

Using Undergraduates as Teaching Assistants at a State University

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Abstract

This paper describes a program that uses undergraduates as teaching assistants to staff large computer science classes, particularly at the introductory level. Creating such a program at a state school presented special challenges, but the program has become a mainstay for the department's undergraduate program. The program has been so successful that we have expanded it to cover some sophomore and junior level courses, including a discrete mathematics course. Among the benefits of the program are reduced overall cost, improved quality of instruction, the formation of an undergraduate community and the practical experience that the undergraduate teaching assistants themselves gain.

Categories and Subject Descriptors

K.3 [Computers & Education]: Computer & Information Science Education – Computer Science Education.

General Terms: Management

Keywords: CS1, CS2, undergraduate TA

1 Background

This program was based on the undergraduate teaching assistant program that the author created at Stanford University [1] and that has continued to thrive under Eric Roberts [2]. Stanford has a highly selective undergraduate population that is particularly well suited to such a program. It wasn't clear whether such a program would work at a fairly traditional state school. There have been challenges along the way, but we have managed to create a parallel program that, if anything, is even more important to this department than it is to the Stanford department.

The University of Arizona is the land-grant institution for the state of Arizona and has over 34 thousand students, approximately 26 thousand of them undergraduates. By law the university admits all Arizona residents who graduate in the top half of their high school class.

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Many incoming freshmen are not well prepared for university work and fewer than half complete an undergraduate degree within six years. The university also has many nontraditional students including undergraduates who are older and who have full-time jobs and families to support.

Each year over 400 entering freshmen declare their intent to major in computer science and most end up taking at least one introductory course from the department, but only 100 or so are admitted to the major each year. This disparity between those intending to major in CS and those who perform well enough to be admitted to the program causes significant stress in the introductory courses. We aren't simply taking the top 100 candidates each year. We admit every student that we believe will succeed in the program and most students who are admitted graduate in a timely manner. But many students take our introductory courses believing they can succeed when they cannot.

2 Program Overview

2.1 Structure

Most of our lower division courses are four units. Students meet in a single large lecture hall three times a week but they split up into various small-group discussion sections once a week. Undergraduates run these sections and we refer to them as "section leaders." Our typical courses have enrollments between 100 and 200 students and include the following staff:

- **Instructor:** The faculty member who lectures and has primary responsibility for the course.
- **Head TA:** A section leader who works directly with the instructor to help administer the course. In simplest terms, the head TA manages the other section leaders, providing the instructor a single point of contact for important tasks. Typical duties include making up grading criteria for assignments, making up handouts for weekly discussion sections and helping the instructor with new programming assignments. The head TA job takes about 10 hours a week. Some students do just the head TA job, but more often the head TA also has a section.
- **Section Leaders:** The undergraduate TAs who do the bulk of the work. Students are assigned to a specific section and are expected to attend regularly. Section size is between 12 and 18 depending upon the subject. Individual section leaders run an hour-long section and grade homework for their students. Exams are typically graded as a large group-effort with all staff involved (an evening of pizza and grading). The job takes about 10 hours per week, as described below.

The overall program has various staff as well:

- **Program Coordinator:** The faculty member who runs the overall section leader program. The time demands for this job vary widely depending upon how mature the program is. Once the program has been in place for a while, it almost runs itself. It is still important for a faculty member to take ultimate responsibility for the program to ensure that quality and professionalism are not compromised.
- **Section Leader Coordinators:** A pair of students who together manage the administrative details of the overall program. They teach a weekly training class for new section leaders and coordinate details like the maintenance of web pages and the scheduling of lab hours. They interact with staff members in the department to handle details like payroll and computer accounts. They also interview and select new section leaders. The coordinator job typically takes 10 hours per week, but some coordinators spend more time because they are interested in improving some specific aspect of the program. Coordinators also sometimes do a section in addition to coordinating to get 20 hours a week of work.

We currently employ approximately 45 section leaders, 5 of them head TAs, and 2 coordinators for five courses with a combined enrollment of approximately 650 students.

2.2 Section Leader Duties

We advertise the section leader position as taking up a total of 12 hours a week as follows:

- 3 hours attending the class they are working for
- 2 hours grading homework for their students
- 2 hours in “interactive grading” for their students
- 2 hours as the on-duty helper in the lab
- 1 hour in a staff meeting for their course
- 1 hour in a “community meeting” for all courses
- 1 hour presenting section

New section leaders have an extra hour in which they attend a weekly training class for a total of 13 hours per week.

