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Integrating Service Learning and the Entrepreneurial Mindset in a Teaching and Leadership Course for Graduate Teaching Assistants

Ms. Hyena Cho, University of Illinois Urbana-Champaign

Hyena Cho is a Ph.D. student in the Department of Education Policy, Organization and Leadership at the University of Illinois at Urbana-Champaign, concentrating on Human Resource Development. She holds a B.A. and M.A. in Education from Yonsei University in Seoul, South Korea. Prior to her doctoral studies, she worked as a medical education researcher at Ajou University Medical Center. Her research focuses on workplace and organizational learning to foster creativity and inclusive learning culture, with a particular emphasis on adult learners in STEM and medical fields.

Joshua E. Katz, University of Illinois at Urbana - Champaign

Joshua E. Katz is a Ph.D. student in the Department of Curriculum and Instruction, DELTA program, at UIUC, where his research centers on collaborative learning in engineering education and other STEM disciplines. He obtained his B.S. in Technology and Engineering Education in 2019 and his M.S. in STEM Education and Leadership in 2021 from Illinois State University. Additionally, he holds a professional educator license for secondary education in Technology and Engineering Education in Illinois.

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

Dr. Blake Everett Johnson is a Teaching Associate 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.

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

Dr. Yuting W. Chen received the B.S. degree from the 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 and the Director of Women in Engineering at the University of Illinois Urbana-Champaign. Her current interests include recruitment and retention of under-served students in STEM, leadership development for undergraduate and graduate students, and curriculum innovation in Electrical and Computer Engineering.

Dr. Marcia Pool, University of Illinois Urbana-Champaign

Dr. Marcia (”Marci”) Pool is the Assistant Director for Education at the Cancer Center at Illinois and a Teaching Associate Professor in Bioengineering. She holds a Ph.D. in Biomedical Engineering, has served for sixteen years as teaching faculty/staff in biomedical/bioengineering and nine years in departmental/institute educational administration, and is an ABET program evaluator for Bioengineering/Biomedical Engineering. She focuses on identifying and evaluating mechanisms to enhance the educational experience and develop students into engineers and researchers. Her work includes interventions to enhance training for high school students, undergraduate students, and predoctoral (graduate students) and postdoctoral trainees through training programs such as NIH T32s. These programs include curricular, extracurricular, and professional and career development components with required evaluation and tracking of student participants.

Mr. Saadeddine Shehab, University of Illinois Urbana-Champaign

I am currently the Associate Director of Assessment and Research team at the Siebel Center for Design (SCD) at the University of Illinois at Urbana-Champaign. I work with a group of wonderful and talented people at SCD’s Assessment and Research Laboratory to conduct research that informs and evaluates our practice of teaching and learning human-centered design in formal and informal learning environments.

My Research focuses on studying students’ collaborative problem solving processes and the role of the teacher in facilitating these processes in STEM classrooms.

Integrating Service-Learning and the Entrepreneurial Mindset in a Teaching and Leadership Course for Graduate Teaching Assistants

Abstract:

This work builds on previous efforts describing a training course for engineering Graduate Teaching Assistants (GTAs) at a large midwestern university. The course presents teaching and leadership topics as transferable skills that benefit GTAs, whether they pursue careers in industry or academia. One innovation in the course is an optional service-learning project wherein GTAs design and deliver educational content to a local K–12 classroom. In a previous paper, we compared the impact of the project on GTAs who chose to participate versus those who did not. We used the TPACK framework as an assessment tool to show which knowledge domains had been developed throughout the semester. GTAs' pedagogical knowledge, as well as other domains in TPACK, showed significant growth from the teaching and learning course. A subsequent framework built on each lesson topic was then employed. For each category, there was also a substantial development in the pedagogical knowledge topics.

In the fall 2024 semester, the service-learning project was modified to utilize the KEEN Framework for Entrepreneurial Mindset Learning (EML) by the Kern Entrepreneurial Engineering Network (KEEN). Project participants were introduced to the framework in a workshop and then asked to use it to design university-level content. Upon instructor review, the content is then evaluated for publishability on the engineeringunleashed.com website, which is the online community where members of KEEN can share educational content ("KEEN Cards") they have developed using EML.

An optional following track to the Service-Learning project is made available where GTAs can gain additional credit in the course by modifying their first KEEN Card for applicability to a K–12 classroom. Undergraduate Teaching Catalysts (TCs), who are pre-service teachers from the College of Education, make connections with local K–12 teachers and create profiles of them and their classrooms. The TCs also lead workshops where they guide the GTAs to modify their content for delivery to the K–12 students. Near the end of the semester, the GTAs visit the classrooms and lead the students through exercises they have developed.

