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Preparation and Role of Undergraduate Teaching Assistants in a Makerspace and in a Traditional Laboratory Course

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With many universities exploring ways to increase undergraduate student engagement and reduce budgets for graduate teaching assistants, undergraduate teaching assistants are being used more often. Undergraduate teaching assistants can assist with teaching and grading, and they have the advantage of typically being a recent student in the same course, so they have first-hand knowledge and understand the material from the student perspective. As they are helping their peers, they understand the level of interest, enthusiasm, and energy in the course. Additionally, they "learn by doing" and gain a deeper understanding of the material. However, they typically differ from graduate student teaching assistants in age and experience, so faculty members must work with the undergraduate teaching assistants differently. For example, as undergraduates, they usually need more help to 'learn how to teach' and resolve potential classroom problems. They may also require more preparation for the classroom or lab and more consistent and deliberate guidance and feedback throughout the semester.

At Penn State, the number of undergraduate teaching assistants, referred to as Learning Assistants (LAs), increased, in part, as a budgetary solution to reduce the cost of instruction for courses that historically used graduate teaching assistants. After several semesters of growing the number of LAs, a more formal preparation program began for lab courses that consists of a common course regardless of lab or course. Students complete mandatory institutional and facility-specific training, develop essential communication skills, and learn to support the College of Engineering's mission. A follow-on course allows the LAs to employ their skills in a specific lab. This paper details the onboarding and the role of the LAs in two different areas in the College of Engineering, specifically a Makerspace that is open to all students and an Aerospace Engineering lab for third- and fourth-year students. The Makerspace has used LAs for several decades, while the Aerospace lab has just started. The paper concludes by describing lessons learned and best practices as well as short- and long-term goals for the improvements of LAs' roles and responsibilities.

Introduction

At Penn State, as at many other institutions, support for undergraduate courses is provided by graduate teaching assistants (TAs). Graduate TAs generally assist faculty with preparing assignments, holding recitation sections and office hours, and grading. The efficacy of a TA includes a multitude of factors, including both how knowledgeable and how approachable the undergraduate students perceive the TA to be [1]. As graduate students come from different undergraduate disciplines and cultures, their background knowledge and experiences can be quite different than the undergraduates, creating a disconnect between the students and the TA.

For over a decade, STEM faculty have reported the benefits of undergraduate learning assistants (LAs) who aid student learning. LAs can be preferable to TAs for a variety of reasons: cost is

lower, and they more closely understand what the current students are experiencing. Previous work has reported on undergraduate teaching assistants facilitating collaborative learning activities [2], held office hours [3], and provided peer support during class sessions [4].

Benefits to students

In previous work, student satisfaction emerged as a consistent positive outcome when LAs were involved in STEM courses. Lav [4] found that undergraduate learning assistants improved students' sense of belonging and confidence in large lecture neuroscience courses.

Student preferences strongly favored LA support over traditional teaching assistant or instructor interactions in several contexts. One paper reported that many students preferred to seek help from LAs rather than from graduate TAs or instructors [3]. In another study, preliminary qualitative work suggested that students were more comfortable revealing their thinking to LAs than to TAs or instructors, noting that LAs can create safe yet vulnerable learning environments [5]. Other work similarly reported that most students agreed that LAs helped them learn and increased satisfaction with the course and teaching [6].

Benefits to Learning Assistants

LAs can benefit from this role, developing professional characteristics including self-confidence, communication, and leadership skills, while also acquiring knowledge of discipline-specific content and laboratory skills. These findings were supported by self-reported Likert scales and rubrics, as well as observational data from both undergraduates being mentored and graduate teaching assistants [7].

Engineering educators search for ways to engage engineering students through experiential learning opportunities that increase learner engagement and build connections between academics and their future careers [8]. Serving as a lab-related LA brings many experiential learning components including problem-based, active, cooperative, and hands-on learning [9]. This makes lab-related LA-led programs beneficial to the institutions and students.

