaching Assistants' Learning of Pedagogy

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Abstract

It is essential to train engineering Graduate Teaching Assistants (GTAs) to be good educators. Evidence shows that most GTAs are unprepared for instruction. Literature suggests that when one receives training in teaching, one can acquire several transferable skills, such as effective communication, leadership, problem-solving, etc. GTA training programs aim to equip GTAs with proficient teaching skills while applying these transferable skills in their classrooms and future careers.

To assist engineering GTAs in honing their teaching skills, the research team developed a graduate teaching and leadership course. In Spring 2022, the Technological, Pedagogical, and Content Knowledge (TPACK) survey was used to assess the impact of the course on the GTAs' TPACK. Although it was found that the course positively impacted the GTAs' TPACK, the team did not assess the impact of each of the course's modules on the GTAs' learning. This follow-up study addresses the critical need for effective pedagogical development among engineering GTAs, focusing on the assessment of Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK). Recognizing the gap in validated instruments tailored to GTA training, the research team developed and implemented a specialized survey designed around the course.

The research commenced with the validation of the newly created survey instrument. Through extensive factor analysis, the validity of the survey was established, ensuring its alignment with the essential elements of PK and PCK. The survey comprises 40 items across 11 domains, reflecting the course modules' targeted pedagogical and leadership outcomes. The instrument's reliability was affirmed by Cronbach's alpha coefficients exceeding 0.75 for all domains, highlighting its consistency in measuring GTA pedagogical development.With the participation of 124 engineering GTAs in the pre-survey and 114 completing both pre- and post-surveys, the research team utilized the Mann-Whitney U and Wilcoxon Signed-Rank tests to evaluate the impact of the intervention. The findings demonstrated a significant enhancement in GTAs' skills across all surveyed domains, irrespective of their prior teaching experience. The study's results validate the survey instrument's utility in capturing the nuanced aspects of GTAs' pedagogical growth and confirm the targeted course modules' efficacy in advancing their teaching and leadership proficiency. Plans for ongoing instrument refinement and the potential for broader application underscore the study's significance in elevating GTA training effectiveness and pedagogical excellence.

Introduction

Graduate Teaching Assistants (GTAs) in engineering disciplines serve as a cornerstone of the teaching framework in higher education, bridging the gap between faculty and undergraduate students. While navigating their graduate studies, GTAs are thrust into diverse instructional roles, ranging from supporting faculty in large lectures to autonomously conducting laboratory sessions and recitations. Their influence is palpable in introductory STEM courses, where the caliber of teaching can significantly sway undergraduates' decisions to persist in STEM fields. However, despite their pivotal role, GTAs often embark on their teaching journeys with minimal instructional experience. This scenario sets the stage for a reliance on trial-and-error learning processes in the absence of systematic feedback or structured guidance on effective teaching methodologies.

This paper delves into the multifaceted challenges and opportunities that GTAs encounter, focusing on the necessity of enhancing their pedagogical skills within the engineering education context. The research team scrutinizes the existing literature on GTA professional development (PD) programs, highlighting the variability in their effectiveness and the pressing need for a more cohesive approach that bridges disciplinary and pedagogical competencies. Furthermore, the team explores existing frameworks for GTA training evaluation, including the Technological Pedagogical Content Knowledge (TPACK) and the newly proposed Engineering Integration Pedagogical Content Knowledge (EIPCK), to underline the importance of a focused improvement on Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK). Through the lens of this research, the team aims to address the gaps identified in the literature by proposing and validating a novel survey instrument designed to measure the specific elements of PK and PCK among GTAs in engineering, thereby offering insights into the targeted interventions required to bolster their teaching effectiveness. This introductory exploration sets the stage for a comprehensive analysis of the challenges GTAs face in engineering disciplines and underscores the critical need for targeted PD to equip them with the essential tools for fostering an engaging and effective learning environment. As such, this paper is relevant for administrators, instructors, and researchers in that it shows the importance of establishing a system that supports PD of GTAs (administrator relevance), describes the implementation of service learning in a course (instructor relevance), and connects the work and findings to literature (researcher relevance).

Background

GTA in engineering

Graduate Teaching Assistants are pivotal to the teaching infrastructure in higher education, particularly within the STEM disciplines, such as engineering. These individuals, who are themselves pursuing graduate degrees, undertake a variety of teaching roles, from assisting faculty in large lectures to leading small laboratory or recitation sessions [1]. Their contributions are especially significant in introductory STEM courses, where the quality of teaching directly influences undergraduate students' decisions to continue in STEM fields [2]–[6].