The section leader spends the first 2 hours of grading alone, going through all of their students’ programs and assigning a score to each according to the official grading criteria. The section leader then meets one on one for approximately 10 minutes with each student for “interactive grading.” This gives the section leader an opportunity to explain to each student what mistakes they made and how they might avoid them in future programs. Interactive grading is time consuming, but worth the cost. Many students, however, don’t show up for their interactive grading sessions, even though part of their grade is affected by not showing up. We also exempt students who get 90% or above on a particular assignment from attending interactive grading for that assignment given that they have mastered the material at the A level.

The 2 hours that each section leader spends in the lab allows us to provide excellent coverage of the lab seven days a week with particularly heavy coverage in the prime time hours when students are most likely to be working on assignments.

When I first put together the list of hours for the section leader position, I assumed it was an underestimate. I include no time, for example, for the section leader to prepare for their section. Plus many section leaders put in more than 2 hours in the lab and they often have extra duties like midterm grading and special help sessions for students who are struggling.

As it turns out, however, the right number has consistently averaged out to be 10 hours per week overall. We have a 16 week semester

and I have been able to predict with great accuracy the total hours worked by the equation:

$$(10 \text{ hours/position}) * (\# \text{ of positions}) * (16 \text{ weeks})$$

The total number of positions is simply the number of sections plus the number of head TAs plus 2 for the coordinators.

It is worth noting that new section leaders consistently put in many more hours than experienced section leaders. Our new section leaders don’t report their first 3 hours of work each week because they are taking a 1-unit training class. Even so, they average 13 or 14 hours a week during the semester (that’s after subtracting 3 for the training class). The overall number still comes out to be around 10 hours per week for the program, which means that the experienced section leaders are putting in fewer than 10 hours per week (or reporting fewer than 10 hours). It helps that some weeks are less busy than others, particularly at the beginning of the semester, which lowers the average.

3 Special Constraints of a State School

Stanford is a private school with significant resources and is well known for admitting “well rounded” students who have many talents. So it wasn’t surprising that the section leader program was relatively easy to set up there. Setting it up at a state school hasn’t been quite so easy for a number of reasons.

3.1 Cost of the Program

The section leader program turns out to be a bargain relative to the cost of graduate teaching assistants, but I have faced a recurring panic reaction that the cost of the program is exploding out of control. This perception will probably always be an issue because the costs are less predictable than with graduate students. Graduate students are generally on fixed appointments and we know before the semester even starts exactly how much we are going to pay them. The section leaders report their hours weekly and it is much easier to get nervous about future weeks, especially when budgets are tight. So one of the burdens any program coordinator is likely to face is the need to watch the expenses closely and to spend time explaining and justifying budgets and expenditures.

The total cost for our section leader program this semester will be approximately \$75 thousand (10 hours per week * 16 weeks * 50 positions * \$9.50/hour). Our standard TA formula would assign a 20-hour TA for each 50 students. So for the 650 students serviced by this program, we’d assign 13 TAs. We pay approximately \$6,500 to each TA for a total cost of \$85 thousand. So the section leader program is about 10% less expensive than our standard TA formula. In the early years the program was closer to a 30% reduction relative to graduate students, but it was necessary to have that kind of dramatic savings to convince people that the program was affordable.

3.2 Student finances

If the department has to worry about its budget, the students have to worry twice as much. In the Stanford program each student had a single job (one section or just coordinator). I learned early on at the University of Arizona that I had to accommodate students who needed more hours of work. I was concerned that they might be overworked, but they explained to me that if I could give them only 10 hours a week of work, then they would have to find another job. So it made more sense to give them 20 hours a week of work

This manifests itself in section leaders who do two sections and in coordinators and head TAs who take a section in addition to their normal duties. We have even had a section leader with three sections working 30 hours per week. He was an outstanding section

leader and did a wonderful job, but we wouldn't allow many of our section leaders to take on that kind of burden. This doubling up of duties provides a slight savings to the department because we don't, for example, have to pay a section leader twice for attending class or attending staff meetings.

Our pay scale is generous for the University of Arizona but we are not competing with local industry. Students know that they can make more than \$20 per hour at our local IBM offices.

