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The Impact of a 16-Week Preparation Course on the Technological Pedagogical Content Knowledge of Graduate Teaching Assistants in Engineering

Dr. Saadeddine Shehab, University of Illinois, Urbana-Champaign

Saadeddine Shehab is currently the Associate Director of Assessment and Research at the Siebel Center for Design (SCD) at the University of Illinois at Urbana-Champaign. He works with a group of undergraduate and graduate SCD scholars at SCD's Assessment and Research Laboratory to conduct research that informs and evaluates the practice of teaching and learning human-centered design in formal and informal learning environments. His research focuses on studying students' collaborative problem-solving processes and the role of the teacher in facilitating these processes in STEM classrooms that feature the learning of STEM through design.

Mr. Joshua E Katz, University of Illinois, Urbana-Champaign
Emma Kirby, University of Illinois, Urbana-Champaign
Dr. Marcia Pool, University of Illinois, Urbana-Champaign

Dr. Marcia Pool is a Teaching Associate Professor and Director of Undergraduate Programs in the Department of Bioengineering at the University of Illinois at Urbana-Champaign (UIUC). She has been active in improving undergraduate education including developing laboratories to enhance experimental design skills and mentoring and guiding student teams through the capstone design and a translational course following capstone design. In her Director role, she works closely with the departmental leadership to manage the undergraduate program including: developing course offering plan, chairing the undergraduate curriculum committee, reviewing and approving course articulations for study abroad, serving as Chief Advisor, and representing the department at the college level meetings. She is also engaged with college recruiting and outreach; she coordinates three summer experiences for high school students visiting Bioengineering and co-coordinates a weeklong Bioengineering summer camp. She has worked with the Cancer Scholars Program since its inception and has supported events for researcHStart. Most recently, she was selected to be an Education Innovation Fellow (EIF) for the Academy for Excellence in Engineering Education (AE3) at UIUC. At the national level, she served as the Executive Director of the biomedical engineering honor society, Alpha Eta Mu Beta (2011-2017) and is an ABET evaluator (2018-present).

Prof. Yuting W. Chen, University of Illinois, Urbana-Champaign

Dr. Yuting W. Chen received the B.S. degree from University of Illinois Urbana-Champaign in 2007, and the M.S. and Ph.D. degrees from Rensselaer Polytechnic Institute in 2009 and 2011, all in Electrical Engineering. She is currently a Teaching Associate Professor in Electrical and Computer Engineering at University of Illinois Urbana-Champaign. Her current interests include recruitment and retention of under-represented students in STEM, K-12 outreach, integrative training for graduate teaching assistants, service learning, and curriculum innovation for introductory computing courses.

Prof. Blake Everett Johnson, University of Illinois, Urbana-Champaign

Dr. Blake Everett Johnson is a Teaching Assistant Professor and instructional laboratory manager in the Department of Mechanical Science and Engineering at the University of Illinois Urbana-Champaign. His research interests include experimental fluid mechanics, measurement science, engineering education, engineering leadership, and professional identity development.

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The Impact of a 16-week Preparation Course on the Technological Pedagogical Content Knowledge (TPACK) of Graduate Teaching Assistants in Engineering

Abstract

Technological Pedagogical Content Knowledge (TPACK) is an important framework that defines teachers' competencies for teaching effectively with technology. Graduate teaching assistants (GTAs) in engineering need to develop their TPACK so they can effectively fulfill their teaching responsibilities and be better prepared for future teaching or industry careers, which usually entails communicating effectively with others and mentoring interns and other team members. Research studies have shown that semester-long courses (16 weeks) are the most effective preparation formats for preparing GTAs to teach in engineering; however, the content that constitutes such a course and the impact of the course on the GTAs' TPACK domains still require further exploration. The purpose of this study is to assess the impact of a semester-long preparation course on the TPACK domains of GTAs in Engineering.

In Spring 2022, 165 GTAs took a semester-long teaching and leadership preparation course for engineering graduate students. The course was composed of fourteen 50-minute weekly sessions, seven bi-weekly written assignments, and one optional service learning project. Forty-seven students participated in the study. They completed a validated and reliable pre- and post-survey that is composed of 28 items to assess the impact of the course on the teaching competencies associated with the TPACK domains. The results of paired sample *t*-tests indicated positive impacts on the GTAs' pedagogical knowledge, content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge domains. Years of teaching experience, year in school, and engineering major were not significant factors. Future courses need to include guided activities that can assist the GTAs in merging the pedagogical and technological knowledge into the content knowledge domain. One way to accomplish this would be to make the service learning project mandatory and provide the needed support for the GTAs to make the connections between what they want to teach (content), how to teach it (pedagogy), and what technological tools can be used to teach it (technology). Future studies will explore possibilities of implementing this and its impact on the GTAs' TPACK domains.