"Pre-flection" and reflection surveys are administered to the GTAs before and after the project. Statistical analysis will be conducted to determine the effectiveness of the two project tracks in helping GTAs understand the EML framework and improve their teaching abilities.

Introduction

Background of GTA training course

A team of engineering faculty from a public research university piloted a training course for graduate teaching assistants (GTAs) in 2017, focusing on teaching pedagogy and leadership development [1]. The course takes the format of weekly seminars, in which a guest speaker presents an interactive session within the course scope each week. Topics range from holding office hours and general rubric design to presentation skills and ethics. Early feedback was sought from faculty members who work with a large number of graduate teaching assistants (GTAs) to ensure alignment with the needs for proper training [2]. A mixed-methods study was conducted to compare two groups of GTAs: those not enrolled in the course (comparison group) and those enrolled in the course (focus group) [3]. Quantitative analysis revealed that both groups understood the transferability of teaching skills to the professional workplace. In the qualitative study, four themes emerged as transferable skills from teaching: communication, leadership, project management, and teamwork. GTAs in the focus group were more likely to recognize the transferability of teaching skills to leadership, project management, and teamwork skills.

Course enrollment has grown significantly since the first offering and now stabilizes at 280 in the fall semester and 150 in the spring. The instructional team meets weekly to reflect on each session and provides feedback to the guest speaker afterward. Topics are swapped in and out based on these reflections and student feedback. After several iterations of the course with significant changes to the topic lineup, a quantitative study using a 28-item TPACK survey was conducted to examine the impact of the course on GTA's development in TPACK domains [4]. These are pedagogical knowledge (PK), content knowledge (CK), technological knowledge (TK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPCK). Results from pre- and post-surveys revealed significant differences in GTA development across all TPACK domains. The study also showed that the number of years in graduate school and prior teaching experience are not substantial factors in changes in GTAs' development in these domains. As a follow-up to the TPACK study, a new survey instrument is proposed and validated to measure the effectiveness of each course topic on the development of GTA's skills in PK and PCK domains [5].

In addition to the regular rotation of teaching and leadership topics covered in the course, an optional service-learning project was introduced during COVID-19 [6]. Initially, GTAs worked together virtually to create K–12 learning modules to be shared with teachers in local schools. Once COVID measures were lifted and classes returned to in-person at the university, GTAs who chose to undertake the service-learning project would present the module in person at a K–

12 classroom. To engage all stakeholders, a summer workshop with local K–12 educators was held to understand their needs and challenges for a sustainable collaboration with university faculty and staff on service-learning [7].

As more undergraduate engineering courses at the university started to infuse an Entrepreneurial Mindset into their curriculum, the course instructors took a proactive approach to piloting a KEEN workshop targeted for GTAs [8]. Those who attended the optional workshop created a KEEN card on an engineering topic and completed both pre- and post-surveys, and they will receive extra credit in the course. GTAs also had the opportunity to convert their KEEN card into a K-12 learning module after participating in a service-learning workshop [9].

Literature Review on Entrepreneurial Mindset in Engineering Graduate Education

The Entrepreneurial Mindset (EM) is broadly defined as a collection of attitudes, behaviors, and cognitive skills that orient an engineer toward opportunity recognition, innovation, and value creation [10], [11]. This concept has evolved significantly since its initial framing by McGrath and Mac Milan, who described EM as a habitual way of thinking about entrepreneurship, whether within an existing organization or through launching new startups [12]. This focuses more narrowly on venture creation. Over time, the concept expanded beyond the entrepreneurship and business disciplines to encompass a broader disposition toward identifying, evaluating, and action-oriented opportunities [11]. Recently, scholars highlighted key EM competencies such as risk-taking, resilience, problem-solving, and interpersonal and communication skills. These skills enable students to translate opportunity into action and learn from failure [13]. A study on the perception of engineering faculties suggested that these competencies are learnable [13].

While EM education has traditionally been rooted in business school, the urgency to produce entrepreneurial engineers has grown steadily in recent decades [14]. Following major economic shifts after World War II, Harvard Business School pioneered efforts to integrate entrepreneurship into its curriculum during the 1940s [15]. Meanwhile, STEM education has classically prioritized scientific discovery itself, often neglecting the iterative process required to translate discoveries into economically or socially impactful outcomes [13]. As recognition of innovation's economic and societal value grew, so did the demand for engineers with an EM. In response, the Kern Family Foundation established the KEEN, bringing together like-minded institutions committed to advancing EM in engineering education. This shift significantly increased the availability and integration of entrepreneurship education within engineering programs [11].