Despite the critical role GTAs play, research indicates that they often begin their teaching roles with limited prior instructional experience. This lack of experience necessitates a reliance on a trial-and-error approach to develop teaching skills, a process not systematically supported by formal feedback or guidance on teaching practices [7]–[9]. This challenge is particularly evident in facilitating collaborative problem-solving activities, a key component of engineering education, where GTAs struggle to implement effective strategies to support student-student interaction and learning [10], [11]. Even after targeted training, the translation of collaborative problem-solving theories into practical teaching strategies remains a significant challenge, largely due to the absence of concrete guidelines [12].

Graduate Teaching Assistants are often the primary point of contact for students in laboratory and recitation sections, where their approachability and relatability, due to closer age and experience levels, can significantly enhance the learning environment [13]–[16]. This dynamic positions GTAs as crucial facilitators of both subject matter and research-based knowledge, potentially impacting students' satisfaction and perception of value in their laboratory experiences [13]. However, the effectiveness of GTAs is contingent upon their ability to integrate subject matter expertise with pedagogical strategies to actively engage students and provide meaningful feedback [17], [18].

The breadth of responsibilities shouldered by GTAs includes leading laboratories, facilitating discussions, grading, and sometimes even full course instruction [17]. These tasks demand not only a deep understanding of the subject matter but also a versatile set of teaching strategies to cater to diverse learning needs [18], [19]. Despite the critical role that they play, GTAs, like many early career academics, often lack formal training in effective teaching practices, particularly those specialized for STEM disciplines [20], [21]. This gap underscores the importance of providing GTAs with adequate professional development (PD) opportunities to prepare them for their multifaceted instructional roles[22], [23].

Current literature on GTA PD programs presents a mixed picture of their effectiveness. While some programs have shown promise in enhancing GTAs' instructional skills and pedagogical understanding, the overall impact on teaching quality and student outcomes warrants further investigation [24], [25]. This variability in program outcomes highlights the need for a more systematic approach to GTA PD, focusing on the development of both disciplinary and pedagogical competencies.

Existing frameworks

Several frameworks exist for evaluating GTA training programs, each offering a unique perspective on the development and assessment of GTA pedagogical skills. The Technological Pedagogical Content Knowledge (TPACK) framework, initially proposed by Mishra and Koehler [26], is a comprehensive model that can be applied to GTA training, emphasizing the integration of content knowledge, pedagogical knowledge, and technological knowledge in teaching practices [27]. This framework is particularly relevant in STEM disciplines, where technology plays a crucial role in both research and teaching. In the previous work, the research team utilized the TPACK survey to assess the effectiveness of the GTA training program. The results suggested that the focus of the intervention was mainly on pedagogical content knowledge (PCK) and pedagogical knowledge (PK) domains [28]. But the team could not find frameworks that connected GTAs' activities to their PK and PCK. Newer frameworks like the Engineering Integration Pedagogical Content Knowledge (EIPCK) conceptual framework focus on the need for PCK and its subcomponents, namely, 1- Knowledge of Orientation to Teaching Engineering, 2- Knowledge of Engineering Integration Curriculum, 3- Knowledge of Students' Understanding of Engineering, 4- Knowledge of Engineering Teaching Strategy, and 5- Knowledge of Assessment in Engineering [29]. The close relation of this work to the EIPCK framework is evident in the attempt to operationalize its components for practical application and assessment. By tailoring the survey instrument to measure the specific elements of PK and PCK in the GTA training course, which adheres to the outlined knowledge framework in EIPCK, the research team seeks to provide a concrete mechanism for evaluating and enhancing GTA teaching practices within the engineering discipline. This approach acknowledges the complex interplay of content knowledge, pedagogical strategies, and the unique context of engineering education, aiming to equip GTAs with the necessary tools to foster an engaging and productive learning environment.