Introduction

Graduate teaching assistants (GTAs) are graduate students who assist professors in teaching courses through performing teaching practices such as presenting information, explaining certain concepts to students, communicating with students and assessing students' learning outcomes [1]. Nevertheless, for GTAs to implement effective teaching practices, they need preparation programs that can facilitate their knowledge of what they teach, how to teach, and how to leverage the growing technological affordances while teaching [2].

TPACK is an important framework that defines teachers' knowledge domains for teaching effectively with technology [3]. It integrates the pedagogical, content, and technological knowledge domains and focuses on the connections between these domains [4], [5]. Such a framework can assist scholars in understanding and measuring the development of knowledge that teachers need to design, implement and evaluate learning experiences with new and advanced digital technologies [6].

In engineering, GTAs' preparation programs are becoming more essential given the complexity of the teaching responsibilities that is prescribed by the difficulty of disciplinary content, the role of technology in the content, and the objectives of the engineering programs that now include acquiring soft skills, such as collaboration and communication, in addition to the knowledge of the engineering content. Research studies have shown that semester-long courses (16 weeks) are the most effective formats for preparing GTAs to teach in engineering and computer science [7]. Nevertheless, for these courses to be effective, they must offer GTAs opportunities to learn, apply, and reflect on different teaching practices so they develop competencies associated with the TPACK domains. In this study, an existing semester-long teaching and leadership preparation course for engineering GTAs is evaluated by assessing its impact on their TPACK.

Background

GTAs in Engineering

Graduate Teaching Assistants play an important teaching role in universities. They often lead laboratory or recitation sessions and engage in teaching practices such as providing feedback, grading exams and assignments, and evaluating students' performance in a course. When starting their appointments, GTAs usually have yet to gain any prior teaching experience [8]. This means that the GTAs need to develop teaching competencies that allow them to design, implement, and evaluate curriculum and instruction that aims to prepare students to acquire the knowledge of a discipline and professional skills such as collaboration and communication. In engineering, these competencies must include engineering-specific teaching competencies such as teaching quantitative problem solving skills, the evaluation of multiple and/or optimal solutions [9], [10], the theories and principles of an engineering field, and model construction or practice [11]. Consequently, in order for GTAs to effectively perform their teaching duties in engineering courses they need to have teaching competencies associated with how to teach (pedagogy), what to teach (content), and what technological tools to include (technology) given the role of technology in supporting teaching methods such as collaborative learning [12] and in many engineering fields [11].

What is TPACK?

Technological Pedagogical Content Knowledge (TPACK) is an essential framework that defines teachers' competencies for teaching effectively with technology [5]. Within the TPACK framework, there are seven domains. The first three include technology knowledge (TK), content knowledge (CK), and pedagogical knowledge (PK). The last four combine the first three to create pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK). These seven domains determine a teacher's actions in the learning contexts or settings [13], [14]. Table 1 presents the definitions of the TPACK domains that constitute the TPACK framework [15], [5], [4].

Table 1
The definitions of the seven TPACK domains ([4], p. 3–10)

Pedagogical Knowledge (PK)	Knowledge about the process and practices or methods of teaching and learning and how it encompasses educational purposes, values, and aims (e.g., student learning, classroom management, lesson plan development and implementation).
Content Knowledge (CK)	Knowledge about the actual subject matter that is to be taught (e.g., central facts, concepts, theories, procedures).
Technological Knowledge (TK)	Knowledge about standard technologies and how to operate them (e.g., from books and chalkboards to the internet and digital video).
Pedagogical Content Knowledge (PCK)	Knowledge of pedagogy that is applicable to the specific teaching content (e.g., knowing what teaching approaches fit the content, knowing how elements of content can be arranged for better teaching).
Technological Pedagogical Knowledge (TPK)	Knowledge of how teaching may be changed as a result of using particular technologies (e.g., knowing that a range of tools exist, ability to select based on fitness and of affordance of these tools for pedagogical practices).
Technological Content Knowledge (TCK)	Knowledge about how technology and the content are reciprocally related (e.g., knowing how subject matter can be changed by the application of technology).
Technological Pedagogical Content Knowledge (TPCK)	Knowledge for good teaching with technology which requires understanding how technologies can support teaching subject matter.

