Utilizing Peer Learning Assistants to Improve Student Outcomes in an Introductory ECE Course

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Abstract

This evidence-based practice paper reports on the implementation of Peer Learning Assistants (PLAs) in an introductory Electrical and Computer Engineering (ECE) course. The course Introduction to Microcontrollers was identified as having a peak 20% no-pass rate, the highest of any ECE course in the first or second year. As a sophomore-level course and generally the first-course students take after declaring as an ECE major, it was considered a priority to improve student pass-rate, interest, understanding, and reputation of this course.

To meet these needs, PLAs were added to the course for three semesters and the results were evaluated using a combination of standardized surveys, custom surveys, and analysis of grade data. Initial indications are positive but not yet statistically significant. The program has resulted in an increase in course ratings by students (5.21 to 5.36 with $p<0.12$), a small decrease in no-pass rates (15.8 to 14.3% $p=0.25$), positive perception surveys returned 76% very positive responses, and improved perception of learning for inexperienced programmers ($p=0.01$). In addition, there appear to be intangible benefits to PAs, TAs, Professors, and the department. These include confidence and communication skills for the PLAs and reduced variability in the course over time. Finally, it is shown that students rate TAs and PLAs as equivalently effective at helping them learn.

Introduction

Peers as mentors, facilitators, and team leaders are not new ideas [1]. They have been tried out in many forms over the years [2, 3] and have been shown to generally improve student outcomes in the first years of college [4, 5, 6].

Peer Learning Assistants are a similar, yet less common intervention with fewer studies and less consistency in implementation [7, 8, 9]. PLAs are almost always undergraduate students. Often they are utilized merely as an alternative to graduate teaching assistants with some added benefits such as knowledge of the curriculum and familiarity with the student experience [1, 9, 10]. This work continues in the methodology developed in [8], where PLAs were tasked as being a combination of mentors, guides, and curriculum tutors who are explicitly removed from the grading process. This PLA implementation showed excellent traction on technical learning (a weakness identified in the more common belonging-focused peer mentoring programs.) The research in [8] further showed that PLAs provided a lower barrier to engagement between PLAs and students. The benefits of peer mentoring and PLAs span more than just the outcomes of the students taking the targeted course. Many studies [11, 12] have emphasized the benefits to the mentors, the mentees, professors, and the university.

It is important to differentiate a PLA, in this work, from normal TAs. The PLAs role is to help students with all aspects of a course, including homework, exams, labs, and project work. They *do not grade* student work. PLAs are undergraduate students who have taken the course in question and performed reasonably well (usually A and B grade students.) Selection for the PLA position is usually based on the student's ability to communicate and their drive to help others learn. Table 1 illustrates the basic differences of the two roles.

Table 1: Comparison of TAs and PLAs

Teaching Assistant (TA)	Peer Learning Assistant (PLA)
Graduate student	Undergraduate student
Present pre-lab lecture	Re-touch confusing topics 1-on-1
Grade in-lab milestones	Help debug!
LMS maintenance	Hold office hours
Grade pre-lab and post-lab	Mentor and advise students

Reasons for Intervention

Introduction to Microcontrollers had a consistently higher no-pass rate than other introductory ECE courses (as high as 20% in some semesters). The high no-pass rate undermined preparation for later courses and negatively affected retention within ECE. Student feedback rated Introduction to Microcontrollers is a particularly challenging course in our program (based on class comments and time committed) yet also one of the most useful courses (from graduating student surveys in the ECE Senior Design capstone course.) ECE students' backgrounds and programming experiences varied. Some groups, notably transfer students, struggled more in Introduction to Microcontrollers. Student meetings held by our professional academic advising, something we wish to highlight, were one of the first indicators to flag these concerns.

Literature documents holistic professional academic advising [13, 14]. Such advising in ECE played a noteworthy role in recognizing an issue with this course and assisted in creating a solution. Students are required to meet our departmentally owned and embedded ECE academic advisor each semester to holistically review degree progress, provide planning, support, and advocate for students' needs, including mental health concerns. Academic advising is complementary to degree-field-focused faculty advising and mentoring. Advising is integrated with other ECE student administration, including the course scheduling processes, class management, and curriculum. The academic advisor was key in hearing consistently concerning feedback about Introduction to Microcontrollers in student advising meetings, holding a broad overview of the student cohort, understanding departmental context, and seeing a wider picture of the course over a period of time. As a result of hearing student feedback, academic advisor advocacy was utilized to affect change in the course.