Challenges in utilizing Learning Assistants

As in most jobs, in order to perform well, LAs require appropriate training. Most previous STEM LA programs include some form of pedagogical training, but that training is as variable as the STEM courses it is used in. One program utilized a 2-credit pedagogy course meeting weekly, another required enrollment in a math and science education seminar, while another included a separate pedagogical class for LAs [5], [10], [11].

Current Work

Differentiation at Penn State

Most of the reported LA implementations documented in the referenced literature were for large STEM courses with LAs facilitating collaborative learning activities, holding office hours, and

providing peer support during class sessions. The current paper details the implementation of LAs in lab environments, including a Makerspace and a discipline-specific upper-class lab course.

Identified need and opportunity

With growing enrollments, newer larger facilities with increased capabilities, and lower funding for graduate students or full-time staff, the departments at Penn State were finding it difficult to find sufficient funding and staffing to safely and effectively operate the hands-on learning spaces of the Makerspace and the discipline-specific labs. Given the volume of visitors to the Makerspace during a single semester, trained, committed LAs are needed so that the labs can operate safely and smoothly and serve the students and the College of Engineering. At Penn State, a formal preparation program began for the education of students working as LAs in lab courses. These programs are detailed below.

Makerspace

The Makerspace at Penn State's College of Engineering is staffed by LAs seven days a week: weekdays from 8 AM to 10 PM and Saturday and Sunday from noon to 4 PM. This collaborative space is essential for all first-year design courses and projects, senior capstone projects, and many other courses in between. Additionally, the Makerspace holds frequent extra-curricular guided-building events where students, faculty, and staff are guided by the LAs and other staff to build a project. The same constituents are also able to work on personal projects, subject to a few restrictions. Main Makerspace statistics for one semester are summarized in Table 1.

LA selection

The Makerspace has been functioning continuously for over 30 years, but recently moved to a new, significantly larger facility. Prior to that move, the Makerspace employed 10–12 undergraduate LAs and entertained several hundred visitors a year. Prospective LAs were usually regular users of the space who were invited to apply for the position. However, with the move to the new facility and the increase from 10–12 to 60+ LAs, a more formal application and training program was developed. The LAs have a great deal of autonomy in the Makerspace and are relied upon to ensure a physically and psychologically safe environment across the 40,000 ft^2 facility. As a result, the training commitment is significant and rigorous, and there is an expectation that LAs will work for several semesters. With this in mind, the hiring process has also become more rigorous. There is a strong pool of undergraduate students interested in becoming an LA. For example, last semester, there were over 100 applicants for the six available LA positions. The quality of these applicants is quite strong, with a majority of the LAs having high GPAs and engagement in their majors. LAs have had representation from every College of Engineering major as well as disciplines outside of engineering like Architecture, Astrophysics, Digital Arts and Media Design, and Economics.

Table 1. Makerspace usage summary from Fall 2025 semester

	Number of visits to Makerspace	Average number of visits per user	Average visit duration
Course and individual projects	Approximately 24,000	7.5	91 minutes
Evening guided-building events	Approximately 800	-	120 minutes

LA planning and implementation

Once LAs are selected, they participate in the Makerspace training program which consists of an introductory common course and a follow-on course. While the training was developed and piloted from 2022–2024, it was not implemented as a course until 2025. Presenting the material through a course increases accountability and provides a means of recognizing the significant amount of material and learning outcomes associated with the training. For the Makerspace, the common course, ENGR 397: Foundations, is taken by all LAs. This is a 2-credit course led by faculty who oversee the Makerspace on the Penn State main campus. The mode of delivery is a blend of online modules, hands-on activities, and in-person sessions.

This Foundations course introduces new LAs to foundational safety practices, compliance requirements, and operational protocols. Students complete mandatory institutional and facility-specific training, develop essential communication skills, and learn to support the instructional mission. Emphasis is placed on maintaining a safe, inclusive, and efficient learning environment for all visitors and collaborators.

