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Teaching Assistant Professional Development through Design: Why They Participate and How They Benefit

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Introduction

At The Ohio State University, one goal of the first-year engineering program is to foster professional development, not only of the students enrolled in classes, but of the unit's teaching assistants (TAs). These undergraduate and graduate students serve in the classroom, grade assignments, support open lab hours, and attend trainings. Additionally, some TAs choose to spend extra hours developing the spring semester robot design project offered to first-year engineering students. Participating in this curriculum development project not only directly impacts the first-year students' design experience but also gives the TAs a unique opportunity for professional development. They are responsible for all aspects of project development and creation, including designing the competition scenario, constructing the physical course the robots compete upon, and designing and programming the course control electronics. This development and creation is extremely time-intensive. College students already balance many different life aspects, and yet, every year, a core group of TAs embrace this time-intensive challenge and excel. To further explore this TA experience, this study addresses the following research questions: *Why do TAs participate in the development and creation of the robot design project? What skills, if any, do they develop through their participation?*

Impetus for this Work

Many first-year engineering programs have a common curriculum that all students are required to take.[1] These courses tend to be large in size, having multiple sections of the same class. For example, at Ohio State, the first-year program teaches courses to over 2000 students a year. Due to their size, implementing these programs often requires the use of TAs.[2-4] These TAs may be graduate students (GTAs) and/or undergraduate students (UTAs) who are typically enrolled in engineering programs while conducting their teaching responsibilities. The roles of TAs in first-year engineering courses at Ohio State and other institutions vary from instructional staff to lab supervisors to graders.[3-5] In addition to their various roles and responsibilities, TAs are tasked with balancing their teaching roles with other roles such as that of students and researchers.[6] This complex circumstance makes it essential to understand their experiences, to ensure these activities are valuable, both to the program and the TAs themselves.

Despite the widespread use of TAs in first-year engineering and beyond, there is limited information about TAs' experiences in the classroom in engineering, let alone their experiences that do not directly fall within normal teaching duties. This paper aims to expand the understanding of TAs' experiences by gathering data about their perspectives regarding their assistance in developing, constructing, and implementing a first-year robot course design project. The next section will describe the context of this project in detail for two primary reasons:

1) A comprehensive understanding of the setting will help situate the qualitative analysis that follows, enabling other readers to determine the transferability of these results to their own instructional situations.[7]

2) Some of the TA responsibilities described here may be different than those at other institutions; this account may allow other programs to consider giving their TAs opportunities such as those discussed below.

The Robot Project

All first-year engineering students at Ohio State are required to enroll in a two-semester engineering course sequence. Honors-designated students may choose to participate in the honors program.[8] This program is a special sequence featuring smaller class sizes (36, as opposed to 72 students) and additional content (C/C++ in addition to Excel and MATLAB) covered at a faster pace. The first-semester course focuses on problem solving and computer programming, while the second-semester course focuses on graphics and a design project. The most popular design project option for honors is the robot project.[9]

The robot project is a ten-week design-build development of an autonomous robot. Students are given a budget, a scenario with tasks for the robot to accomplish in a time limit, a microcontroller,[10] and access to a program-run store to purchase materials. Students work in teams of 3 or 4 to complete the project, building the robot, adding sensors, and programming the microcontroller. Robots are limited to a 9”-by-9” footprint and 12” in height. The project culminates in a public competition. Teams are also required to document the process with a written report, an oral report, and an electronic notebook.[11]

The competition scenario, intended to give a real-world context to the project, changes each year, and thus, the physical course the robots compete on must be rebuilt annually. Past scenarios have ranged from a home assist robot to a Mars rover to a farming robot. Each course brings its own unique features. This approach allows the robots to be new and innovative each year.

The Role of TAs

TAs play a crucial role in the development and execution of the robot project. The development is split into three teams: scenario development, course construction, and course electronics. Each team consists of two leads, typically Graduate Teaching Assistants (GTAs), as well as a team of TAs (both graduate and undergraduate) that help out with the development. All TAs who work with the honors program are expected to assist outside of the classroom (20 hours per semester) with various projects to keep the overall program running smoothly. Assisting with the robot project is just one of many choices, and it is one of the most time-intensive options. Still, teams of TAs opt to help prepare each portion of the project, and some TAs work on multiple aspects of it. Undergraduate Teaching Assistants (UTAs) are compensated on an hourly basis, while the GTAs’ hours count toward their expected employment load.