Academic advising at our institution is largely decentralized. Autonomous departmental advising roles, such as that in ECE, are unique and fluid. They contain a wide range of student support and related academic activities as well as provide the ability to be more holistic in some senses than collegiate advising roles. The advantage of such advising roles appear little documented, although some literature exists to support academic advising at different levels of the university system [15], student services and faculty partnerships [16, 17, 18, 19] and the value of wider institutional vision and advisor connections [20] to student success.

On understanding of the course issues, we sought to find a mechanism to address disparate needs and help all students to be more successful in the course. We believed it essential that we retain academic rigor in Introduction to Microcontrollers, while supporting students more effectively, maintaining student retention and also simultaneously reducing the time burden, programming concerns and additional challenges to students. We therefore reviewed interventions for additional course support including increasing graduate TA appointments, supplementing instructional materials, and reducing quantity of content covered. We chose to pursue the idea of PLAs.

The research questions originally driving implementation of our PLA program were:

1. Does the addition of PLAs reduce no pass rates in the course?
2. Does the addition of PLAs improve student perceptions of the course?

In addition, the following questions became important throughout the development of the program:

3. Does the PLA program improve the perceptions of less experienced programmers more than others?
4. Are PLAs more or less effective than TAs at helping students' learning?

Implementation

Introduction to Microcontrollers (EE 2361) is intended for sophomore ECE students in a large state research university. Students spend 3 hours in lecture, 1 hour in discussion, and 2 hours in the lab per week. Typically the course is offered every semester with up to 143 students in an on-sequence semester (Spring) and roughly 40 to 60 students off-sequence (Fall). The course extensively covers the fundamentals and applications of microcontrollers, such as architecture, Assembly/C languages, basic input/output, indirect addressing, timer, interrupts, input capture, output compare, serial communication, analog to digital conversion, etc. Throughout the semester, students are expected to work on six labs (covering 12 sessions), five to seven homework assignments, one to two midterm exams, a final exam, and a final term project. The course involves a nontrivial amount of software programming both in assembly and C as well as wiring hardware, testing, and debugging. After completing all course requirements, students will be comfortable programming any microcontroller and implementing simple to medium embedded system designs.

In our implementation, similar to Pivkina [8], PLAs advised and helped students through all aspects of the course, including homework, quiz preparation, and laboratory work. PLAs held office hours and attended lab weekly. PLAs did not grade or evaluate student work in an attempt to make them more approachable to students. Also, our program integrated PLAs into the continual improvement process within the department, providing feedback, and contributing to the development of layered curricular course materials. PLAs have the advantage of essentially participating in the course twice from differing perspectives, making them excellent partners for continuous improvement.

PLAs worked alongside Teaching Assistants (TAs) in ECE labs and hosted additional office hours outside of class. The PLAs were focused on reducing the time students spend on simple mistakes, enhancing complex task learning, and providing encouragement. The PLAs were recruited from undergraduate students that have previously taken EE 2361, were recommended by professors/staff, and demonstrated a keen interest in helping other students learn and succeed in ECE. As undergrads themselves, PLAs were often, but not always, close in age to the students in the lab. PLA duties included lab attendance (2hr/wk/section), office hours (1hr/wk/section), and prep time (1 hr/wk). In the lab, responsibilities included answering student questions, clarifying teaching topics, and proactively intervening to reduce student struggle. TAs lead the lab, including a short introductory lecture. They are responsible for all critical question-response and grading in-lab. They work approximately 5hr/week per 2-hr lab section, inclusive of prep and grading time. There were one PA and one TA assigned with a maximum of 12 students per lab section (up to 4 sections per TA, 3 sections per PA.) The introduction contains a short review of differences between PLAs and TAs with a summary shown in Table 1.