Our pay scale has four levels:

Level	Pay
SL-I (intro course)	\$8/hour plus \$0.50/hour per semester of experience (max of \$10/hour)
SL-II (advanced course)	\$9/hour plus \$0.50/hour per semester of experience (max of \$10/hour)
SL-III (head TA)	\$10/hour
SL-IV (coordinator)	\$12/hour

We found it helpful to create these as official job classifications with Human Resources.

At Stanford we had first-time section leaders work without pay during their first term, taking a 3-unit teaching techniques class. This seemed like a logical approach given that the first term is the greatest learning experience for a section leader. But I found at Arizona that students couldn't afford to be section leaders for a semester without pay. This has partly to do with the fact that Stanford was on the quarter system while Arizona is on the semester system, meaning that Stanford students gave up just 10 weeks of pay instead of the 15 our students would give up. But I think it had more to do with the fact that Stanford students can more easily afford to go to college without a job. In any event, we decided to reduce the units on the training course to 1 unit and we instruct new section leaders to subtract 3 hours each week when reporting their hours for pay.

3.3 Firing Section Leaders

I never fired a section leader at Stanford and I thought that was a positive aspect of the program. Section leaders like the idea of job security, so it was good to let people know that once they were in the program, they were in as long as they wanted the job.

Our track record at the University of Arizona hasn't been quite so stellar. We have had section leaders who seemed competent during their interviews but who turned out to be unreliable. We have fired only one section leader in the middle of a semester because he was missing so many of his assigned duties. But in several other cases, we have chosen not to hire back particular section leaders who were not performing adequately.

Our current policy is that section leaders are automatically rehired if they want to continue as long as they fulfill all of their minimal requirements (attending class, presenting their section, showing up for their lab hours and grading homework in a timely manner). Some of our problem cases have been very specific, as in a section leader who just doesn't grade homework or a section leader who never attends class. But more often we have had section leaders who seem to have a breakdown of some kind and suddenly do poorly at all of their duties. In all cases, we provide people feedback long in advance of deciding to let them go.

3.4 State Laws

Faculty at state universities have to deal with the kind of bureaucracy inevitable in government supported enterprises. There

is often a multi-way political tug-of-war between the Legislature, the Governor, the Board of Regents, citizen-sponsored ballot initiatives and so on. Plus the state schools get caught up in the fiscal problems that states must address. No matter how well-intentioned the political players are, an unintended consequence is often that legitimate programs are hurt.

For example, to ensure that faculty aren't shirking their grading responsibilities, some state legislatures make it illegal for an undergraduate to grade work from another undergraduate. Our section leaders not only grade other undergraduates, they even grade graduate students who take our courses.

Fortunately for us the faculty at Arizona have championed the idea that we will use undergraduate "preceptors" to help staff large general education courses across all disciplines. Our program fits nicely under the preceptor umbrella.

Another example came from an attempt to eliminate unpopular classes with a miniscule enrollment. Our classes have a huge enrollment, but breaking them up into discussion sections makes them appear to the statisticians as if they were tiny classes. One would think that this could simply be explained with a phone call or a memo, but that doesn't always work in a state university. It could very well be that the Legislature did not intend to affect my discussion sections, but they didn't just institute a policy or make a suggestion. They passed a law and the Board of Regents and the University have a fiduciary responsibility to obey that law. The problem comes from the "one size fits all" approach inherent in state governance. Even the most detailed laws with multiple exception clauses will tend to overlook some situation that the lawmakers did not intend to change.

4 Creating the Program

The undergraduate section leader program at the University of Arizona was created piece by piece over a period of five years and the development of the program matched almost exactly its evolution at Stanford.

This has been something of a disappointment for me, because I would have thought that having figured out the program once at one university would allow me to create it quickly at another university. But a program like this takes time to nurture and develop. One factor was the pipeline phenomenon that some of these changes could take place only when I had a pool of experienced section leaders. But the single biggest limitation was my own time constraints. Bringing this program into existence took an incredible amount of time. I got no official credit for doing this, so I had to do it in spare hours when I wasn't doing other work that was required of me.