The TPACK framework has been used throughout science, technology, engineering, and mathematics (STEM) fields to aid in professional development (PD) for teachers. Chai reviewed studies that integrated STEM education and TPACK in teacher professional development [16].

Findings noted that integrating TPACK in professional development could offer a direct format to track the teachers' knowledge changes as a result of the professional development, and Brinkley-Etzkorn pointed out that the TPACK domains can be used as a conceptual framework to examine the impact of professional development on instructors and measure its effectiveness on teachers' knowledge of teaching [17]. In a study that assessed the impact of a professional development course on pre-service educators' TPACK using the survey collection method, Schmidt et al. found that the competencies associated with the seven TPACK domains had grown considerably after the course and were in the "good" or "excellent" range of improvement [3]. Given the importance of the TPACK framework in characterizing the different knowledge domains for a teacher to teach effectively with technology and given its role in planning and evaluating preparation programs that aim to prepare teachers for performing their teaching duties, this framework is used in this study to understand the impact of a semester-long preparation course on GTAs in engineering.

GTAs and TPACK

Building on findings from the reviewed studies that show that teachers' performance is directly related to the TPACK domains that are described by the TPACK framework [18], it is argued here that GTAs in engineering need to develop teaching competencies that are associated with the TPACK domains to effectively fulfill their teaching responsibilities and be better prepared for future teaching or industrial careers [19]. Nevertheless, like teachers, GTAs need support in order to develop these competencies.

Research studies have shown that GTA or TA preparation programs can have a positive impact on their teaching (e.g. [20]). Research studies have also shown that semester-long courses (16 weeks) are the most effective formats of programs that aim to prepare GTAs to teach in engineering or other STEM fields [21]. For example, a training course that was implemented with computer science teaching assistants had them work on five modules: human resources questions, classroom teaching, helping and supervising lab sessions, assessment, and reflection and discussion [7]. At the end of the course, the teaching assistants took a survey to determine the effectiveness of the course content. Results indicated a positive impact on their teaching skills. These studies also indicated that impactful preparation courses for teaching assistants included activities that engage them in problem-based learning, service-learning, collaborative learning, and reflection. However, the content that constitutes such preparation courses and the impact of such courses on the GTAs' teaching competencies that are associated with the seven TPACK domains still require further exploration. This study aims to address this gap by answering the following questions:

1) What is the impact of an existing semester-long preparation course on the TPACK of GTAs in engineering?
2) Does the years of teaching experience, year in school, and engineering major influence the GTAs' TPACK development in the course?

Methods

Design

In this study, a design-based research methodology by Mckenney and Reeves was used to design, implement, and evaluate the course [22]. Quantitative measures were used to assess the impact of the course on the TPACK of GTAs in engineering and examine if factors such as years of teaching experience, year in school, and engineering major influenced the development of GTAs' TPACK in the course. Findings from this study will inform future iterations of this course.

Context of Study

In Spring 2022, 165 GTAs took the course. The course consisted of fourteen 50-minute weekly sessions, seven bi-weekly written assignments, and one optional service learning project. The weekly sessions followed a lecture-type series with different guest speakers introducing the TAs to key pedagogical topics such as Bloom's taxonomy, active learning, rubric design, student motivation, and ethics. The seven bi-weekly assignments engaged the GTAs by asking them to write their reflections on personal teaching experiences related to the topics presented in the course. The service learning project was optional, and it required the GTAs to design and teach an engineering module in one of the local schools' classrooms. Service learning is also an experimental education procedure that involves "reciprocal learning" [23], [24], allowing both providers and recipients to benefit from the activity. The assignment required students to design an engineering module and teach it in one of the local schools' classrooms at the end of the course [19]. It is hypothesized that exposing GTAs to pedagogical practices, having them reflect on these in light of their ongoing teaching experience, and offering them the opportunity to participate in the service learning assignment will positively impact their PK directly and the other PK related domains such as TPK, PCK and TPACK indirectly.

Participants

This study had forty-seven consenting participants in total. They were all graduate teaching assistants in the Grainger College of Engineering.