The Entrepreneurial Mindset framework was introduced by the Kern Entrepreneurial Engineering Network (KEEN), which was established in 2004 with two initial partner schools.

The framework is oriented around the "Three Cs" of Curiosity, Connections, and Creating Value, whereby engineering students will be taught engineering and engineering design through the lens of identifying opportunities to make large-scale impacts. Currently, the framework is being taught in nearly 70 member colleges and universities that are part of KEEN, including a diverse range of institutions that span public and private schools, religious and secular institutions, undergraduate-only schools, and doctoral institutes with high research activity [10]. The stated student learning outcomes for each of the Three Cs are:

- Demonstrate constant curiosity about the changing world (Curiosity)
- Explore a contrarian view of accepted outcomes (Curiosity)
- Integrate information from many sources to gain insight (Connections)
- Assess and manage risk (Connections)
- Identify unexpected opportunities to create extraordinary value (Create Value)
- Persist through and learn from failure (Create Value)

Building upon the KEEN framework and its foundational mission, the network's stated goal is to graduate engineers with an EM who can create personal, economic, and societal value through meaningful work [10]. KEEN emphasizes instilling an action-oriented mindset in undergraduate students in science, engineering, and technology, ensuring they are equipped not only with technical expertise but also with the cognitive and interpersonal skills needed to drive innovation in complex, real-world environments [13]. To this end, KEEN has developed an educational ecosystem that supports interdisciplinary collaboration, authentic problem solving, and opportunity recognition across various institutional contexts. These efforts are not confined to undergraduate education alone; instead, they provide a scalable model that is increasingly influencing the design of graduate engineering curricula. Graduate engineering courses may incorporate interdisciplinary team projects, industry-sponsored problems, or research-to-commercialization case studies to reinforce EM competencies. In such environments, students not only apply advanced technical theory but also hone skills in opportunity recognition, stakeholder engagement, and iterative innovation [16], [17].

Exemplary KEEN Cards Developed by GTAs - Examples

GTAs were asked to individually or in groups draft a KEEN Card related to a topic they chose to teach at the university level. Specifically, the students were tasked with completing the preliminary sections of the card, including the title, authors, brief summary, introduction, learning objectives, lesson resources, implementation procedures, assessment, and instructor tips. They were also instructed to focus on the 3Cs—the core framework of KEEN Cards—to ensure that their draft addressed at least one of these components. To support the drafting process, GTAs received a worksheet with brief instructions and an evaluation rubric designed to help them aim for publishable-quality KEEN Cards on the engineeringunleashed.com website. The rubric evaluated several areas, such as the level of detail, educational outcomes, clarity of writing, creativity and engagement, high-impact practices, and overall task completion. Additionally, it included criteria specific to the selected 3Cs, assessing how well the drafts incorporated the EM principles. A total of 16 KEEN Cards were collected, and two exemplary examples among them are as follows.

Example 1: Convective Heat Transfer Lab: Investigating Free and Forced Convection

A GTA developed this KEEN Card to teach convective heat transfer. It incorporates all three of the 3Cs, making it a well-rounded example. Specifically, the card aims to increase curiosity by using hands-on experiments and encouraging students to ask questions, such as "How does the thermal conductivity of different materials affect heat transfer?" or "Why does orientation impact the heat transfer coefficient?" For connections, it integrates concepts from related disciplines, including fluid mechanics, thermodynamics, and materials science. This interdisciplinary approach aligns with the idea that fostering connections promotes systems thinking [18]. Finally, although the card does not explicitly address whose problems it aims to solve or identify specific stakeholder needs [18], it emphasizes the broader goal of contributing to society by improving energy efficiency. This reflects a motivation to create positive societal value [19]. Taken together, the card effectively demonstrates the meaning of each of the 3Cs and how they can be applied within a specific teaching context.

Example 2: Exploring Spanning Trees and Spanners

This KEEN Card, developed collaboratively by a team of two GTAs, focuses on guiding learners to explore the properties and limitations of spanning trees and spanners in graph algorithms. Notably, the card focuses exclusively on curiosity among the 3Cs, leveraging group discussions to encourage learners to construct inputs that identify when minimum spanning trees (MSTs) fail, and modifying existing algorithms to address these issues. It facilitates the students to challenge existing ideas, explore unexpected scenarios, and critically analyze algorithmic limitations. In particular, it exemplifies curiosity in the aspect of uncovering information [18]. Additionally, its detailed instructor tips provide educational interventions to enhance learner engagement and interest, aligning effectively with curiosity and underscoring its educational value [18].