I assume that others might find themselves with similar constraints, so I thought it might be helpful to describe the stages I went through in creating the program year by year:

Year	Status
1	One instructor, just section leaders: I couldn't force this on any other instructors until I had made it work for me in my own courses. During this initial phase there was no formal training for the section leaders. I would have had to do the training myself because I didn't have coordinators and I just didn't have the time. So training was more informal in the form of tips I gave during our weekly staff meetings. We also had no head TAs, although this was mostly because of limited finances
2	Multiple instructors. Once I had a pool of somewhat experienced section leaders, I felt I could branch out to

	cover other classes and hope that the experienced section leaders would help train the new section leaders.
3	Section leader coordinators: After 2 years, I had a pool of experienced section leaders from which to choose a pair to coordinate the overall program. I then spent time with them figuring out how to offer the training course for new section leaders.
4	Staffing a junior level class: This was the year in which we first staffed our “object oriented programming and design” course with section leaders.
5	No major changes: You have to have at least one year to focus on other things.
6	Head TAs, staffing a discrete math course: We finally added head TAs at this point. They turned out to be extremely helpful, but they also increased the overall cost of the program. We also started the experiment of using this structure not just in the programming classes but also in a new discrete math course we were offering.

5 Going Beyond CS1 and CS2

Our experience at the introductory level was so positive that we decided to extend ourselves a bit by also using section leaders for our junior-level course in object-oriented programming and design. At the same time we increased the units for the course from 3 to 4 and introduced a weekly discussion section. It has turned out to be yet another challenge to figure out how to use undergraduates effectively in this class, but the reward has once again been well worth the investment. Much has been said about the need for people to learn OOP through “mentoring” and the section leader approach has allowed us to give more individual attention to students.

Last year we started our boldest experiment yet—the use of section leaders in a discrete math course. We are still in the early stages of that experiment, so we don’t know how it will turn out in the long run. But so far things have gone fairly well.

One of our greatest challenges for the discrete math course comes from the strength of the section leader program itself. Section leaders find that teaching people to program can be great fun. Students enjoy programming and their enjoyment translates into happy section leaders. We don’t see quite the same level of joy at the prospect of learning how to do proofs. But math can be fun as well and we have been blessed with a number of undergraduates who are on a kind of personal mission to teach their fellow computer science students to appreciate mathematics. Still, we have concerns about our ability to staff the course long-term. It was the most difficult course for us to staff this semester, although the section leaders who chose to work in the course were among our best.

6 Section Leader Training

As noted earlier, new section leaders take a 1-unit “teaching techniques” course. This is graded pass/fail. The course is run by the two section leader coordinators with the assistance of the faculty program coordinator. We meet once a week for an hour to cover some specific aspect of the job. Sometimes there is homework, but most often we do everything within the one hour. We typically have 10 to 15 new section leaders each semester.

The single most useful training exercise is to videotape the new section leaders. The new section leaders are generally very nervous about this, so we videotape their section and let them review the tape on their own.

Below is a list of training topics we have used in the approximate order in which they are presented.

- **Getting Started:** We review policies and procedures (e.g., filling out timesheets, getting paid) and answer any questions. Then we discuss ideas for how to “break the ice” in their first section.
- **Grading Programs I:** This is the first of several related sessions. We give them a fictitious programming problem along with six or seven student solutions. We ask them to break up into pairs or threes to figure out a score out of 20 for each of the student solutions. We then make a big grid and record the scores for each student solution that each section leader pair has come up with. The scores are generally similar, but there will always be one or two programs that have wildly varying scores. We use these differences to stimulate a discussion of what is good or bad about the various solutions.
- **Grading Programs II:** We continue the previous week’s example by designing a formal 20-point grading criteria for the assignment. This involves a general discussion of the philosophy of grading. For example, many novices are fond of negative grading (here are 45 ways to lose 20 points). We force them to come up with criteria expressed in a positive way (here are the 20 points and how they are accumulated).
- **Grading Programs III:** We divide them into pairs again and use the grading criteria from the previous week to assign scores to each of the sample programs. Again, we make a grid to summarize what scores each group gave out and, again, there are usually one or two programs that have a nontrivial difference. This leads to a refinement of the criteria and a discussion of how graders interpret criteria.
- **Difficult Students:** In this session we role play one or two difficult students. We again use the grading example we have been working on. Now they have to deal with grading not just as an abstract exercise but as a personal experience. We try to simulate some of the common situations they will encounter, especially with students who argue about the score they receive. We discuss how to handle such situations including the important point that they always have the option of sending the student to the head TA or instructor if they feel they can’t handle the student.
- **Discussion Section:** We have a group discussion of how to be effective in their weekly discussion sections. We make a list of “good” and “bad” things that a section leader can do.
- **Difficult Concepts I:** We talk about how to teach difficult concepts to students. As an example, we consider how to solve recursive tracing problems where students are given a “mystery” function and various inputs. We break up into pairs and have each pair develop and present one idea.
- **Difficult Concepts II:** Tracing recursion can be difficult, but it is a mechanical process. This time we consider recursive programming where students are asked to write their own solution to a problem using recursion. We again break into pairs and have each present their best idea for teaching this.
- **Gender Issues:** We bring in an outside speaker to discuss issues of gender that come up in teaching.
- **Teaching Styles I:** We invite one of our experienced section leaders to give a 25-minute example of how they would present a particular topic in section. Then we discuss what we saw as strengths and weaknesses of the presentation.