Focused improvement

Graduate Teaching Assistant training in engineering disciplines has predominantly concentrated on enhancing PK, a crucial component for effective teaching. However, there is a noticeable gap in the literature concerning the exploration of the sub-elements of PK and PCK. This oversight has implications for the depth and specificity with which GTA training programs can address the nuanced needs of teaching in engineering contexts. The reliance on unvalidated surveys in studies attempting to focus on these elements further complicates the ability to draw reliable conclusions about the efficacy of interventions aimed at improving GTA teaching practices [30]. Additionally, the use of comprehensive frameworks, while beneficial in broadening the scope of GTA training, has shown limitations in directly connecting TA practices with PCK or PK, suggesting a disconnect between theoretical frameworks and practical application in the classroom [28]. Therefore, the research team developed a survey instrument that focuses on the different course modules of the semester-long course and is based on the PCK and PK components. To understand the effectiveness of this survey, the team asks the following research questions:

1. What is the validity and reliability of the newly developed survey instrument in measuring the specific elements of Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK) among Graduate Teaching Assistants (GTAs) in engineering disciplines?
2. How does the targeted intervention, assessed based on the areas identified by the validated survey, affect the development of Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK) among Graduate Teaching Assistants (GTAs) in this course?

Methods

Study design

In the present investigation, a methodological framework grounded in design-based research was employed. This approach facilitated the systematic design, execution, and evaluation of the semester-long course focused on improving the teaching and leadership of GTAs. Central to this study was the deployment of quantitative methodologies to gauge the efficacy of the course. This deployment was accomplished through the development and validation of a survey instrument specifically tailored to the course the GTAs participated in within the engineering discipline.

The objective of this assessment was twofold. First, it aimed to ascertain the extent to which the course influenced the pedagogical development of GTAs. Second, it sought to explore the potential moderating effects of various demographic and academic variables, including the GTAs' years of teaching experience, academic year status, and specific engineering majors.

Context

During the Fall semester of 2023, a cohort of 258 GTAs (155 Master’s students, 103 Ph.D. students) enrolled in a one-credit hour innovative pedagogical development course. Students may choose to take it as pass/fail or standard letter grade. The course was structured to span over a fourteen-week semester, featuring weekly sessions of 50 minutes each. These sessions adopted a lecture-style format, enriched by the contributions of various guest speakers and the use of active learning methods, especially Think-Pair-Share exercises. The experts introduced the GTAs to a plethora of vital pedagogical topics. The curriculum encompassed diverse areas such as Student Interaction Techniques, Office Hours Management, Upholding Academic Integrity, Design of General Rubrics, Active Learning Strategies, and Support for Student Mental Health. Additional topics included Ethics in Education, Student Motivation, and Leadership in the classroom, enhancing Pedagogical and Pedagogical Content Knowledge and overall GTA preparedness [31].

To facilitate reflective learning, the course incorporated seven bi-weekly written assignments. These assignments required the GTAs to introspect and document their personal teaching experiences, drawing direct correlations with the theoretical concepts and strategies discussed in the weekly sessions.

Furthermore, the course offered an optional Service Learning project. This project was designed as a practical application of experiential education. This approach fosters mutual benefits for both the service providers (GTAs) and recipients (K–12 students). Participating GTAs were tasked with the design and execution of an engineering module, which they would subsequently teach in a classroom setting at a local school. This project served as a unique experience, enabling GTAs to apply their accumulated pedagogical knowledge in a real-world educational environment [28].

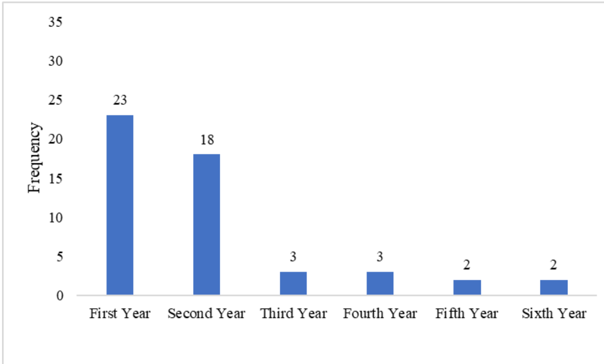
Participants

Within the scope of this study, the initial participant pool consisted of 258 students enrolled in the course. Of these, a subset of 124 students provided their consent to partake in the preliminary survey, which was instrumental in the validation process of the survey instrument. This initial engagement was crucial for ensuring the reliability and relevance of the survey in the context of this study.

Subsequently, a total of 50 students from the consenting group successfully completed both the pre- and post-course surveys. This completion rate reflects the participants' longitudinal engagement with the course and their willingness to contribute to both the initial and final assessments.

Demographic information

Figure 1a shows the frequency of the years in graduate school of the 50 consented GTAs. Most of the consented GTAs in the course were in their first and second years of graduate school. Figure 1b shows the frequency of the engineering disciplines for the 50 consenting GTAs. Twenty-two GTAs had teaching experience, such as being a teaching assistant (TA), a course assistant (CA), or an educator at a school. Twenty-eight GTAs had no teaching experience.