Methods

Study Design

All authors value teaching GTAs, which forms the foundation of this study's design and data analysis. This research is part of an ongoing design-based implementation research project that began in Fall 2020. The authors have been researching teaching and learning at a large public university in the Midwest. All authors also have vast experience in educational research, including instructional design and teaching methodologies.

Context

In Fall 2024, 276 GTAs enrolled in a resourceful pedagogical development course. The course lasted fourteen weeks and had 50-minute weekly sessions. Each lesson adopted a lecture-style structure, sometimes complemented by a guest speaker. During these sessions, pedagogical methodologies, especially Think-Pair-Share, were used. These experts initiated various crucial pedagogical topics for the GTAs. The curriculum this semester consisted of topics on Student Interaction Techniques, a Panel of GTAs, Office Hours, Presenting Solutions, Academic Integrity, Rubric Design, Informal Early Feedback, Active Learning, Clifton Strengths, Presentation Skills, Student Motivation, Ethics, Student Mental Health, and a course wrap up during the last week [2].

Each student received seven bi-weekly reflective learning assignments throughout the semester. In these assignments, GTAs reflected on their teaching experiences by relating to the various pedagogical strategies learned during the weekly sessions.

During this course iteration, enrolled students were offered the service-learning project and an additional KEEN track. The KEEN track offered additional learning experiences on Entrepreneurial Mindsets. This pedagogical framework allows students to view lesson building with a focus on engineering disciplines. Similar to the past, the service-learning project allowed GTAs to apply the pedagogical knowledge they had learned to a teaching experience. The KEEN track enabled students to write independent or collaborative lessons using the KEEN Framework.

Students were invited to participate in the KEEN track at the start of the semester. A "preflection" and later a reflection survey were given to the students to set a baseline for their pedagogical knowledge and entrepreneurial mindsets using the [5] and [20] frameworks. A series of 42 questions were asked to the students on their pedagogical knowledge, pedagogical content knowledge, ideation, open-mindedness, interests, altruism, empathy, help-seeking, and a general question section.

In the weeks that followed, these students were invited to participate in a KEEN workshop led by several research team members. During this presentation, the KEEN was clearly defined for the students. The history, backgrounds, and connections to the 3Cs were explained to each participant. The workshop facilitators allowed students to give examples and express their thoughts between the slides. Once the Entrepreneurial Mindset slides were complete, a researcher demonstrated the Engineering Unleashed website to the GTAs. The researcher explained an example published KEEN Card, discussing each section in depth. At the end of the workshop, additional resources were given, and questions were answered. This workshop was run three times (two on Zoom and one in person) to accommodate GTAs' schedules. An additional recording was posted on the course's learning management system.

After the workshop, students were assigned the KEEN card assignment to focus on connecting a lesson topic to one or several of the 3Cs. These lessons were written independently or collaboratively with a maximum of three students per group. Some lesson topics included human-AI collaborations, materials science, and code generation. Research team members then reviewed these KEEN Card lessons and graded them on a scale to be published on the Engineering Unleashed website. The criteria for evaluating these lessons included detailed information, educational outcomes, clarity of writing, engagement and creativity, high-impact practices, completion of the KEEN card task, and connections to the 3Cs (Curiosity, Connections, and Creating Value). Each score was totaled, and the lessons with the highest scores were considered for submission.

After participating in the KEEN Track, students were also invited to further build on their KEEN card lesson to participate in the service-learning opportunity. Students modified their KEEN card lessons to fit a K–12 classroom. Teaching Catalyst, which is comprised of pre-service undergraduate students, helped with these alterations. At the end of the semester, the participating students taught their redesigned lesson to local middle school students. This program has allowed students to gain unique experiences, applying their collected pedagogical knowledge in a real-world educational setting [4].

At the end of the semester, students who participated in these programs were emailed to fill out the reflection survey, which asked the same questions as the "preflection" survey. The participating students received appropriate credit for each program and milestone completion.

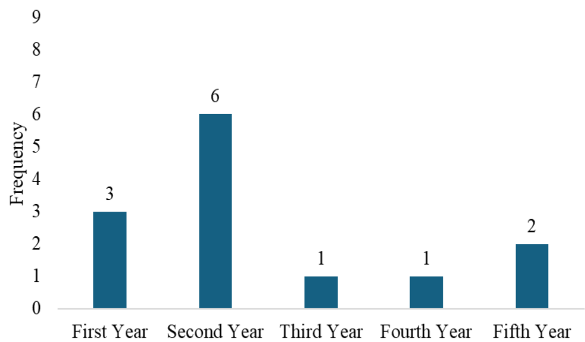
Participants

In this study, the initial participant population consisted of 276 students enrolled in the GTA training course. Of these students, 32 GTAs consented to participate in the preliminary survey. 13 students from the consenting group completed both the reflection and post-survey. This completion rate reflects the students' longitudinal engagement with the course and their willingness to contribute.