While not the focus of this paper, it is worth noting that the authors of this work and many previous works [1, 21, 7] have noticed that training procedures and preparation of TAs and PLAs makes a significant difference in the quality of the delivered course. A series of meetings throughout the semester were utilized to help TAs and PAs prepare for the course. Each semester the meetings included a TA orientation, stand-up semi-weekly meetings (student-led with instructor present), and a formal retrospective wrap-up session. These meetings, combined with requiring the completion of labs at least two weeks ahead of students, seem to prepare PAs and TAs well.

Evaluation

Evaluation of the intervention was accomplished through mixed methods. First, the Student Rating of Teaching surveys provides a standardized link to students' overall impression of the course before and after the intervention (three questions, N=7 semesters). Second, surveys containing Likert-like and open-ended questions were utilized to judge the effectiveness of the PAs and TAs. They attempt to determine if the program was going well and solicit feedback on the program during implementation (Resp. rate = 55%, N=125). Next, a survey was distributed to the PLAs to determine the program impacts on PLAs and their opinions of the program (Resp. rate = 60%, N=9) in Fall 2019. Finally, aggregate non-identifiable end-of-term grade data was gathered and compared between semesters to determine pass/no-pass rates (N=7).

Student Rating of Teaching Surveys (SRTs)

SRTs are a standard method of rating every course at the University of Minnesota. They provide responses to general questions about a course. For example, did the course foster a deeper understanding of the subject matter, improve student interest in the subject matter, and would students recommend the course. The advantages of using SRTs to evaluate an intervention include a solid historical baseline for comparing interventions, consistency in questions since 2015, and a very high response rate (class time is reserved for completing the surveys.) The limitation of SRTs include a lack of focus on the specific intervention. While the questionnaires are split into sections such that students evaluate the course separately from the instructor, lab space, etc. there is still strong coupling between these components of a class.

Figure 1 shows a positive trend in the SRTs for the course over the past 10 semesters. The first vertical green line indicates the last major lab revision. The second vertical green line indicates the beginning of the PLAs program. A improvement in both the mean and standard deviation of responses to all three questions can be observed (i.e., the course evaluations improved and became more consistent). The first two semesters using PLAs (Spring 2018 and Fall 2018), in particular, seems to indicate improved results, though the final semester impacts that appraisal somewhat. A discernible pattern of fall being more of a struggle than spring can be identified over the last seven semesters. This trend potentially negatively biases the results with 2 of 3 semester after PLAs being low and only 2 of 4 semesters before PLAs being low.

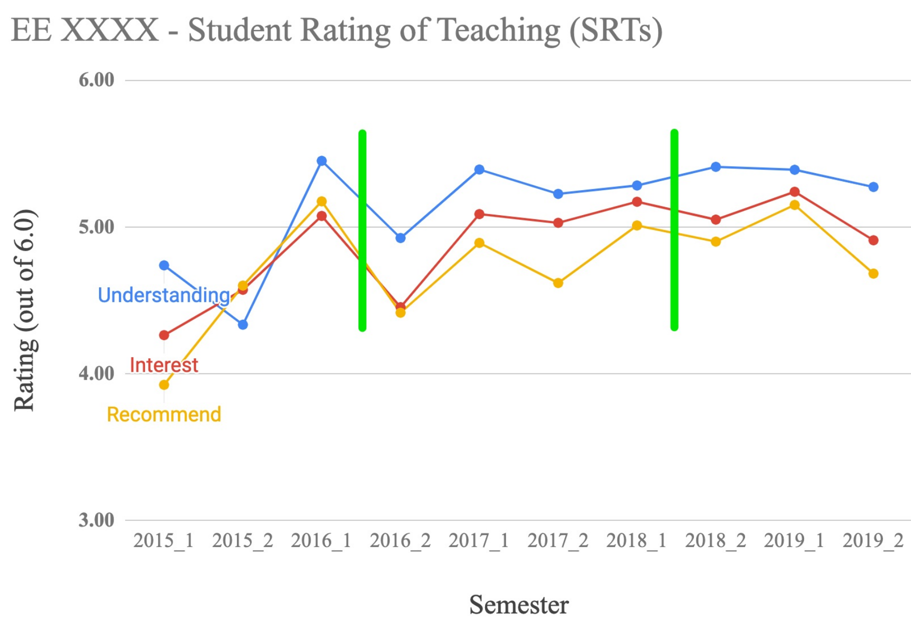

Figure 1: SRT Results for the past ten semesters. The first vertical green line indicates the last major update to the lab manual. The second vertical green line indicates the beginning of the Peer Learning Assistant Program.