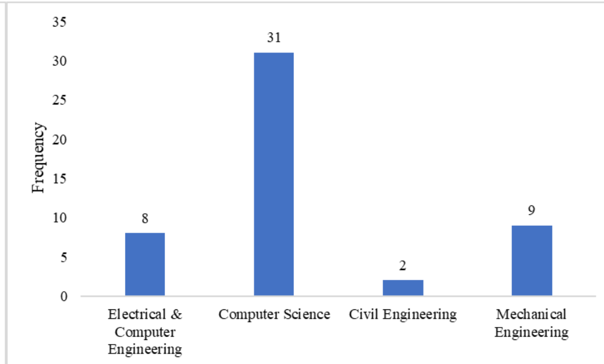


Figure 1a. Year in graduate school of GTAs

Figure 1b. Engineering disciplines of GTAs

Data collection

Data collection in this study was meticulously conducted through a set of pre- and post-surveys administered to the participants. Each survey comprised 47 items, designed to evaluate the impact of the course on the pedagogical and leadership development of the Graduate Teaching Assistants.

The method of data collection involved the use of Google Forms, a platform chosen for its accessibility and ease of use, which facilitated efficient and widespread participation among the GTAs. The survey itself was structured into fifteen distinct sections. The initial two sections were dedicated to gathering consent and demographic information from the participants, providing a contextual background to their responses.

The remaining thirteen sections of the survey were intricately aligned with the twelve course topics followed by an overall assessment of the course. Within each of these sections, participants were presented with three to four items, formatted as statements. The responses to these items were captured using a 5-point Likert scale, where a rating of 1 indicated strong disagreement and 5 signified strong agreement. This scaling system allowed for nuanced capture of the GTAs' perspectives and experiences, offering insight into the various dimensions of their pedagogical development as influenced by the course.

Analysis Procedure

In this study, the analytical focus centers on evaluating the influence of the course modules on both the pedagogical and leadership development of the GTAs. To this end, a specialized survey was devised, with each section tailored to correspond with a specific lesson module. The initial step in the analytical process of the research team involved validating this newly developed survey. A comprehensive factor analysis was employed to ensure the structural integrity of the survey and its relevance to the targeted developmental domains.

To assess the impact of the course on the GTAs' pedagogical and leadership development, a detailed analysis of the responses from both the pre- and post-course surveys was conducted. This analysis involved the application of the Wilcoxon Signed-Rank test to each of the 47 individual survey items, as well as to the aggregate data from each of the twelve distinct sections of the survey. This non-parametric test was chosen for its efficacy in detecting differences in rankings between two independent samples, thus providing a robust statistical foundation for the findings.

Additionally, to explore the potential influence of variables such as the GTAs' specific engineering major, their year in graduate school, and their cumulative years of teaching experience, a Wilcoxon Signed-Rank test was performed. This test was applied to the data collected across all twelve sections of the survey. The Wilcoxon Signed-Rank test, a non-parametric method, was particularly suited for this analysis, as it allowed for the comparison of paired samples to determine whether their population mean ranks differ.

Instrument development

The initial phase in the creation of the survey entailed an extensive review of existing literature, highlighting numerous instruments previously employed in assessing GTAs' pedagogy within educational environments. These existing instruments focused predominantly on evaluating aspects such as technology skills and proficiencies, teachers' beliefs and attitudes, the support provided for technology use, and the challenges encountered therein.

While constructing the survey, the objective was distinctly defined: to develop items that would effectively gauge the GTAs' self-assessment of their pedagogical development across the various domains addressed in the course. Insights gleaned from the existing surveys informed both the style and approach of the instrument, guiding the creation of items that specifically targeted the GTAs' self-perceived growth in pedagogical skills as influenced by the course modules.

The survey development process was iterative and collaborative within the research team. This phase involved repeated revisions of the survey items, ensuring clarity and relevance. To establish the content validity of the initial pool of 60 items, the research team engaged experts who possessed specialized knowledge in the relevant course modules. These experts, drawing on the principles outlined by Lawshe [32], provided critical evaluations of the items for content validity.