Demographic Information

Figure 1 illustrates the frequency of the years in graduate school of the 13 consenting GTAs. Most of the consenting students for the course were in their first or second years of graduate school. Figure 1b shows the frequency of the engineering disciplines for the 13 consenting

GTAs. Of the 13 students, 10 had prior teaching experience. Students who had teaching experience were teaching assistants (TAs), course assistants (CAs), or tutors. Three students had no prior experience with teaching. Of the 13 consenting students, 10 participated in all the KEEN track assignments, while three attended only the GTA training course.



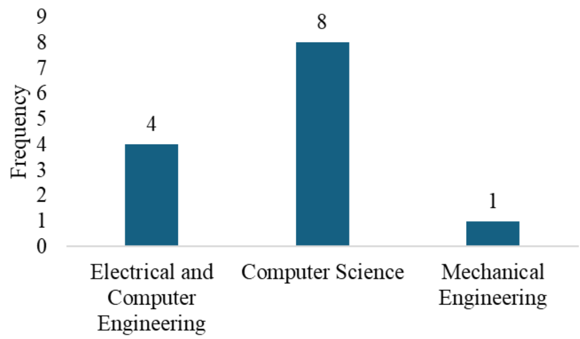


Figure 1a. Year in graduate school of GTAs **Figure 1b. Engineering disciplines of GTAs**

Data Collection

Data in this study was collected by distributing the preflection and reflection surveys at the start and end of the semester, respectively. The surveys comprised 42 questions designed to evaluate the graduate teaching assistants' pedagogical knowledge and Entrepreneurial Mindset.

The data collection was done using Google Forms, a platform chosen for its accessibility and ease of use, which enabled participation among GTAs. The survey was separated into ten exclusive sections. The first two sections collected consent and demographic information from the GTAs, providing additional background.

The following eight survey sections incorporated pedagogical knowledge and questions related to the Entrepreneurial Mindset. Within each section, GTAs were presented with three to eleven questions. Each question was formatted by the research team with statements and a 5-point Likert scale, where a rating of 1 indicated "strong disagreement" or "never or rarely true of me," and 5 indicated "strong agreement" or "always or almost always true of me." The first two sections were adopted from [5]'s survey, while the other survey sections were adopted from [20]'s survey. These scales allowed respondents to share distinct perceptions and experiences related to the development of their pedagogical and entrepreneurial mindsets attributed to the course.

Analysis Procedure

In this study, the analysis focuses on evaluating the KEEN Entrepreneurial Mindset track compared to the general pedagogical and leadership development from the GTA course. The survey was utilized, with each section corresponding to crucial topics within the course and KEEN tracks. The two surveys used in this study are valid and reliable [5], [20]. The impact of the KEEN track on students can be understood by conducting a detailed analysis of the surveys. This study employs the quantitative analysis method of the Wilcoxon Signed-Rank test for each of the 42 individual survey items, as well as the aggregation of data from each of the ten distinct sections of the survey. This non-parametric test was selected to detect distinctions in ranking between two independent variables.

Additionally, a Wilcoxon Signed-Rank test was implemented to explore the potential influences of variables (i.e., KEEN track vs. Standard GTA track and teaching experience). This non-parametric test was chosen for its suitability in comparing two independent groups to determine whether their population distributions differ. A Wilcoxon Signed-Rank test was performed to compare the various engineering majors and years in graduate school with the differences in pre-survey and post-survey scores. This non-parametric test was selected because it analyzes differences between three or more independent groups.

Results

GTAs Pedagogical and Entrepreneurial Mindset

A Wilcoxon-Signed Rank test was performed to measure the impact of the standard course and optional KEEN track on the students' preflection and reflection survey responses. Table 1 shows a significant improvement in the GTAs' Pedagogical Knowledge, Pedagogical Content Knowledge, and Ideation domains. In contrast, the domains of altruism, empathy, help-seeking, interests, and open-mindedness have no significant differences.