The scenario team chooses a scenario from a list of ideas suggested by that year’s TAs. They then brainstorm, choose, and refine the individual tasks the robots will be expected to complete. These tasks typically involve functions such as pushing buttons, flipping switches, or transporting objects. Tasks are also suggested by TAs, and the leads narrow down the tasks to a manageable number. The goal of the design is for 100% of the student teams to be able to complete at least 70% of the course. Following the design of each task, the team creates the scenario description document. This extensive packet details each and every facet of the robot course, and it is used as a guideline for student introduction to the year's theme. The document (typically around 15 pages) contains point values that will be used in competitions and grading, as well as the competition rules.

The construction team is responsible for physical building of the robot course. TAs design and manufacture the required features and objects for each course task. The also design many aesthetic additions to help keep with the theme, including painting schemes. Since 8 identical course sections are needed, consistent manufacturing techniques must be employed to ensure uniformity. TAs learn valuable techniques with woodworking, including use of power tools, such as drill presses and table saws. CAD models of two of the more recent courses are shown in Figure 1 (an archeological dig) and Figure 2 (a candy shop). Each course is composed of 4 sections, so that up to 4 robots may compete simultaneously. Each of the 8 square segments that compose the course is 3' by 3'.

Figure 1. CAD Model of Robot Course for Archeological Dig Scenario (2013)

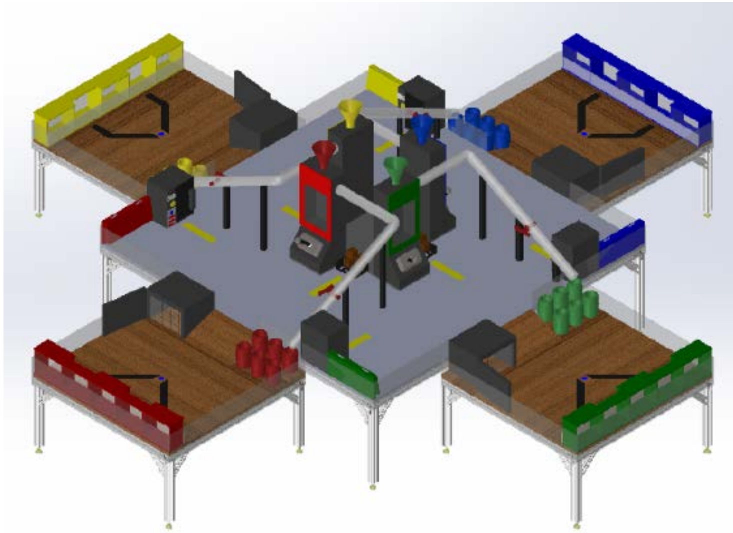

Figure 2. CAD Robot Course Model for Candy Factory Scenario (2014)

These two figures, presented chronologically, also illustrate one of the many significant contributions made by TAs to the continuous improvement of the program. The course in Figure 1 has wooden bases, as did the ones from earlier years. These bases needed to be rebuilt each year with the new course, and there were some small but noticeable issues with consistency from one course section to another. Following the 2013 competition, TAs from the construction team took on the responsibility of designing, ordering, and building aluminum course bases to be reused each year. The aluminum bases not only provide uniformity to the course support, but have reduced construction time. Now the new courses are constructed atop medium-density fiberwood sheets that are attached to the aluminum bases.

The electronics team develops and maintains all hardware and software associated with operation of the course. This includes the Robot Positioning System, a TA-designed location system based on image processing of QR codes. The TAs on the electronics team are responsible for designing and maintaining custom circuit boards that are used to control course electronics such as switches, LEDs, and motors. They are also responsible for wiring under the course. Finally, the TAs write the software to operate the course hardware.