Learning Objectives for the Makerspace Foundation course include

1. Demonstrate knowledge of institutional safety and compliance requirements by completing required certifications and assessments.
2. Apply facility-specific operational procedures for inventory, asset management, and communication systems.
3. Identify and address potential safety hazards, including psychological and physical safety risks, in the specific lab environment.
4. Explain the lab's mission and conduct guided tours for visitors.
5. Implement time management and task organization strategies to support TA responsibilities.

Modules that support the instruction are Compliance and Orientation; General Safety Training; Protecting Visitors; Operations and Communication; and Efficiency and Continuous Improvement

The follow-on 1-credit course, ENGR 397: Advanced Applications, develops the LAs skills for a specific lab. The ENGR 397 (Applications) lists the ENGR 397 course (Foundations) as a prerequisite. The mode of delivery is a blend of hands-on lab training, peer teaching, and equipment certification modules. This course includes advanced training for specific labs, focusing on technical equipment operation, visitor instruction, facility maintenance across multiple specialized areas, and mentorship. Students gain certification in certain areas such as the woodshop, electronics/IoT, additive manufacturing, and textile/fabrication labs, as well as learn how to deliver training and ensure safe usage of equipment.

Learning Objectives for the Advanced Applications course include

1. Operate specialized equipment in woodshops, electronics/IoT, additive manufacturing, and textile fabrication spaces at a certified level.
2. Deliver effective training and safety instruction to visitors in multiple technical domains.
3. Perform basic maintenance and troubleshooting for assigned equipment and systems.
4. Apply design and fabrication principles to assist visitors in creating high-quality prototypes and projects.
5. Demonstrate leadership and mentoring skills by guiding interdisciplinary project teams and fostering safe, inclusive workspaces.

Aerospace lab

In contrast to the Makerspace, the aerospace lab is not open to all students in the College of Engineering but is taken only by aerospace majors during their third or fourth year. The number of aerospace majors has continued to increase, resulting in this aerospace lab currently serving 1.5x more students each year than three years ago. Simultaneously, the dedicated aerospace lab space has doubled. With this increase in students and facilities, the department is able to bolster student involvement and learning in this lab course by decreasing the number of students in each lab section to five or fewer. These changes have resulted in a significant increase in the number of lab sections, and, therefore, a change in staffing each semester, as summarized in Table 2.

Table 2. Aerospace lab course enrollment and support

	Number of students enrolled in lab course	Number of lab sections	Maximum number of students in each lab section	Number of graduate students available to support labs	Number of trained undergraduate LAs
Fall 2024	44	8	6	2	0
Spring 2025	90	17	6	6	0
Fall 2025	99	24	5	4	6
Spring 2026	133	28	5	4	11

Note that these changes also reflect that, as an R1 institution, most graduate students have research obligations and funding and are not available to take on a TA role.

LA Selection

This lab course is taught every semester at Penn State but a standard process for recruiting LAs for this particular lab was implemented in late 2024. Each semester, the faculty announce that high performing-students will have the opportunity to be considered for an LA role in upcoming semesters. If selected as an LA, they will either receive 3-credits for an independent study course that may be used as one of their technical electives or be paid for working up to 10 hours a week.

As the logistics of designating the LAs for next semester takes some time, at the mid-point of the semester, the faculty identify students who are performing well, earning the top 20% of grades in addition to positive observations by faculty and current TA/LAs on their performance and engagement during lab. These high-performing students are asked if they would consider a role as an LA in an upcoming semester. Those who indicate availability and interest are invited to an informational small-group or one-on-one meetings with the faculty to discuss the responsibilities, training expectations, benefits, schedule, and pay. By the end of the semester, students are asked to commit to the LA role for the following semester, and the hiring process is started. This process has been implemented for the past two semesters, resulting in a significant increase in the number of LAs who support the aerospace lab course.

LA planning and implementation

The aerospace LAs complete an LA-foundations course which has some similarities to the Makerspace Foundations course. This course is a 0-credit, asynchronous course delivered through Penn State's LMS.