The above data were analyzed by grouping the semesters into two groups: “Before PLAs” (yet after new labs were introduced) for four semesters, Fall 2016 to Spring 2018 and “After PLAs” for three semesters, Fall 2018 to Fall 2019. Means and standard deviations are compared in Table 2. The data show a not statistically significant difference between the populations in a single-sided t-test assuming unequal variance with a p-val of between 0.12 and 0.26. Since the data sets are at least partially correlated, you can’t directly infer the combined p-val, but it may be lower than 0.12. Thus the authors conclude that the PLA program probably improved students' general opinion of the course and improved their perceived understanding, interest, and willingness to recommend this course.

Table 2: Population Comparison of SRT Data

	Underst.	Interest	Recomm.
Before PLAs	5.21±0.20	4.94±0.33	4.73±0.27
With PLAs	5.36±0.07	5.07±0.17	4.91±0.23
Mean Shift	0.15	0.13	0.18
Mean Shift as % of StdDev.	90%	51%	70%
p-val	0.12	0.26	0.20

Furthermore, the data show a substantial decrease in the variance of the responses after the addition of the PLAs (again in Table 2.) This indicates that the PLAs may improve course consistency in the face of changing student and TA populations compounded with different faculty coming on board to teach the course.

No-pass Rates

Within our university and many others, no-pass rates are measured as the percentage of students that receive D grade, F grade, or Withdraw (DFW) from the course. The DFW rate was a primary motivator for the adoption of this intervention in our department. It was hoped that this program would improve these rates. The time series of the DFW rate for the course is shown in Figure 2.

The peak in 2017 can be seen, as well as a slight reduction in the DFW rate, dropping below 15% in the first two semesters of the PLA program. Unfortunately, the trend reversed slightly in the Fall of 2019. It should be noted that the Fall 2019 semester had an unusually low number of participants (N=38 vs. a previous average of around 60 per fall semester.) It is unclear at this point why the population shifted, but it may have increased the sensitivity of the DFW measurement to quantized noise.

When grouped into populations "before" and "after" PLAs, a small not statistically significant improvement in the mean (-1.6% mean shift, p-val = 0.25) can be observed. There is no clear evidence which suggests an improvement in the DFW rate.

Student Survey Results

Students completed anonymous surveys at the end of all three semesters of the PLA program. These surveys were designed to answer several research questions and also provide an opportunity for students to give feedback on the PLA program. Included in the survey were two demographic questions that asked students to self-assess their experience and skill in general programming.