Collaboration between each team is integral to the project's success. Actions and timelines of one team directly effect and sometimes limit the possibilities for another. It has been assumed that TAs involved with one or multiple of these groups learn skills that are directly applicable in the engineering world and that they also learn important teamwork strategies that are useful talking points in job interviews. TA involvement in the robot project is crucial for the project's success, yet it also affords TAs opportunities to improve their skills and experiences as engineers. This study sought to better understand TAs' experiences working on the robot project and to also find out what the TAs perceived as the benefits and drawbacks of committing time to this effort. Additionally, since working on any of these teams is a significant responsibility, it was desired to know why the TAs choose these particular ways to spend their out-of-class hours.

Methods

One of the researchers, an instructor in the program, sent an e-mail to all the program's TAs, inviting them to take a survey about their experiences with the robot project design. The invitation stated that the program wanted to learn about both the "drawbacks and benefits of participating in the out-of-class activities associated with getting the competition course ready for the robot class." No incentives were associated with this invitation. Quantitative questions asked about the number of terms spent as a TA and the number of terms spent assisting with robot course development. Qualitative questions centered on reasons for choosing this activity, benefits, and drawbacks. The TAs were also asked to indicate whether each benefit or drawback was something they expected or had been a surprise. Following these questions, there were more specific questions asking the TAs to identify skills they brought to the project, along with skills they developed as a result of working on it. They were also asked if this project work had any implications on their job searches. The questions are included as an appendix.

The quantitative measures were taken to characterize the experience levels of the sample, but the majority of the survey data was qualitative in nature. The resulting study was executed from a phenomenological interpretivist perspective,[12-13] as the data and conclusions drawn from them are very much a product of the environment in which these TAs and the researchers work. Further, the participants represented a range of perspectives on the TA experience, given that they had varying degrees of experience and worked on different aspects of the project.

The coding scheme emerged from initial review of the data, and, as expected, was refined as the study progressed. Two members of the research team independently read through the qualitative responses and generated possible coding frameworks. One coder was an instructor with the program. The other was a UTA who has a thorough knowledge of the robot project, but who had not participated in preparing the physical course or scenario (and therefore did not take the survey.) After conferring and determining a scheme, a set of codes and descriptions was shared with the rest of the research team (two other instructors and a GTA who has worked on the course development but did not take the survey) for feedback. A few refinements resulted; then the original two researchers independently applied the scheme to all the data. When compared, the internal consistency was over 90%, and further discussion introduced more refinements that brought the coders into nearly complete agreement. For instance, in discussing the codes for drawbacks of participating in the project, the number of categories was reduced by combining comments about limited resources and being constrained by other teams' decisions into the heading of "constraints." The rich data generated illustrates these students' impetus and professional development, as described in more detail below.

Analysis and Results

Participants

Twenty-four TAs provided information about their involvement in developing the robot course. Their levels of experience varied, as reflected in Table 1. They also represented a number of different majors, as shown in Table 2. The survey did not ask questions to distinguish between graduate and undergraduate TAs. This was not believed to be necessary, as both GTAs and

UTAs take on significant roles in the project development. Further, all but one of the GTAs with the program started working with the robot course as UTAs, and the survey sought descriptions of their overall experience during their years of service to the project.

Table 1. Distribution of TA Experience

Terms	**# of TAs**	**%**
1 or Less	8	33%
2	4	17%
3	7	29%
4	0	0%
5	2	8%
6	0	0%
7	1	4%
8	2	8%

Table 2. Majors of Responding TAs

Computer Science	8
Electrical & Computer	6
Mechanical	6
Biomedical	3
Materials Science	1

Reasons for Involvement

TAs reported a variety of reasons for becoming involved in the project, as shown in Table 3. Explanations of the categories are given below.

Table 3. Distribution of Why TAs are Involved with Robot Project Development
(N = 24, with multiple responses per person possible)

Why TA is Involved	**Number of TAs**
Enjoyment	8
Technical Learning	8
Interested	5
Payment	3
Use Talents	2
Pay It Forward	1
Sense of Community	1
Diversify Talents	1
Build Resume	1
Seeking Challenge	1

Eight of the 24 TAs participated in the development because they enjoyed it. Some went as far as to mention that they enjoyed participating in the design project so much that it is the reason they serve as a TA. Another mentioned initially choosing construction because it would “take [his] mind off classes and it fit very easily into [his] schedule. However, it grew on [him] and [he] really enjoyed seeing the course come together.” An equivalent number of TAs, 8, were involved because of the technical learning that comes out of their involvement. Skills ranging from “woodworking and finishing” to “hardware and the electronics” were learned by the TAs.