Learning Objectives for the aerospace lab foundations course include

1. Exhibit understanding of how to protect and disclose student educational records to comply with Family Educational Rights and Privacy Act (FERPA).
2. Recognize the diverse cultural perspectives and learning preferences of our students and the inclusive classroom practices that improve learning.
3. Define academic integrity and the process for promoting integrity of students.
4. Explain the key characteristics of effective communication.
5. Identify active learning strategies that can be beneficial to teaching.
6. Demonstrate knowledge of institutional safety and compliance requirements by completing required certifications and assessments if leading a lab course.

This course takes 10–15 hours to complete. New LAs are asked to complete the modules and the embedded knowledge checks by the second week of the semester.

In the second stage of aerospace LA lab training, the faculty and small groups of the LAs meet weekly. These meetings are designed to develop deeper understanding of the foundational content, to share insights about how students are learning in the lab, and to review the technical content relevant to the labs.

Outcomes

These programs were developed out of necessity to fully staff the lab spaces at Penn State. Significant drivers included a need to minimize costs and to ensure that enough interested, knowledgeable assistants could be deployed to ensure proper lab operation. The formalized program for recruiting and training LAs has accomplished this goal. Significantly more undergraduate students pursue these opportunities, resulting in coverage of the lab spaces with the use of few graduate TAs or full-time staff. The cost difference is significant: LAs costs no more than 20% of what it would cost to employ graduate students and full-time staff to fill these roles.

Faculty observations on benefits to students

Faculty observations indicate that students who engage with LAs explain fundamental concepts more effectively, participate more in hands-on activities, and exhibit more positive peer interactions. While students learn well from graduate teaching assistants, the engagement and interactions with peer undergraduate learning assistants seem more relaxed and interactive, thus producing a more dynamic learning environment. Moreover, since the LAs and students had the same undergraduate courses and knowledge, discussions or questions could refer to overlapping concepts or knowledge. Additionally, discussions between LAs and students are on a similar academic level, such that LAs' answers were readily understandable and not more complex than needed.

Student feedback on working with trained LAs

Students at Penn State were informally interviewed on their perspective on working with an LA in the lab spaces. As in previous publications, students express feeling comfortable interacting with LAs. Many of the interviewed students made remarks like

"It is nice to know that (the LA) knows what is going on in our classes and the semester."

"(The LA) knew how to help me because she knew what it was like to be confused by this lab."

Additionally, students remarked they did not hesitate to text the LA with a question, something they said they would not have been comfortable doing with a graduate student or professor.

Faculty observations on benefits to LAs

Faculty observe that the LAs themselves develop critical skills in communication, teamwork, and pedagogy, in addition to a reinforced understanding of the fundamental knowledge relevant to the lab spaces.

LA feedback on their experience

Anonymous feedback from aerospace lab LAs was collected at the end of each semester through an online survey that included both 5-point Likert scale questions and open-response questions. The complete survey is included in the appendix.

The Likert scale questions probed the aerospace LA's perceived changes in abilities related to career competencies for STEM occupations [13]. The responses are tabulated in Figure 1.