Data Collection and Analysis Procedures

The participants completed a validated and reliable pre- and post-survey composed of 28 items to assess the impact of the course on TPACK of GTAs [15]. The pre- and post-surveys were collected via Google forms. The survey was composed of eight sections. The first section included questions to collect demographic information. The remaining seven sections were associated with the seven TPACK domains. Each section had four 5-point Likert scale items, with 1 being strongly disagree and 5 being strongly agree.

To determine the impact of the course on the GTAs' TPACK, the GTAs' pre- and post-survey responses are used to conduct paired sample *t*-tests on each of the twenty-eight survey items and each of the seven sections of the survey. In addition, the survey responses per each section were used to conduct paired sample *t*-tests per section. To determine if the GTAs' engineering major, year in graduate school, and years of teaching experience affected the impact of the course on the GTAs' TPACK, a repeated measure ANOVA was performed on each of the seven sections of the survey.

Results

Demographics information

For the forty-seven consented GTAs, Figure 1 shows the frequency of the engineering disciplines, Figure 2 shows the frequency of the years in graduate school, and Figure 3 shows the frequency of GTAs who had or did not have teaching experience before taking the course.

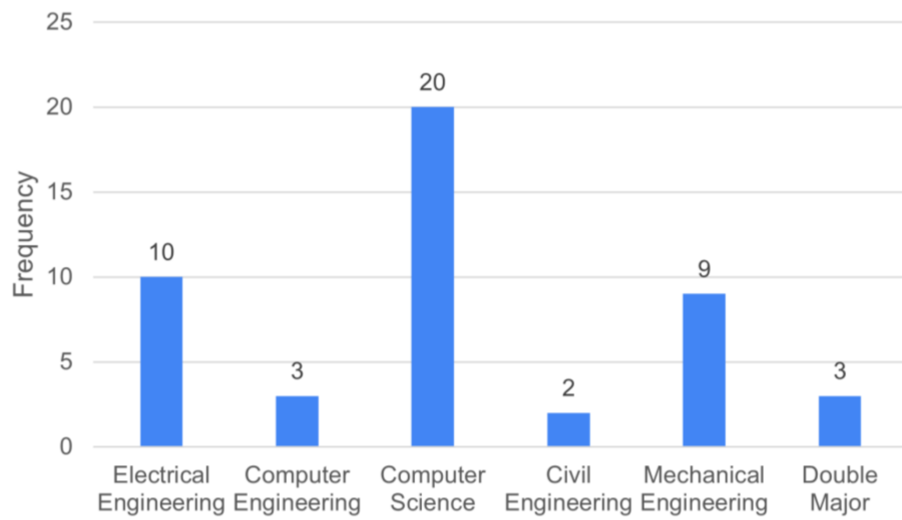

Figure 1. Engineering disciplines of the forty-seven GTAs

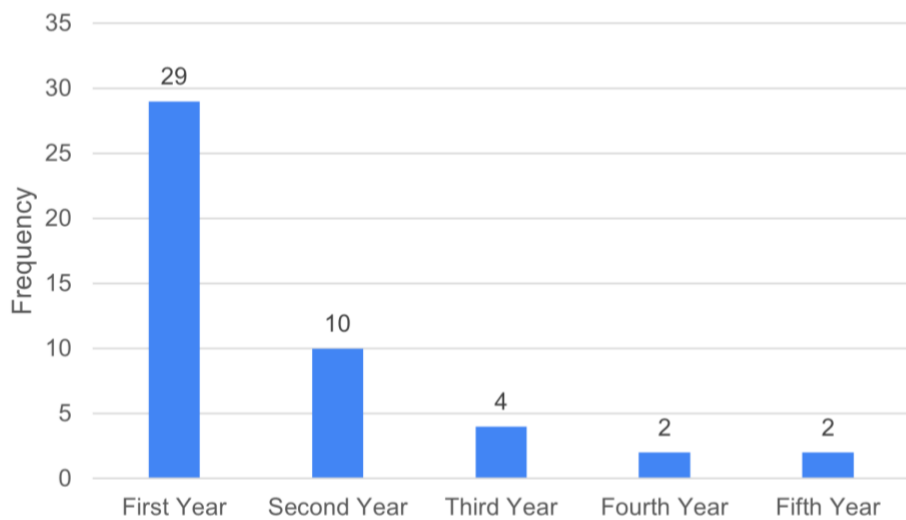

Figure 2. Year in graduate school of the forty-seven GTAs

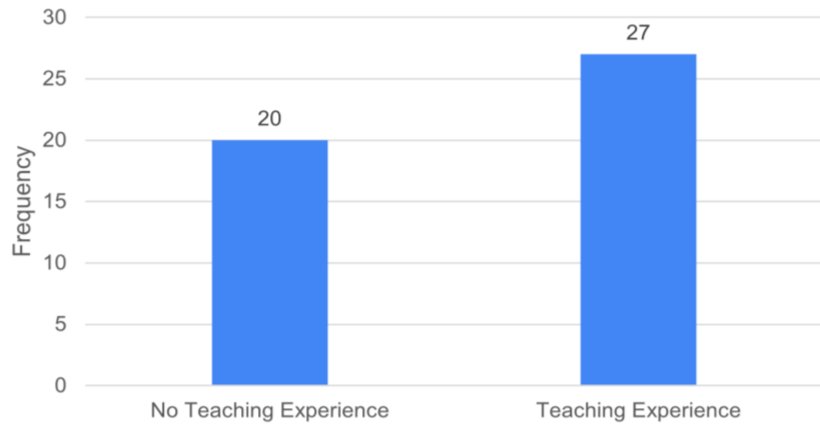

Figure 3. GTAs' (n=47) Teaching Experience

Impact of the Course on the GTAs' TPACK

To measure the impact of the course on the GTAs' TPACK, a paired sample *t*-test was conducted on the participants' pre- and post- survey responses. The results of the test indicate a significant improvement in GTAs' competencies associated with several TPACK domains. The results presented in Table 2 indicate a significant positive impact of the course on all four items associated with the GTAs' pedagogical knowledge (PK) and the GTAs' PK domain.

Table 2
Paired Sample *t*-tests results of PK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I can adapt my teaching based upon what students currently understand or do not understand.	4.15	.66	4.40	.54	*t*(46) = -2.60, ***p* = 0.013***