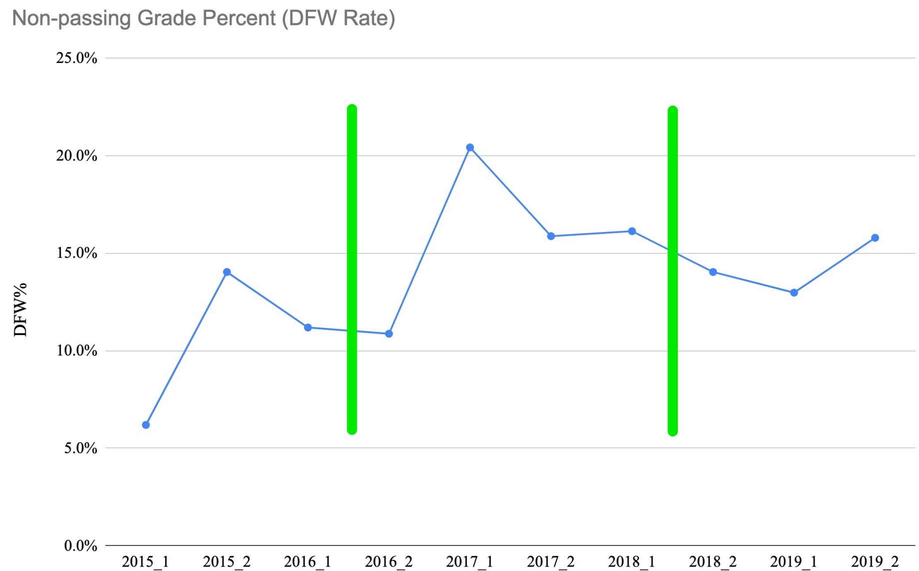

Figure 2: Percent of non-passing grades (DFW) for EE 2361 over the past 10 semesters. Vertical green bar indicates beginning of the PLA program.

Table 3: Population Comparison of DFW Data

	DFW rate
Before PLAs	15.8±3.9%
With PLAs	14.3±1.4%
Mean Shift	-1.6%
Mean Shift as % of StdDev.	37%
p-val	0.25

The first research question addressed was, “Are PLAs more or less effective than TAs in assisting students’ learning.” To address this question, two Likert-like questions were analyzed:

- (Q1) How effective was your Peer Assistant (PA) at helping you learn?
  - Not Very Effective, 1 ... 6 , Extremely Effective
- (Q2) How effective was your Teaching Assistant (TA) at helping you learn?
  - Not Very Effective, 1 ... 6, Extremely Effective

The data did indicate that students were willing to rate TAs and PAs differently with 20% of respondents with a difference in rating of >= 2 points. Meaning that while some students judged their TA or PA better than the other, on average, they were comparable. A two-tailed t-test shows that PLA’s effectiveness (4.98±1.18) was neither significantly higher nor lower than TAs effectiveness (4.95±1.27) with a p-val = 0.85.

While PLAs were not significantly different than TAs, the survey utilized two additional questions to determine if students had a positive impression of the PLA program. These questions are listed below:

- (Q3) Do you agree or disagree with the following statement, "The Peer Assistant (PA) helped me be more successful in the EE 2361 course."
  - Strongly Disagree, 1 ... 6, Strongly Agree
- (Q4) If you had to guess, how much of an improvement did the peer assistants provide in your grade for this course?
  - Multiple Choice: 0, 0.5, 1.0, or 1.5 letter grades

The responses to both of these questions reflect very favorably on the PLA program (shown in Figure 3). There is a clear positive bias in the responses with the mean at 5.1, 76% >5, and 90% >4 on a 6-point Likert-like scale. The median response indicates that students, in general, felt PLAs contributed to their success, resulting in a perceived net improvement in student performance by at least half a letter grade (79% of responses.) To reiterate, the *students* indicate they *feel* the peer assistants provide a positive impact on their learning. The authors did not attempt to obtain individually identifiable grades.

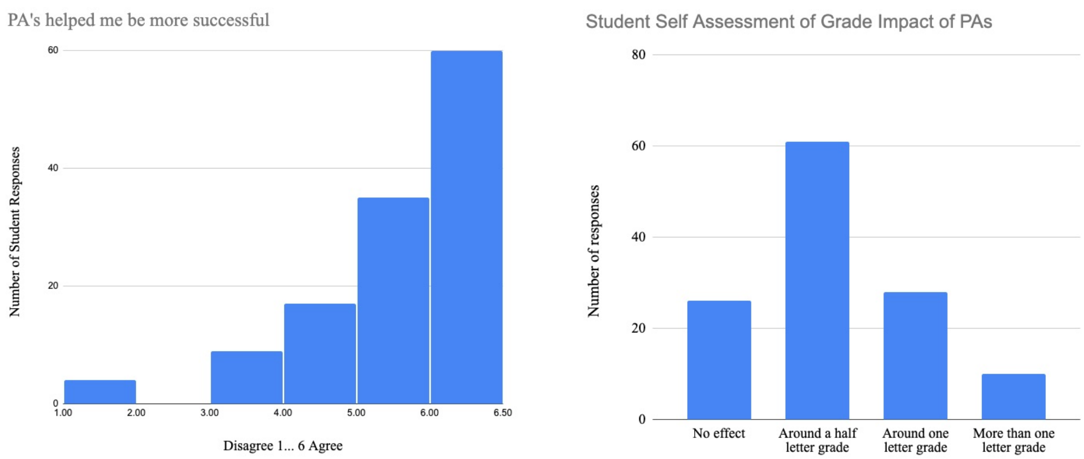

Figure 3: Student responses to Q3 (left) and Q4 (right)