Table 1. Wilcoxon Signed-Rank Test results (*N* = 13)

Domains	Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon signed-rank test		
			Z	***p***	***r***
Pedagogical Knowledge	3.65 (0.30)	4.13 (0.15)	-2.311	0.021*	-0.641
Pedagogical Content Knowledge	3.42 (0.04)	3.85 (0.09)	-2.552	0.011*	-0.708
Altruism	4.48 (0.14)	4.81 (0.07)	-1.450	0.147	-0.402
Empathy	2.87 (0.16)	2.90 (0.04)	-0.154	0.878	-0.043
Help Seeking	3.28 (0.08)	3.65 (0.04)	-0.665	0.506	-0.184
Ideation	3.59 (0.22)	4.01 (0.19)	-2.135	0.033*	-0.592
Interest	4.03 (0.10)	4.15 (0.13)	-0.565	0.572	-0.157
Open Mindedness	3.94 (1.40)	4.16 (1.47)	-1.024	0.306	-0.284

*Significant, $p < 0.05$

KEEN track vs. standard track

A Wilcoxon Signed-Rank test was used to determine the differences between students who followed the optional KEEN track or the standard GTA course, who only participated in course lessons. Of the 13 students, three participated in only the standard coursework, opting not to do any work in the optional KEEN track, though they did complete both the preflection and reflection surveys. The other ten students completed the KEEN track as well as both of the surveys. As demonstrated in Table 2, significant differences were observed among students in the KEEN track for Pedagogical Knowledge and Pedagogical Content Knowledge, while no significant differences were observed among those in the standard track.

Table 2. Wilcoxon Signed-Rank Test results (N_{KT} = 10; N_{ST} = 3)

Domains		Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon Signed-Rank test		
				Z	***p***	***r***
Pedagogical Knowledge	KT	3.35 (0.80)	3.88 (0.77)	-1.975	0.048*	-0.625
	ST	4.67 (0.38)	5.00 (0.00)	-1.342	0.180	-0.775
Pedagogical Content Knowledge	KT	3.15 (0.69)	3.55 (0.88)	-2.226	0.026*	-0.704
	ST	4.33 (0.63)	4.83 (0.29)	-1.342	0.180	-0.775
Altruism	KT	4.33 (0.73)	4.85 (0.39)	-1.897	0.058	-0.600
	ST	5.00 (0.00)	4.67 (0.58)	-1.000	0.317	-0.577
Empathy	KT	3.67 (0.97)	3.63 (1.14)	-0.171	0.864	-0.054
	ST	4.33 (0.67)	4.67 (0.58)	-0.535	0.593	-0.309
Help Seeking	KT	3.30 (0.81)	3.44 (1.32)	-0.307	0.759	-0.097
	ST	3.20 (1.56)	4.33 (1.15)	-0.535	0.593	-0.309
Ideation	KT	3.52 (0.52)	3.82 (0.52)	-1.481	0.139	-0.468
	ST	3.85 (0.10)	4.67 (0.58)	-1.663	0.102	-0.943
Interest	KT	4.00 (0.77)	4.00 (1.02)	-0.565	0.572	-0.157
	ST	4.11 (0.19)	4.67 (0.58)	-1.089	0.276	-0.629
Open Mindedness	KT	4.34 (0.63)	4.69 (0.38)	-1.263	0.206	-0.399
	ST	4.75 (0.25)	4.67 (0.58)	0.000	1.000	0.000

*Significant, $p < 0.05$

Teaching Experience Differences

A Wilcoxon Signed-Rank test was used to determine the differences between students with prior teaching experience (TE) and those with no teaching experience (NE). There were ten students with previous teaching experience, while three contributors had no prior teaching experience. As depicted in Table 3, there were significant differences in the pedagogical knowledge and pedagogical content knowledge domains. All the other domains were not significantly different. For the group members with no teaching experience, no domains were significantly different.

Table 3. Wilcoxon Signed-Rank Test results (N_{TE} = 10; N_{NE} = 3)