I can adapt my teaching style to different learners.	3.70	.75	4.17	.73	*t*(46) = -4.67, ***p* = <0.001***
I can use a wide range of teaching approaches in a classroom setting.	3.47	.86	3.94	.89	*t*(46) = -3.09, ***p* = 0.003***
I can assess student learning in multiple ways.	3.66	.79	3.96	.91	*t*(46) = -2.05, ***p* = <0.047***
PK Domain	14.98	2.39	16.47	2.55	*t*(46) = -3.99, ***p* = <0.001***

*Significant, $p<0.05$

The results presented in Table 3 indicate a significant positive impact of the course on two of the four items associated with the GTAs' content knowledge (CK) and the GTAs' CK domain.

Table 3
Paired sample *t*-test results of CK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I have sufficient knowledge about my teaching subject.	4.15	.69	4.36	.79	*t*(46) = -2.12, ***p* = 0.040***
I can use a subject-specific way of thinking in my teaching subject.	3.98	.68	4.21	.81	*t*(46) = -1.91, ***p* = 0.062**
I know the basic theories and concepts of my teaching subject.	4.38	.64	4.60	.65	*t*(46) = -2.22, ***p* = 0.031***
I know the history and development of important theories in my teaching.	3.53	.12	3.55	.97	*t*(46) = -0.148, ***p* = 0.883**
CK Domain	16.04	2.19	16.72	2.54	*t*(46) = -2.13, ***p* = 0.038***

*Significant, $p<0.05$

The results presented in Table 4 indicate a significant positive impact of the course on one of the four items associated with the GTAs' technological knowledge (TK). The course had no significant impact on the GTAs' TK domain.

Table 4
Paired sample *t*-test results of TK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I keep up with important new technologies	4.17	.89	4.19	.80	*t*(46) = -0.19, ***p* = 0.850**
I frequently play around with the technology.	4.02	.94	4.19	.90	*t*(46) = -1.35, ***p* = 0.185**
I know about a lot of different technologies	4.06	.87	4.15	.78	*t*(46) = -0.70,

					***p* = 0.485**
I have the technical skills I need to use technology	4.34	.64	4.64	.53	*t*(46) = -3.28, ***p* = 0.002***
TK Domain	16.60	2.88	17.17	2.43	*t*(46) = -1.68, ***p* = 0.100**

*Significant, *p*<0.05

The results presented in Table 5 indicate a significant positive impact of the course on all four items associated with the GTAs' Technological Pedagogical Knowledge (TPK) and the GTAs' TPK domain.