Five of the TAs became involved because they found the work associated with the development of the design project to be interesting. These interests ranged from “electronics” to “hardware.” Some included more specific interests in their comments including “LabView” and “circuit boards.” Additionally, UTAs are compensated for the hours they spend working on the project development. Three of them mentioned this payment as an influencing factor in their involvement. Two TAs were interested in using their talents and major-related skills as part of the involvement, and one TA was interested in each of the remaining categories. Those categories included “paying it forward,” building a sense of community, diversifying technical talents, building their resume, and completing a challenging project.

Benefits

The TAs described a variety of benefits connected with working on the project, which in many cases were also the reasons they chose to get involved. The benefits are summarized in Table 4. Also indicated are how many TAs reported that these were benefits they were seeking when they joined the project and how many were surprised by the benefit.

Table 4. Distribution of Benefits Cited by TAs
(N = 24; each person could identify up to 5 benefits.)

Benefit	**Number Mentioning**	**Number Seeking**	**Number Surprised**
Learning	21	17	2
Friendship	12	9	2
Paying forward	11	10	0
Fun	10	8	1
Accomplishment	8	6	2
Teamwork	7	5	2
Job Search	5	4	1
Application	4	4	0
Leadership	3	2	1
Money	3	3	0
Knowing	1	0	1

Twenty-one of the 24 reported learning from the experience, the most common benefit described. While most of them (17) expected to acquire new skills or knowledge, 2 stated that they were surprised that they learned something. Some of the specific examples given ranged from electronics and programming (used in the control of the competition course) to project management skills, painting techniques, and machining skills. The second most common reported benefit, coming from 12 TAs, was developing friendships. Nine of these TAs were seeking this, but 2 were surprised by it. In describing this benefit, some of the TAs talked about "bonding," "building community," and "building relationships." Indeed, a strong camaraderie is observed amongst the TAs who take primary responsibility for crucial aspects of course development.

Another commonly cited benefit was the ability to "pay it forward" by doing something to support the program they had participated in themselves as first-year students, helping the current students in the process. As one TA put it, it is a chance to "help shape the course of the project for the benefit of the students." None of them found this benefit to be a surprise.
A significant fraction of the respondents (10) said it was fun to be part of the project, with only one of them surprised by it. Related to this, 8 of the TAs found the sense of accomplishment they got from the project to be a benefit. Putting the comments together, they find that working on a challenging project of consequence where they and others get to see the working results is very gratifying. Two of the TAs were surprised by this, but 6 were seeking it.

Seven TAs identified the teamwork as a benefit, with one elaborating about "working on a multidisciplinary project and interacting with engineers with different background and different ideas of 'what's right.'" Clearly, working on this project provides the TAs with an opportunity to strengthen their teamwork skills. Five of the TAs reported that their experience with the project has aided in their job search, with 4 of them saying that it was an expectation of theirs going into the project. Three talked about resume building, one said it put the program's TAs "at a huge advantage" in interviews, and one credited the project with getting him his first co-op. The remaining benefits, mentioned by four or less of the respondents, were having the opportunity to apply what they were learning in the classroom to a project, being paid for their time, developing leadership skills, and just knowing more about the workings of the project than they otherwise would.

Drawbacks

In addition to the benefits found by the TAs, they also faced some drawbacks in their experience with the design project. Table 5 summarizes the responses to this question.

Table 5. Distribution of Drawbacks Reported by TAs
(N = 24; each person could describe up to 5 drawbacks.)

Drawback	**Number Mentioning**	**Number Expecting**	**Number Surprised**
Time	18	15	3
Scheduling	8	6	2
Management	7	2	5
Stress	7	5	2
Expectations	4	3	1
Lack of Appreciation	3	1	2
Constraints	2	1	1

Eighteen TAs reported that the time required to complete their portion of the project was a negative side to their experience. All of these TAs mentioned time commitment first in their list of drawbacks. However, it was not unexpected by the TAs; 15 of the 18 who mentioned time as the first drawback anticipated that the project would consume much of their time. Closely related to this, scheduling issues were the second most frequent drawback mentioned by the TAs. One mentioned that it is “sometimes hard to fit in the commitments necessary each week.” This stems from the set deadline associated with the robot project and the fact that all of the TAs are students. Six TAs anticipated this drawback, with 2 finding the schedule conflicts to be a surprise.