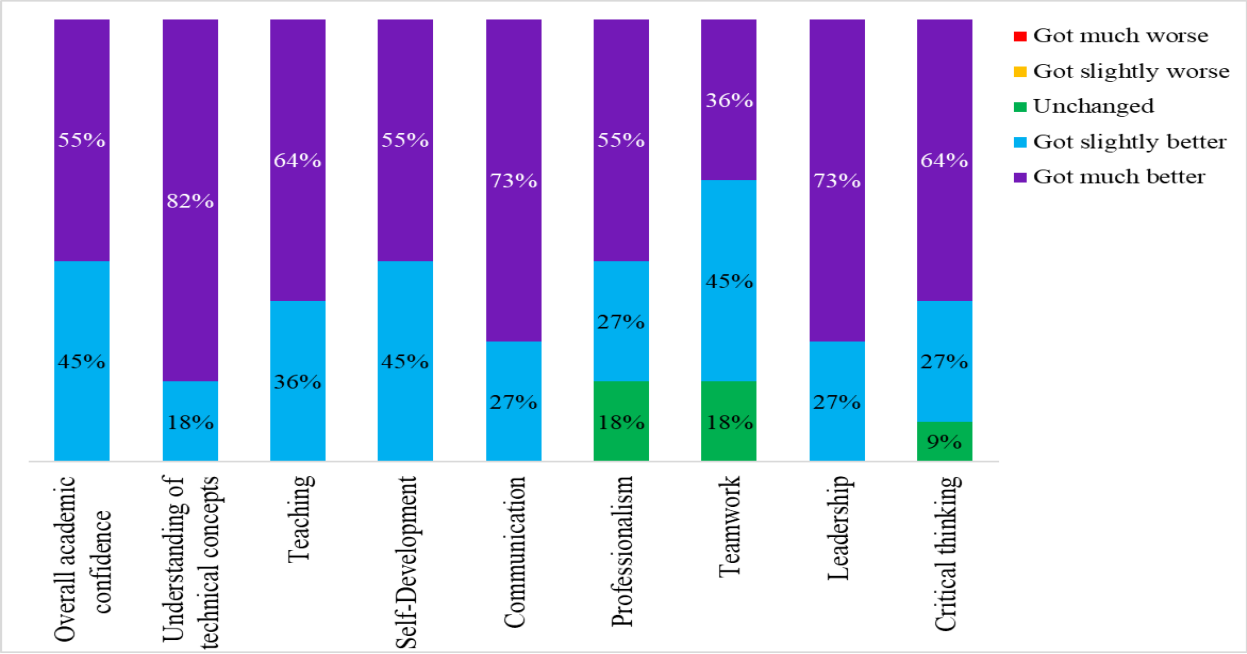

Figure 1. Aerospace LAs responses to prompt "Through the experience of serving as a Learning Assistant (LA), how has your ability changed in the following areas?".

More than 95% of the responses indicate perceptions of positive changes in the competencies, with responses of *Got slightly better* or *Got much better*. The most notable perception of significant gains came in the areas of understanding of technical concepts, communication, and leadership. A majority of the LAs feel they also improved in academic confidence, teaching, self-development, professionalism, and critical thinking, just as the faculty had observed. The gained abilities -- or even just improved confidence -- will benefit the LAs beyond this course. Note that 5% of students perceived no change in their abilities in professionalism, teamwork, and critical thinking. As the LAs were selected for being some of the top aerospace students, it is plausible that their skills were already strong in these areas.

The survey also included open-response questions derived from a previous LAs perception survey [12], designed to probed the LAs' thoughts on the LA experience. The free response survey questions spurred valuable input from the aerospace LAs on what they learned, both through the training and through the lab experience. Below, the responses are grouped into themes.

The LAs implemented good pedagogy, as introduced in the training modules, when a student asked questions of the LAs in the lab:

> *I like to ask the student where the question is coming from and have them attempt to break down the fundamentals and explain the situation. I want to see if they can reason out the answer before I give it / explain in more detail.*

The LAs express that they gain perspective on the challenges of effective teaching:

> *I learned how painful it can be when you think you taught a topic well and then you read through the papers and what is written does not show that (the students) understood.*

The LAs gain appreciation for the challenges and hard work of being a professor:

> *I realize how much work really goes into running the lab and the level of understanding that is needed to effectively teach these concepts.*

> *I learned that the professors go through exponentially more work behind the scenes than students realize to ensure a safe and successful lab.*

The LAs recognize the benefits from the LA experience:

> *It delighted me to see my teaching and communication abilities as an LA improve over the semester. I also learned and understood way more of the course content through the teaching process that I hadn't understood as a student.*

The survey results reflect that the LAs gained valuable skills through the experience.