Table 5
Paired sample *t*-test results of TPK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I can choose technologies that enhance the teaching approaches for a lesson.	3.68	.78	4.09	.78	*t*(46) = -3.47, ***p* = 0.001***
I can choose technologies that enhance students' learning for a lesson.	3.56	.83	4.04	.86	*t*(46) = -3.37, ***p* = 0.002***
I can adapt the use of the technologies that I am learning about to different teaching activities.	3.78	.83	4.15	.86	*t*(46) = -3.25, ***p* = 0.002***
I am thinking critically about how to use technology in my classroom.	3.62	.90	4.06	.96	*t*(46) = -2.69, ***p* = <0.001***
TPK Domain	14.66	2.88	16.34	3.02	*t*(46) = -4.19, ***p* = <0.001***

*Significant, *p*<0.05

The results presented in Table 6 indicate a significant positive impact of the course on one of the four items associated with the GTAs' Technological Content Knowledge (TCK) and the GTAs' TCK domain.

Table 6
Paired sample *t*-tests results of TCK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I know how technological developments have changed the field of my subject.	4.00	.86	4.23	.79	*t*(46) = -1.56, ***p* = 0.125**
I can explain which technologies have been used in research in my field.	4.06	.73	4.34	.73	*t*(46) = -2.16, ***p* = 0.037***
I know which new technologies are currently being developed in the field of my subject.	4.00	.86	4.10	.79	*t*(46) = -0.96, ***p* = 0.341**
I know how to use technologies to participate in scientific discourse in my field.	3.94	.73	4.17	.79	*t*(46) = -1.97, ***p* = 0.055**
TCK Domain	16.00	2.72	16.85	2.67	*t*(46) = -2.15, ***p* = 0.037***

*Significant, $p<0.05$

The results presented in Table 7 indicate no significant positive impact of the course on any of the four items associated with the GTAs' Pedagogical Content Knowledge (PCK) and the GTAs' PCK domain.

Table 7
Paired sample *t*-tests results of PCK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I know how to select effective teaching approaches to guide student thinking and learning in my teaching subject.	3.38	.87	3.51	1.32	*t*(46) = -0.56, ***p* = 0.576**
I know how to develop appropriate tasks to promote students' complex thinking of my teaching subject.	3.40	.80	3.55	1.25	*t*(46) = -0.73, ***p* = 0.469**
I know how to develop exercises with which students can consolidate their knowledge of my teaching subject.	3.38	.87	3.62	1.26	*t*(46) = -1.84, ***p* = 0.242**
I know how to evaluate students' performance in my teaching subject.	3.66	.92	3.83	1.24	*t*(46) = -0.76, ***p* = 0.452**

PCK Domain	13.83	2.88	14.51	4.77	$t(46) = -0.88$, **$p = 0.383$**

*Significant, $p<0.05$

The results presented in Table 8 indicate a significant positive impact of the course on three of the four items associated with the GTAs' Technological Pedagogical Content Knowledge (TPACK) and the GTAs' TPACK domain.

Table 8
Paired sample *t*-tests results of TPACK section

	Pre		Post		
Survey Item	Mean	SD	Mean	SD	Paired *t*-test
I can use strategies that combine content, technologies, and teaching approaches in my teaching.	3.81	.77	4.02	.77	$t(46) = -1.87$, **$p = 0.067$**
I can choose technologies that enhance the content for a lesson.	3.79	.72	4.02	.71	$t(46) = -2.20$, **$p = 0.033$***
I can select technologies to use in my teaching that enhance what I teach, how I teach, and what students learn.	3.83	.70	4.11	.70	$t(46) = -2.55$, **$p = 0.014$***
I can teach lessons that appropriately combine my teaching subject, technologies, and teaching approaches.	3.64	.85	4.09	.75	$t(46) = -4.28$, **$p = <0.001$***
TPACK Domain	15.06	2.68	16.23	2.67	$t(46) = -3.41$, **$p = 0.001$***

*Significant, $p<0.05$

Effect of Factors on the GTAs' Development of the TPACK Domains

A repeated measures ANOVA is performed to determine if the years of teaching experience, year in school, and engineering major are factors that influence the GTAs' development of the TPACK domains in the course. The results presented in Table 9 indicate that only the GTAs' majors affected the GTAs' development of GTAs' CK.