Post-evaluation, the research team convened to meticulously review and integrate the experts' feedback. This collaborative effort led to the refinement and adjustment of several survey items, tailoring them to align accurately with the pedagogical domains of all twelve-course modules. The final instrument, as a result of this rigorous development process, comprised 47 items. These items were designed to capture the GTAs' self-assessment of their pedagogical progress. For each item, participants were asked to respond using a five-level Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Instrument validation

To explore the factorial structure of the survey, all 47 items of the instrument were subjected to an exploratory factor analysis with oblique rotation (oblimin). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .84. Bartlett's test of sphericity $\chi 2$ (1103) = 1281.36, $p < .001$, indicating that correlation structure is adequate for factor analyses. The maximum likelihood factor analysis with a cut-off point of .35 and the Kaiser's criterion of eigenvalues greater than one [33], [34] yielded a ten-factor solution as the best fit for the data, accounting for 73.71% of the variance.

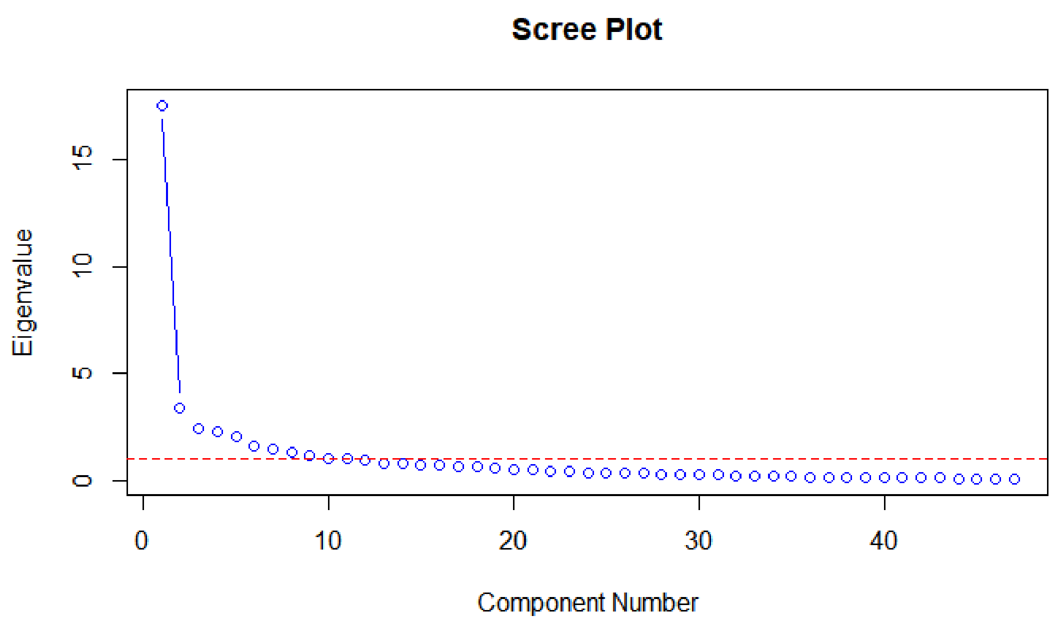


Figure 2. Scree Plot for estimating number of factors (Factors = 10)

Despite the above results, the research team decided to utilize a twelve-factor solution as the initial framework for the survey, utilizing the twelve-course modules in the program and focusing on distinct topics. This model accounted for 77.51% of the variance. The results of this factor analysis are presented in Table 1. Based on the factor analysis results, S1Q1, S1Q2, S1Q3, S1Q4, S12Q4, S13Q1, and S13Q2 were removed from the survey. Following their removal, a CFA for the remaining eleven domains were run, excluding the above factors. Maximum likelihood (ML) extraction was used to estimate the model. The base 12 factor model after removing the questions based on the factor analysis alone yielded acceptable results.