The third most frequently mentioned drawback was the management associated with the project. One TA emphasized this by commenting on “EXTREMELY poor management.” Many TAs must take on several roles, which can be difficult to balance. It should also be noted that for the lead TAs, this may be the first experience they have in truly leading a team of other students. Seven TAs experienced this drawback, with only 2 anticipating the poor management. Stress from the project was also mentioned by 7 teaching assistants. Stress was due to “the deadlines,” the requirement to “get things working correctly in a short amount of time,” and the “lack of communication.” Of the TAs who mentioned stress, 5 expected this drawback. Another drawback related to this was the feeling that the expectations were too high. One TA commented that he faced “a lot of pressure to get [the course] working.” Another mentioned that “nobody ‘expects’ you to work additional hours, but it is expected that these projects get done by TAs.” Four of the TAs mentioned high expectations as a drawback, with 3 of them anticipating this challenge.

Of the 24 TAs who answered the questionnaire, 3 said they felt under-appreciated in their position on the robot course design team. Only 1 TA anticipated this drawback with the other 2 being surprised with this outcome. One of the surprised TAs is quoted as saying, “considering the amount of skill and effort required to do the development I do, I occasionally feel under-appreciated.” Another gave perspective on this drawback in saying, “I think there is a slight lack of understanding within the [honors] program for the skills required to do electronics work. This leads to a lack of appreciation for the work that the TAs do to keep making cool robot courses for future students.”

Like any engineering project, there are constraints on the development of the robot course. These constraints include firm deadlines (because the course must be ready when it is time for the students to start the project) and limited resources (because there is one small shop room available for construction work). The developers may also encounter constraints imposed by university systems and procedures for ordering parts and materials. Additionally, decisions made or problems encountered by one of the three development teams can impact the others. Two of the TAs saw these constraints as a drawback to being involved with the design. One of these two found this to be a surprise.

Professional Development

Most (17) described bringing technical skills specific to engineering with them to the project, while others (6) mentioned things more general in nature. Technical skills included such things as programming, CAD, soldering, working with power tools, and working with electronics. More general skills included such things as creativity, organization, and "being crafty." Those who answered the question about where they had developed these skills described a range of experiences, from helping their father around the house, to reading, to co-ops. Most experiences were mentioned only once or twice, with one exception, and that was college courses, which were mentioned 6 times. As reflected in their description of the benefits of getting involved, the TAs found that this was an opportunity to apply the skills they had learned in previous coursework. It is gratifying to note that 4 of the 6 students specifically referred to their time as students in the first-year program.

When asked about skills development, 18 described one or more skills developed, and again, they were a blend of technical and life skills. The responses to this question tended to be the most specific ones of the survey. Fourteen described technical development of some kind. A sampling of the specialized engineering skills mentioned includes circuit board design and assembly, embedded programming, networking electronics, working with Netduinos and BeagleBones, painting techniques, and wood shop skills. One said that troubleshooting skills were stronger, and one spoke of an improved ability in "designing systems from high level concepts all the way down to individual component selection and everything in between."

Ten of the students reported improved professional skills. While some just generally mentioned teamwork or communications, several gave specific examples of management-level skills. Some examples of these were the ability to break a large project into smaller pieces, to manage a team of software engineers, and to "let go and delegate tasks."

Career Implications

TAs were also asked about how their participation helped them in their search for employment, be it a fulltime job, a co-op, or an internship. Thirteen of the TAs said their participation in the design project development helped them in their job search. Keeping in mind that 8 of the respondents were in their first term of working on the project and 4 more were only in their second term, this means that essentially all of the TAs who had an opportunity to look for employment since becoming involved felt they had improved their job prospects as a result. Seven TAs said their technical experience helped them in their job search. They have been able to talk about the challenges they have faced, the problems they have solved, and the teams on which they have worked.