An even more telling story is created, when the results are broken down by self-assessed demographic data covering programming experience and skill. Little correlation was shown between perceived grade impact and programming skill (mean shift = 0.1±0.50, p-val = 0.28), but a strong correlation was identified between grade impact and programming experience (mean shift = 0.36±0.43, p-val = 0.012). This seems to indicate two potentially interesting ancillary findings. First, PLAs have a greater perceived impact on students with less prior *time* doing programming. Leading the authors, to answer, "Does the PLA program have a greater impact on less experienced programmers?" in the affirmative. Second, this also indicates the possibility that asking students to judge their "skill in programming" without some construct supporting that self-assessment confounds the results.

Table 4: Population Comparison of Perceived Grade Impact

	Grade Impact	n
Prog.Exp. <= 1 sem	0.85±0.41	10
Prog.Exp. >= 1 year	0.49±0.38	66
p-val	0.012	

Finally, the survey contained the question, “Would you recommend that we continue the Peer Assistant program in future semesters?” Every single respondent answered “yes” (n=125.)

The sum of these results lead the authors to conclude that the PLA program resulted in nearly all students viewing the program favorably, but more importantly a statistically significant increase in perceived improvement for students with less previous programming experience.

PLA Evaluation of the PLA Program

At the end of the Fall 2019 term, a survey was sent out to all the PLAs who participated in the program. This survey attempted to determine how the PLAs felt about the effects of the program and what impact it had on them and their career paths. Only nine (N=9) responses to the survey were recorded, due to the total number of PLAs so far in the program being limited to fifteen individuals.

Overall the opinions of the students engaged as PLAs were extremely positive. Every survey respondent answered, “Would you recommend applying to the PA program to a friend? (Yes/No)” with “Yes”. The impact on students was measured by two Likert-like questions with the results shown in the Table 5. Both of these responses were very positive, with scores of approximately 3.5 out of 4.0.

Table 5: PLAs opinion of program Impact on Students

Mean (of 4.0)	Std. Dev.	Grade Impact
3.56	0.53	How much do you feel you improved students learning of fundamental programming concepts
3.44	0.73	How much do you feel you improved students efficient use of lab time (i.e., reduced debugging time, identified simple errors, etc.)

The impact on the PLAs themselves was measured by four Likert-like questions shown in Table 6. These results were more mixed. A clear positive signal was indicated in the first question, assessing the confidence that PLAs felt they gained through the program. The questions addressing impacts on career choices and the value of the program to themselves were above median but more mixed. The authors do not make any additional claims based on these results, other than PLAs generally viewed the experience as positive and would recommend it to their friends.

Table 6: PLAs opinion of program Impact on PLAs

Mean (of 5.0)	Std. Dev.	Grade Impact
4.44	0.53	Being a PA has enhanced my confidence when dealing with students, engineers, professors, or managers.
3.67	1.12	I believe being a PA will help me secure a job or improve my career prospects.
3.78	0.67	I believe being a PA improved my likelihood of someday pursuing a graduate degree.
3.89	0.33	Being a PA was a valuable experience for me.

Resource Concerns and Alternative Funding

While the focus of this work is the effectiveness of the PLA program and its context in research, it has to be recognized that all departments have resource limitations. Every intervention must at some level consider the resource cost burden.

Either due to a shortage of qualified graduate students or budgetary restraints, a PLA infused teaching support model may be worth exploring for some colleges and universities. Students would be enticed by flexible on-campus jobs that enhance their understanding of core concepts while departments reap the benefits of cost-effective student labor that does not induce costly tuition and health insurance benefits. For the most recent fiscal year in the ECE department, a graduate teaching assistant costs $9,986.23 for 12 hours of labor during each of the approximately 15 weeks that class is in session. A PLA only costs $2,700, even offered at a hourly rate above most other on campus undergraduate job opportunities. These funds are important for supporting graduate programs of course, but depending on funding demand, the added flexibility of undergraduate PLA support can make limited funding go further in the right case.