Table 1. Factor loadings for each survey item and its corresponding dimensions

Item	1	2	3	4	5	6	7	8	9	10	11	12	Domains
S8Q1	**0.87**												PK
S8Q2	**0.77**												PK
S8Q3	**0.59**												PK
S8Q4	**0.49**												PK
S1Q4													Interacting with students
S13Q1													TA preparedness
S5Q3		**0.88**											Active learning
S5Q4		**0.78**											Active learning
S5Q1		**0.72**											Active learning
S5Q2		**0.62**											Active learning
S10Q2			**0.95**										Ethics
S10Q1			**0.73**										Ethics
S10Q3			**0.51**										Ethics
S11Q4				**0.87**									Student motivation
S11Q2				**0.61**									Student motivation
S11Q3				**0.60**									Student motivation
S11Q1				**0.43**									Student motivation
S2Q1					**0.88**								Office hours
S2Q4					**0.58**								Office hours
S2Q2					**0.56**								Office hours
S2Q3					**0.51**								Office hours
S1Q1													Interacting with students
S6Q1						**0.78**							Mental health
S6Q2						**0.77**							Mental health
S6Q3						**0.66**							Mental health
S4Q2							**0.70**						Rubric design
S4Q1							**0.65**						Rubric design
S4Q3							**0.63**						Rubric design
S4Q4							**0.52**						Rubric design
S3Q4								**0.67**					Academic integrity
S3Q2								**0.61**					Academic integrity
S3Q1								**0.57**					Academic integrity
S3Q3								**0.54**					Academic integrity
S1Q3													Interacting with students
S9Q2									**0.68**				PCK
S9Q3									**0.63**				PCK
S9Q1									**0.53**				PCK
S9Q4									**0.40**				PCK
S13Q5										**0.57**			GTA preparedness
S13Q4										**0.54**			GTA preparedness
S12Q4										0.50			Leadership
S13Q3										**0.49**			GTA preparedness
S12Q2											**0.68**		Leadership
S12Q1											**0.50**		Leadership
S1Q2											0.37		Interacting with students
S12Q3											**0.36**		Leadership
S13Q2													GTA preparedness

In assessing model fit, various indices are employed, each offering unique insights. The Comparative Fit Index (CFI), as proposed by Bentler [35], compares the model to an independent baseline, with values near 1 indicating a good fit. Similarly, the Tucker-Lewis Index (TLI) or Non-Normed Fit Index (NNFI) is essential for evaluating model fit and complexity, where a value near 1 indicates a well-fitting model. The Root Mean Square Error of Approximation (RMSEA) gauges fit the population's covariance matrix, with 0.05 to 0.10 reflecting fair fit. The Standardized Root Mean Square Residual (SRMR) measures the difference between the sample and hypothesized covariance matrices, where values close to 0, but up to 0.08, denote acceptable fit [36]. The Akaike Information Criterion [37] and the Bayesian Information Criterion [38] are used for model comparison, with the AIC focusing on parsimony and the BIC penalizing for excess parameters. These indices collectively provide a comprehensive evaluation of how well a model fits the observed data. The model proposed herein satisfies all the criteria for model fit.

Table 2. Results of the CFA model after removing items

Model	$\chi 2$	*df*	*p*	CFI	TLI	RMSEA	SRMR	AIC	BIC
12 factor	1140.97	664	<.001*	0.85	0.82	0.08	0.07	8951.27	9320.66

*Significant, $p < 0.05$

Additionally, the research team ran Cronbach's Alpha for all of the 40 items that exist in the survey after the EFA and CFA analysis. The overall value of the alpha for each domain was greater than 0.76, showing strong validity of the survey items.

Table 3. Each section Cronbach's Alpha value

Domains	Cronbach's Alpha	*N* of Items
Office Hours	0.767	4
Academic Integrity	0.795	4
General Rubric Design	0.862	4
Active Learning	0.887	4
Supporting Students' Mental Health	0.876	3
Pedagogical Knowledge	0.879	4
Pedagogical Content Knowledge	0.884	4
Ethics	0.914	3
Student Motivation	0.888	4
Leadership	0.796	3
GTA preparedness	0.806	3
All Sections	0.955	40

Results

Impact of the Course on the GTAs' TPACK

To measure the impact of the course on the pedagogical knowledge of the GTAs, a Wilcoxon Signed-Rank Test was conducted on the participants' pre- and post-survey responses. The test results indicated a significant improvement in GTAs' competencies associated with each of the eleven domains. The results presented in Table 4 designate a significant positive impact on the total domains of the course related to the GTAs' Office Hours, Academic Integrity, General Rubric Design, Active Learning, Supporting Students' Mental Health, Pedagogical Knowledge, Pedagogical Content Knowledge, Ethics, Student Motivation, Leadership, and GTA preparedness.