Domains		Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon Signed-Rank test		
				Z	***p***	***r***
Pedagogical Knowledge	TE	3.35 (0.90)	4.08 (0.91)	-2.254	0.024*	-0.713
	NE	4.08 (1.01)	4.33 (0.58)	-0.447	0.655	-0.258
Pedagogical Content Knowledge	TE	3.28 (0.79)	3.75 (1.02)	-2.410	0.016*	-0.762
	NE	3.92 (0.95)	4.17 (0.76)	-1.000	0.317	-0.557
Altruism	TE	4.43 (0.75)	4.75 (0.47)	-1.160	0.246	-0.367
	NE	4.67 (0.58)	5.00 (0.00)	-1.000	0.317	-0.557
Empathy	TE	3.67 (0.97)	3.67 (1.18)	-0.171	0.865	-0.054
	NE	4.33 (0.67)	4.56 (0.51)	-0.816	0.414	-0.471
Help Seeking	TE	3.34 (0.96)	3.70 (1.20)	-0.255	0.798	-0.081
	NE	3.07 (1.10)	3.47 (1.86)	-1.069	0.285	-0.617
Ideation	TE	3.53 (0.47)	3.90 (0.80)	-1.736	0.083	-0.549
	NE	3.82 (0.51)	4.39 (0.64)	-1.604	0.109	-0.926
Interest	TE	3.93 (0.70)	4.23 (0.98)	-1.275	0.202	-0.403
	NE	4.33 (0.58)	3.89 (1.02)	-0.816	0.414	-0.471
Open Mindedness	TE	4.41 (0.64)	4.78 (0.34)	-1.246	0.213	-0.394
	NE	4.50 (0.43)	4.38 (0.54)	-0.447	0.655	-0.258

*Significant, $p < 0.05$

Major in Graduate School

A Wilcoxon Signed-Rank test was used to determine the differences between students' majors. One mechanical engineering major GTA was excluded from the analysis. The other majors present in the analysis were Electrical and Computer Engineering (ECE, N_{ECE}=4) and Computer Science (CS, N_{cs}=8). Notably, no significant differences were observed in any of the domains in this comparison, as illustrated in Table 4.

Table 4. Wilcoxon Signed-Rank Test results (N_{ECE} = 4; N_{CS} = 8)

Domains		Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon Signed-Rank test		
				Z	***p***	***r***
Pedagogical Knowledge	ECE	3.81 (0.66)	4.25 (0.61)	-1.289	0.197	-0.645
	CS	3.44 (1.01)	3.97 (0.93)	-1.761	0.078	-0.623
Pedagogical Content Knowledge	ECE	3.88 (0.32)	4.06 (0.38)	-1.732	0.083	-0.866
	CS	3.16 (0.96)	3.59 (1.10)	-1.826	0.068	-0.646
Altruism	ECE	4.94 (0.13)	4.75 (0.50)	-0.447	0.655	-0.224
	CS	4.19 (0.75)	4.81 (0.44)	-1.761	0.078	-0.623
Empathy	ECE	3.83 (1.29)	3.92 (0.88)	0.000	1.000	0.000
	CS	3.83 (0.87)	3.71 (1.25)	-0.531	0.595	-0.188
Help Seeking	ECE	3.55 (0.66)	3.40 (0.33)	-0.736	0.461	-0.368
	CS	3.38 (0.90)	3.60 (1.59)	-0.631	0.528	-0.223
Ideation	ECE	3.89 (0.14)	3.84 (0.42)	0.000	1.000	0.000
	CS	3.41 (0.52)	3.98 (0.88)	-2.035	0.042*	-0.719
Interest	ECE	4.00 (0.82)	3.67 (1.05)	-1.633	0.102	-0.817
	CS	4.04 (0.70)	4.29 (0.92)	-0.530	0.596	-0.187
Open Mindedness	ECE	4.88 (0.10)	4.53 (0.44)	-1.289	0.197	-0.645
	CS	4.20 (0.64)	4.72 (0.42)	-1.682	0.093	-0.595

*Significant, $p < 0.05$

Year in Graduate School

A Wilcoxon signed-rank test was used to determine the differences between graduate school years. Notably, no significant differences were observed in any of the domains in this comparison, as illustrated in Table 5.

Table 5. Wilcoxon Signed-Rank Test results (N_1 = 3; N_2 = 6; N_{3+} = 4)