Table 9
Repeated Measures ANOVA results

Factor	TPACK Domains	Significance
Major	PK Domain	$F(1, 5) = .807$, $p = .551$
	CK Domain	$F(1, 5) = 3.046$, **$p = .020$***
	TK Domain	$F(1, 5) = 1.176$, $p = .337$
	TPK Domain	$F(1, 5) = .972$, $p = .446$
	TCK Domain	$F(1, 5) = 1.819$, $p = .131$
	PCK Domain	$F(1, 5) = 2.188$, $p = .074$
	TPCK Domain	$F(1, 5) = 2.04$, $p = .616$
Year in Graduate School	PK Domain	$F(1, 4) = .089$, $p = .985$
	CK Domain	$F(1, 4) = .322$, $p = .861$
	TK Domain	$F(1, 4) = .378$, $p = .823$
	TPK Domain	$F(1, 4) = .453$, $p = .770$
	TCK Domain	$F(1, 4) = 1.138$, $p = .352$
	PCK Domain	$F(1, 4) = .694$, $p = .600$
	TPACK Domain	$F(1, 4) = .389$, $p = .815$
Teaching Experience	PK Domain	$F(1, 1) = .507$, $p = .480$
	CK Domain	$F(1, 1) = 2.903$, $p = .095$
	TK Domain	$F(1, 1) = .665$, $p = .419$

	TPK Domain	$F(1, 1) = 3.236, p = .079$
	TCK Domain	$F(1, 1) = .954, p = .334$
	PCK Domain	$F(1, 1) = .113, p = .717$
	TPACK Domain	$F(1, 1) = .487, p = .489$

*Significant, $p<0.05$

Discussion

In this study, an existing semester-long teaching and leadership preparation course for engineering GTAs was evaluated by assessing its impact on their TPACK. Results indicated that after completing the course, the GTAs' PK, CK, TPK, TCK, and TPACK domains improved significantly while PCK and TK did not. Years of teaching experience, year in school, and engineering major were factors that did not significantly influence the GTAs' development of the TPACK domains in the course, except for engineering major influencing the GTAs' CK, which can be attributed to the differences in the content between the engineering disciplines.

The course specifically engaged the GTAs in lectures that aimed to help them develop their pedagogical knowledge. The lecture content that they received can explain the positive impact of the course on the GTAs' PK. In addition to this course, the GTAs were also registered in other courses and/or research that would help them acquire knowledge of the content and technology related to their field of study. The GTAs were also involved in performing teaching duties in certain courses within their engineering fields of study, which may explain the significant improvement in the GTAs' CK and TCK. In addition, unlike other preparation courses that do not give the GTAs guidance, feedback, or opportunities to reflect on what they are learning [25], this course engaged the GTAs in writing reflections on personal teaching experiences related to the topics presented in the course. The GTAs were also given the opportunity to participate in a service learning project to design and teach an engineering module in one of the local elementary schools' classrooms. These activities may have provoked the GTAs to think about and merge their knowledge of the presented pedagogies with the knowledge of the content and technology that they are acquiring about their fields from other courses, which may explain the significant improvement in the GTAs' TPK, TCK, and TPACK. However, more research is needed to validate and support this explanation by concrete evidence.

Future instances of this course need to include lectures that introduce the GTAs to new technology tools that can be used in teaching and learning. Also, future courses need to include guided activities that can assist the GTAs in merging the pedagogical knowledge into the content knowledge domain. One suggestion could be to make the service learning project mandatory and provide the needed support for the GTAs to make the connections between what they want to teach (content) and how to teach it (pedagogy) before considering what technological tools can be used to teach it (technology).

Conclusion

The purpose of this design-based research study is to evaluate an existing semester-long teaching and leadership preparation course for engineering GTAs by assessing its impact on their TPACK. Findings from this work indicate positive impacts of the course on the GTAs' TPACK; however, future research must approach studying the GTAs' experience in the context of the ongoing teaching duties and other courses that the GTAs may be experiencing at the same time. This contextual detail can be captured through adding additional survey questions, collecting and analyzing the GTAs' reflections, and interviewing a sample of GTAs to better understand how the course activities, such as the lectures and service-learning project, are assisting them in developing their TPACK.

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