Three said that their participation was most useful in their interview, while 2 described it as a helpful addition to their resume. In interviews, they were able to talk about their experiences through the honors program. One mentioned, "eighty-five percent of what [he] talks about in interviews is work on [honors] electronics." Another said that it was on his resume and was brought up during interviews. Two said that their involvement was impressive to recruiters, with one stating that his involvement "redesign[ing] the voltage regulator…really impressed National Instruments," landing him an internship. Five of the teaching assistants mentioned that their experience helped them while working at their co-op or internship. Leadership, time management, troubleshooting, technical skills, project experience and teamwork skills were all applicable in their employment. In the larger context of finding long-term employment, a TA mentioned that "it has helped [him] narrow down some of [his] interests to choose where to look for employment."

Summary and Tricks of the Trade

This study provides an initial outline of why some TAs go above and beyond the call of the average TA to develop and create the robot design project. While these data were taken in the context of one specific first-year program, the detailed description of the context earlier in the paper will help readers to identify elements common to their programs and determine which aspects of this analysis transfer to their situations.

The data show this group of TAs participate for a variety of reasons, such as enjoyment, learning, and applying their knowledge to a project outside the classroom. They also benefit from an increased sense of community and improved professional skills. Additionally, some TAs leverage this experience to gain co-ops and internships. The process is cyclical; they strengthen their skills in the workforce, then return to the first-year program and share what they have learned with others. Drawbacks to their involvement included the time involved, but at the same time, many TAs specifically cited improved project management skills. They also feel the time required to develop and create the robot design project and curriculum is well spent, as they enjoy giving back to the program they participated in as first-year students. Some of the findings believed to be the most generalizable are extended as "Tricks of the Trade" below to assist engineering programs looking to expand the opportunities available to TAs beyond their classroom and grading roles.

Several "Tricks of the Trade" have been identified to help improve the TA experience. It was found that TAs were able to pinpoint numerous benefits that were directly related to their participation in the development of the first year robot design project. Engineering programs should aim to create opportunities for their TAs and students to fully take on unique projects. These projects should give them the chance to use the skills they learn in the classroom, while challenging them to develop and utilize new skill sets. It is important for TAs and students to be able to troubleshoot, work as a part of a team, and take on an individual portion of a project. Creating these possibilities has been shown to help them in their search for employment—both full time and internship/co-op opportunities. Depending on their experience with the program and project, select students can be expected to grow into leadership roles.

When the opportunity for design is put in place, faculty and staff members should remember that the TAs are students themselves. While deadlines are important to any project, it must be noted that TAs have academic deadlines of their own and that their hard work for the program is an additional load. Faculty and staff should be conscientious of their communication efforts and make wholehearted attempts to convey their expectations to the TAs. They should also put in place a framework to facilitate communication between TAs working on different parts of the project. In addition to setting clear expectations, faculty and staff members should make sure to thank the TAs for their hard work. Recognizing the accomplishments of the TAs and giving them feedback will make them more likely to continue to engage in the design project development. In the specific context of the project studied here, this will lead to the creation of more stimulating opportunities for first-year students, some of whom will join the TA ranks themselves, continuing the cycle.

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Appendix: Survey Questions

1. Please select the response below that best represents your involvement in the robot competition course. (Select all that apply)

   scenario development
   course construction
   course electronics
   other (please specify)
   not involved in any aspect of the robot competition design/development

2. How many terms have you worked on ___ including this term?
   1 2 3 4 5 6 7 8 9 10+

3. How many terms have you been a TA including this term?
   1 2 3 4 5 6 7 8 9 10+

4. What is your major?

5. Why did you choose this particular way to be involved in the honors program?

6. Please list up to 5 benefits for working on the robot project.

7. Please list up to 5 drawbacks for working on the robot project.

8. Which, if any, of the benefits identified on the last page were you seeking when you chose to work on this project and which were a surprise?

9. Which, if any, of the drawbacks identified on the last page were you anticipating when you chose to work on this project and which were a surprise?

10. What skills, if any, did you bring with you when you began working on this project? Please describe the skills and where they were developed.

11. What skills have you developed as a result of this work?

12. Has any aspect of your participation in this project helped **you in your job/co-op/internship search**? If so, please describe briefly.

13. Has any aspect of your participation in this project helped **you at your job/co-op/internship**? If so, please describe briefly.