Beyond tapping existing teaching funds, the opportunity exists to utilize scholarship funding to reward students for taking on the role of PLA. These positions do not need to be hourly but can also be awarded in the form of a working fellowship, asking students to perform the duties of a PLA in exchange for scholarship/fellowship awards. This type of program could open up additional sources of funding and potentially invigorate some donors to give to the cause of directly helping current students help other current students. Typically alumni and other donors are drawn to seeing their donated gifts go directly to student support. Additionally, students can tout their selection as more than merely a job, but a scholarship award, further heightening the prestige of the position.

The authors believe that the benefits outweighed the cost for our department, but it is up to each department to make their own judgement on the costs, availability of resources, and benefits of a PLA program.

Discussion and Lessons Learned

A great deal was learned in implementing our PLA program. We can evaluate our original and addition research questions as follows:

1. Does the addition of PLAs reduce no-pass rates in the course?
    - Uncertain, it is probable that the no-pass rate improved a small amount, but it is too early to tell (no-pass rate fell 15.8% to 14.3%, statistical significance was very limited with $p=0.25$.)
2. Does the addition of PLAs improve Student perceptions of the course?
    - A tentative yes, with all three SRT questions indicating a positive trend with the most significant result having a mean shift of 5.21 to 5.36 on a 6 point scale with $p<0.12$. While supportive this quantitative data is not statistically significant. The qualitative student survey provides the bulk of the evidence, with the statement "helped me be more successful" returning 76% of responses being >5 on a 6 point Likert-like scale.
3. Does the PLA program improve the perceptions of less experienced programmers more than others?
    - A very strong yes, students with less than or equal to 0.5 years of experience in programming showed an increase in perceived impact of the PLA program with $p=0.012$.
4. Are PLAs more or less effective than TAs at helping students' learning?
    - PLAs (4.98 ± 1.18) were neither more or less effective than TAs (4.95 ± 1.27), with fairly high confidence $p=0.85$.

In addition to the above research questions, several lessons were learned during the implementation of this program. In large universities, consistency is very difficult to maintain as instructional professors and graduate TAs constantly change. PLAs add another layer of organizational support, communicating organizational methods between new professors, TAs, and PLAs.

Included in the student and PLAs surveys were open-ended questions. While there are too many positive and inspiring anecdotal comments to report in this work, there are two additional observations by PLAs worth reporting.

First, "It would be helpful to REALLY reinforce the point that PAs are here to help and not grade students because, in my experience, students seem to ask more questions and come to office hours more often knowing that they aren't being graded on any of those interactions." – Anonymous PLA. Communicating the roles of TAs and PLAs to students was very difficult in spite of a specific focus on this task from the beginning of this program. This lesson was also noted in [8]. Every effort needs to be made to communicate to students that PAs *do not grade* multiple times throughout each and every semester.

Second, "...PA's...have an easier time revamping the labs to best assist future students." – Anonymous PLA. The recognition that PLAs, due to effectively taking the course twice, make valuable partners in making and assessing curricular changes in courses. The authors can not emphasize this small detail strongly enough. Multiple substantial quality improvements in the course materials have been made due to the feedback and active participation of the PLAs.

Asking students to self-assess their “programming skill” is a fairly common practice in the authors’ department. This input is used to assess incoming students and balance group assignments. The indication, in this work, that simply adding time (a concrete measurement) to the question potentially reduces the error in this self-assessment measure is intriguing and should be investigated further.

Finally, the authors would be remiss if we didn’t mention the energy and enthusiasm that the PLAs have brought to this course. The PLA position is the most commonly requested undergraduate assistant position in the department. Currently, we have one TA with two semesters of experience and three PLAs with three plus semesters of experience. The PLAs organize and contribute to the running of the stand-up meetings and have taken over a large portion of the organization and running of the lab. Introduction to Microcontrollers has become richer and more attractive due to the addition of PLAs. We thank them for their contributions and recommend other departments consider implementing Peer Learning Assistants in their early-program lab courses.

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