Table 4. Wilcoxon Signed-Rank Test results ($N = 50$)

Domains	Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon signed-rank test		
			Z	***p***	***r***
Office Hours	3.67 (0.98)	4.26 (0.59)	-4.523	<0.001*	-0.640
Academic Integrity	3.36 (0.85)	4.23 (0.63)	-4.281	<0.001*	-0.605
General Rubric Design	3.63 (1.00)	4.41 (0.56)	-4.868	<0.001*	-0.688
Active Learning	3.37 (0.96)	4.25 (0.68)	-5.433	<0.001*	-0.768
Supporting Students' Mental Health	3.27 (1.03)	4.09 (0.78)	-4.811	<0.001*	-0.680
Pedagogical Knowledge	3.57 (0.80)	4.30 (0.62)	-4.636	<0.001*	-0.656
Pedagogical Content Knowledge	3.59 (0.72)	4.22 (0.62)	-4.793	<0.001*	-0.678
Ethics	3.32 (1.16)	4.11 (0.76)	-4.038	<0.001*	-0.571
Student Motivation	3.18 (1.08)	4.07 (0.72)	-4.979	<0.001*	-0.704
Leadership	3.56 (1.20)	4.29 (0.61)	-4.464	<0.001*	-0.631
GTA preparedness	3.68 (1.04)	4.47 (0.61)	-4.974	<0.001*	-0.703

*Significant, $p < 0.05$, all items in each category are significant

In order to assess the impact of years of teaching experience, years in graduate school, and engineering majors are factors that influence the GTAs' development, the research team conducted a Wilcoxon Signed-Rank Test on pre-test and post-test scores. Notably, all domains exhibited statistically significant differences depending on the variable change.

Discussion

In this study, the research team set out to understand the effectiveness of individual course modules of an existing semester-long teaching and leadership preparation course for engineering GTAs. Due to the lack of validated surveys that focus on the finer details of what GTAs do, the team developed its own survey focusing on PCK and PK of GTAs, which was developed around the course modules to assess its effectiveness. From the 124 initial consented participants in the pre-survey, 114 fully completed pre-surveys were used to validate the surveys. The research team conducted EFA and CFA to create a 12-factor model that resulted in a survey with 40 items that assesses eleven domains of PCK and PK of GTAs. Additional validity was measured using Cronbach's alpha, which was greater than 0.76 for all domains. The validation process revealed that the domain concerning student interactions was superfluous. Although with regards to the course, this serves as an initial step for GTAs to think about their interactions with students, further topics involving leadership, supporting students' mental health, and office hours domains have a better focus on capturing these interactions. The delayed emphasis on those topics is evident in how the factors were loaded in the EFA.

After validating the survey, the research team performed a Wilcoxon Signed Rank test for the 50 consented participants who participated in both the pre- and post-survey. Results show that there is a significant improvement in GTAs skills in all the domains covered by the semester-long course. Specifically, the strong effect size shows that there were significant improvements in all the domains for the GTAs regardless of having prior teaching experience or not. However, as expected, students with no teaching experience showed a greater effect size than those with prior teaching experience. This result indicates that the course content is structured to benefit GTAs with and without teaching experience. The effect could be due to the format with which each session was structured. For each topic, the course staff would initially identify a guest speaker who had extensive experience and invite that person to present a session. An iterative process was then used to fine-tune each session from one semester to the next, or to rotate in/out a guest speaker. This process ensured each session was high quality and the guest speaker could effectively engage GTAs in interactive activities and discussions. Many of these class activities were embedded in scenarios that were common among the GTAs' usual duties. The GTAs were immersed in a simulated environment, where they would be able to apply skills learned in the class to solve the problems presented. Even for those with prior experience, it is unlikely that they have encountered all the curated scenarios. Therefore, the course content benefited everyone. For example, the guest speaker for the ethics session is a well-respected scholar in the field and an exceptional presenter. The session covered how ethics problems can be approached and the different tests that can be used to evaluate the situations. Two scenarios were given to the class one by one and GTAs would discuss each scenario as a group and then share out. These two scenarios are: (1) a young faculty member being very popular with his/her students and often seen talking to them at his office about sports, movies, and other nonacademic topics; (2) a faculty member who has very little experience in a topic is considering skipping it in the introductory level course that he/she teaches. GTAs often had different opinions regarding these scenarios and the discussion was quite lively.

Our results indicate that this is a promising instrument for measuring improvement of the GTAs in the PK and PCK domains. This survey instrument was designed with a specific purpose in mind: to examine the development of PK and PCK in GTAs. Over the years, several instruments have been developed to measure the pedagogical development of GTAs, such as TPACK, etc. [26]. Readers are reminded that this survey was specifically designed for the GTA program at the home college of the research team and the individual course modules that it contains [31]. Given the results of this instrument, writing additional items for these subscales might strengthen the reliability and validity of the instrument in these areas. Research plans include continual revision and refinement of the instrument, including the addition of more items to some of the sections of the instrument.