Domains		Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon Signed-Rank test		
				Z	***p***	***r***
Pedagogical Knowledge	1	3.75 (0.90)	4.67 (0.58)	-1.604	0.109	-0.926
	2	3.42 (1.06)	3.71 (0.90)	-0.736	0.461	-0.300
	3+	3.94 (0.85)	4.38 (0.66)	-1.604	0.109	-0.802
Pedagogical Content Knowledge	1	3.33 (0.38)	4.50 (0.50)	-1.604	0.109	-0.926
	2	3.13 (0.98)	3.25 (1.02)	-1.732	0.083	-0.707
	3+	3.94 (0.72)	4.25 (0.61)	-1.342	0.180	-0.671
Altruism	1	4.33 (0.58)	4.58 (0.72)	-0.447	0.655	-0.258
	2	4.21 (0.84)	4.79 (0.40)	-1.355	0.176	-0.553
	3+	5.00 (0.00)	5.00 (0.00)	0.000	1.000	0.000
Empathy	1	3.67 (0.00)	4.22 (0.69)	-1.342	0.180	-0.775
	2	3.94 (1.08)	3.39 (1.22)	-1.890	0.059	-0.772
	3+	3.75 (1.20)	4.33 (1.12)	-1.890	0.059	-0.945
Help Seeking	1	2.80 (1.31)	4.20 (0.72)	-1.069	0.285	-0.617
	2	3.00 (0.84)	2.93 (1.51)	-0.314	0.053	-0.128
	3+	4.05 (0.34)	4.30 (0.82)	-0.736	0.461	-0.368
Ideation	1	3.64 (0.33)	4.48 (0.67)	-1.604	0.109	-0.926
	2	3.52 (0.59)	3.79 (0.86)	-1.265	0.206	-0.516
	3+	3.68 (0.46)	4.00 (0.72)	-0.730	0.465	-0.365
Interest	1	4.00 (0.00)	4.33 (1.15)	-0.577	0.564	-0.333
	2	4.11 (0.83)	3.89 (0.83)	-0.736	0.461	-0.300
	3+	3.92 (0.79)	4.42 (1.17)	-1.069	0.285	-0.535
Open Mindedness	1	4.13 (0.33)	4.58 (0.52)	-1.342	0.180	-0.775
	2	4.29 (0.73)	4.56 (0.45)	-0.527	0.598	-0.215
	3+	4.88 (0.10)	4.94 (0.13)	-0.816	0.414	-0.408

*Significant, $p < 0.05$

Discussion

This study aimed to evaluate the effects of incorporating Entrepreneurial Mindset Learning into a Teaching and Leadership course for Graduate Teaching Assistants in engineering. Because the additions to the course came in the form of optional workshops and assignments, the team was able to isolate several variables to determine which aspects of the optional course content were significant. Among the 13 students who completed the surveys, the results showed that Pedagogical Knowledge and Pedagogical Content Knowledge, as defined in the framework developed by [5], were significant, and Ideation, as described in the framework developed by [20], was also significant. In all of our other analyses, where we compared the effects of taking the KEEN track vs. the standard track, the impact of having some vs no teaching experience, the effect of specializing in different engineering disciplines in graduate school, and the effect of a number of years of experience in graduate school, we looked to see what factors also contributed in a significant way to the development of the three aforementioned domains of improvement. The findings show that both Pedagogical Knowledge and Pedagogical Content Knowledge are significantly affected by (i) attending the KEEN training workshop and (ii) having prior teaching experience. Background analyses of our population show that these are not the same populations. Of the three students who did not complete the KEEN track, two had prior teaching experience, and the other one did not. As for the development of Ideation, the significant variable was the engineering discipline. Specifically, GTAs in Computer Science were significantly more likely to develop Ideation in the track.

Students who participated in the KEEN track were excited about learning and engaging in these additional pedagogical frameworks. They were excited about co-writing KEEN cards and gaining feedback to make the lessons more meaningful for their future students, similar to findings in [21].

With this trial of incorporating a KEEN track into the GTA teaching and learning course, future iterations can incorporate other Entrepreneurial Mindset items into the curriculum of the main coursework. Through the KEEN workshop and KEEN Card lesson development activities, which were incorporated as an extension of the course, the results suggest that the students' experience impacted their understanding of the 3Cs and improved their pedagogical knowledge and pedagogical content knowledge. Modifying the structure to include additional interactions for the KEEN Card to be published is a goal.

It is proposed that an iterative feedback loop be established to enhance the effectiveness of the KEEN Card workshop. These multiple feedback sessions would serve as a scaffolding process, enabling GTAs to create, review, and refine their KEEN Cards collaboratively. Additionally, it is pivotal to develop a shared academic language for the concepts of each 3C. Establishing clear and consistent terminology would prevent GTAs' misunderstandings of the concepts.

Conclusion and Future Work

This design-based research study aims to evaluate the KEEN track's Entrepreneurial Mindset path as part of an existing semester-long GTA teaching and leadership preparation course for engineering students. Using the survey frameworks in [5] and [20], the impact on students' pedagogical and entrepreneurial mindsets can be gauged. Results from this work indicate positive influences on pedagogical knowledge and pedagogical content knowledge domains through participation in the KEEN track. Future research must approach studying GTA's involvement in the KEEN track and other activities that can influence these mindset changes. Adding additional open-ended survey questions can help us understand GTAs within their in-course and outside-of-course activities and how these can influence and develop their pedagogical and entrepreneurial mindsets.

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