Lessons learned and suggested best practices

Faculty observe that the selection of the correct LAs is important and that a number of factors contribute to a positive outcome. Note that not all students who have performed well in previous activities or courses will be a strong LA. Ideally, selected LAs should have previously been not just successful but engaged and interactive in the relevant courses or activities. Additionally, LAs should be motivated to interact with the faculty and to create a positive experience for the students. While some LAs are initially uncomfortable interacting with either faculty or students, they must be willing to embrace this discomfort and use the training components and interactions to improve. A final reminder is that the LAs must have sufficient time to dedicate every week to the training and the LA role. To ensure that all of these key criteria are met, the faculty need to have direct knowledge of the possible LAs or have a robust, effective LA selection process with significant opportunities to develop rapport between the faculty and LAs who will be working together and to have a frank conversation about the attitude and commitment that is needed.

For proper planning and on-boarding, it is desirable to select future LAs at least a full semester before they serve as an LA. The current LA selection process is a bit too delayed and final LA

commitments are often not secured until a month before the start of the next term. This can mean that the faculty and LAs are not certain until quite late how many and which LAs will participate in the training and labs in the upcoming semester. Unfortunately, there are often students who are interested in being an LA but who do not have the time in their schedule in the following semester. These students and the faculty then must stay in contact so that when it is time to schedule for the next semester, the students have already been planning to incorporate this LA commitment into their schedules. In addition, it is a smoother working relationship as the faculty and LAs have already established a working relationship.

Limitations and Future work

This work presents limited observational data comparing the impact of undergraduate learning assistants and graduate teaching assistants; it would be valuable to develop a detailed, rigorous study comparing the effectiveness and learning experience for students in these hands-on learning environments. This work does not compare student learning from graduate assistants and undergraduate assistants in knowledge/skill gains, so the pedagogical success is unclear. In addition, as this formal LA preparation program is quite new, more cohorts need to be involved so that there is a larger group of participants and impacted students.

Conclusion

Due to budget and availability constraints, Penn State, an R1 institution, has developed a formal preparation program to engage undergraduate learning assistants (LAs) for engineering labs. This formal program has increased engagement and learning for both students and LAs. In addition, the institutional costs are significantly lower and allow for better staffing of hands-on learning spaces. The developed program ensures that the LAs develop the technical, pedagogical, and interpersonal skills needed to create a safe and educational space. The implementation of trained LAs in the lab courses has been very positive and will be further developed and implemented.

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Appendix

Learning Assistant Survey
Part I: Likert scale questions

Through the experience of serving as a Learning Assistant (LA), how has your ability changed in the following areas?

Use the following Likert scale for your response: 1 Got much worse 2 Got slightly worse 3 Unchanged 4 Got slightly better 5 Got much better

- Overall academic confidence: Believe in one's ability to succeed in academic tasks.
- Understanding of technical concepts: The ability to comprehend, interpret, and apply specialized knowledge.
- Teaching: Effectively convey information in understandable and engaging manner
- Self-Development: Proactively develop oneself and one's career through continual personal and professional learning, awareness of one's strengths and weaknesses, navigation of career opportunities, and networking to build relationships within and without one's organization.
- Communication: Clearly and effectively exchange information, ideas, facts, and perspectives with persons inside and outside of an organization.
- Professionalism: Knowing work environments differ greatly, understand and demonstrate effective work habits, and act in the interest of the larger community and workplace.
- Teamwork: Build and maintain collaborative relationships to work effectively toward common goals, while appreciating diverse viewpoints and shared responsibilities.
- Leadership: Recognize and capitalize on personal and team strengths to achieve organizational goals.
- Critical thinking: Identify and respond to needs based upon an understanding of situational context and logical analysis of relevant information.

Part II: Open-Response questions related to being a Learning Assistant (LA)

1. Describe your role as an LA, i.e., in your LA job, what do you actually do to support the professor and the students?
2. Describe your perception of an LA before you began this role. What is your perception of the LA role now?
3. As an LA, when a student asks you a question, what explicit strategies do you employ to respond to the student's question? (Or what do you do before answering the question?)
4. Have you considered teaching as a career? If yes, why are you considering it? If not, would you consider it in future? Why? Why not?
5. Were there any parts of being an LA that surprised, irritated, or delighted you? Did you learn anything new about yourself or your professor?