Limitations

Due to the limited number of pre-survey participants (114) for validating such a long survey (47 items), the results were at the lower end of the acceptable range for validity.

Conclusion & Future Work

The instrument devised for this investigation offers a foundational tool for probing and fostering the evolution of PK and PCK among GTAs. Initial assessments utilizing the validated survey instrument indicate a significant, positive influence on GTAs' PK and PCK. The employment and subsequent refinement of this instrument are anticipated to stimulate a research trajectory focused on quantifying GTAs' progression in PK and PCK. Such endeavors are expected to enhance GTA development initiatives, equipping them with the necessary data to craft and execute strategies that promote these essential pedagogical competencies. Moving forward, the intention is to deploy the survey at strategic intervals within GTA programs. Analyzing these data will enable the identification of specific junctures or experiences conducive to the growth of each domain. The insights garnered from this process are poised to shed light on the nuanced aspects of PK and PCK development and offer feedback on effective methodologies for nurturing such evolution within GTA training programs.

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Appendix

Pre/Post Survey items

Item code	Survey question
S1	**Interacting with Students**
S1Q1	I know how to interact with students in my teaching role.
S1Q2	I know how to establish rapport with students.
S1Q3	I know how to manage a diverse classroom.
S1Q4	I know how to actively listen when interacting with students.
S2	**Office hours**
S2Q1	I know how to conduct productive office hours.
S2Q2	I know how to create a welcoming environment during office hours.
S2Q3	I know how to handle multiple student queries simultaneously.
S2Q4	I know how to prepare for office hours.
S3	**Academic Integrity**
S3Q1	I know how to address academic integrity issues.
S3Q2	I know how well students understand the boundaries of academic integrity.
S3Q3	I know how to communicate the importance of academic integrity to students.
S3Q4	I know how to distinguish between collaboration and cheating.
S4	**General Rubric Design**
S4Q1	I know how to design effective grading rubrics.
S4Q2	I know how to grade consistently for student learning.
S4Q3	I know how to establish a transparent grading system.
S4Q4	I know how to provide constructive feedback using a rubric.
S5	**Active Learning**
S5Q1	I know how to utilize active learning strategies.
S5Q2	I know how to facilitate group discussions or activities effectively.
S5Q3	I know how to incorporate active learning techniques into lessons regularly.
S5Q4	I know how to ensure student participation for successful active learning.
S6	**Supporting Students' Mental Health**
S6Q1	I know how to support students facing mental health challenges.
S6Q2	I know how to identify signs of mental distress in students.
S6Q3	I know how to handle sensitive conversations with students.
S8	**Pedagogical Knowledge**
S8Q1	I can adapt my teaching based upon what students currently understand or do not understand.
S8Q2	I can adapt my teaching style to different learners.
S8Q3	I can use a wide range of teaching approaches in a classroom setting.
S8Q4	I can assess student learning in multiple ways.
S9	**Pedagogical Content Knowledge**
S9Q1	I know how to select effective teaching approaches to guide student thinking and learning in my teaching subject.
S9Q2	I know how to develop appropriate tasks to promote students complex thinking of my teaching subject.
S9Q3	I know how to develop exercises with which students can consolidate their knowledge of my teaching subject.
S9Q4	I know how to evaluate students' performance in my teaching subject.

S10	**Ethics**
S10Q1	I know how to handle ethical dilemmas in the classroom.
S10Q2	I know how to discuss ethical topics with students.
S10Q3	I know how to make ethical decisions in ambiguous situations.
S11	**Student Motivation**
S11Q1	I know how to motivate disinterested students.
S11Q2	I know how to adapt teaching methods to cater to different student motivations.
S11Q3	I know how to actively work on motivating students.
S11Q4	I know how to consider student motivation when planning lessons.
S12	**Leadership**
S12Q1	I know how to lead a group of students towards a common goal.
S12Q2	I know how to lead in the classroom.
S12Q3	I know how to take initiative in the classroom.
S12Q4	I know how to appreciate the need for TAs to exhibit leadership in the classroom.
S13	**GTA preparedness**
S13Q1	I know how to prepare myself for the role of a TA.
S13Q2	I know how to have a mentor for my TA.
S13Q3	I know how to prepare for a TA role through peer insights.
S13Q4	I know how to present my learnings to peers confidently.
S13Q5	I know how to reflect on my learning experiences regularly.