- **Teaching Styles II:** We continue with a second experienced section leader giving a 25-minute talk on the same subject as the week before and again discuss strengths and weaknesses.
- **10 Best/Worst Things:** We make a list of the ten best things a section leader can do and the ten worst things a section leader can do. We don't really limit ourselves to ten each, but that's the idea. To try to get everyone involved, we go around the room having each person add one thing.

7 Benefits for a State School

The section leader program has several benefits:

- **Lower cost:** As noted earlier, the section leader program costs approximately 10% less than graduate TAs would cost.
- **Improved quality of instruction:** Each graduate TA is replaced with 4 section leaders, which is a great increase in available manpower. While graduate students are supposed to work 20 hours per week, they often don't. They are also paid over a longer period of time (22 weeks versus 16). The undergraduates, by contrast, report every hour they work. They also tend to be more familiar with the lab and with the particular teaching style we use.
- **Community:** When I came to the university six years ago, there was no real undergraduate community. This is a particular challenge for a state school where most students live off-campus and spend as little time on campus as possible. The section leader program provided a context for a large group of undergraduates to get together more informally. This has created a small community from which we've grown a larger community of undergraduates. This has been even more important for our students than it was for Stanford students because the Stanford students were more likely to already feel part of the academic community.
- **The section leaders themselves:** The students who benefit the most from the program are the section leaders themselves. Industry says that they want students with interpersonal skills, who can give presentations and who can work in groups. We develop many of those skills in our section leaders while paying them and allowing them to have fun along the way. A surprising aspect of the program both at Stanford and at the University of Arizona is high turnover. The students that we hire are so talented that they get offers for other kinds of work. The section leader program, then, serves as a launching ground for many undergraduates.

We have mostly anecdotal evidence to support the observations above, but there are some facts worth mentioning.

- In the five years that this program came into existence (1997 through 2001) the department's student units and student enrollments more than doubled (a 130% increase). Many CS departments saw rapid growth during the same period, but we believe that ours was greatly influenced by the section leader program. We supplied a safety net that allowed more students to succeed in the courses.
- In the same period our undergraduate program more than doubled (from approximately 40 a year to 100 a year).

- Our percentage of undergraduate women majors increased from 15% to 20%. We believe this is a direct result of the sense of community created by the section leader program. Compared to the students in the major, women have made up a disproportionately high percentage of the general section leader group (approximately 25%) and particularly of the leadership (approximately 40%). This has occurred without any special preference given to women.
- The department's long inactive student ACM group was revived primarily by a group of section leaders.
- The department underwent an external review about halfway through this period and the committee made excellent comments about the section leader program. They said that many of the students they interviewed commented on the program and how its high quality underscored a problem in the quality of graduate Teaching Assistants.
- In the last two years, approximately ten former section leaders stayed for our graduate program, about half of them in the PhD program. This is a significant change for the department.
- At least half of the undergraduates offered student research opportunities in the department are former section leaders. In fact, some of the CS faculty have expressed a concern that the section leader program is "too attractive" to talented young people who should be doing research instead.

8 Other Schools and Web Resources

Information about our program can be found at:

<http://www.cs.arizona.edu/classes/cs391/>

The Stanford program is described at the following site:

<http://www.stanford.edu/class/cs198/>

Although I don't believe they have ever written a paper about it, Brown University has a similar program for undergraduate teaching assistants that is at least as old as the Stanford program. They have parallel positions (their undergrad TA or UTA is our section leader, their head TA or HTA is our head TA, their meta-TA or MTA is our coordinator). Their program is described at:

<http://www.cs.brown.edu/courses/ta/>

A former Brown undergraduate TA in association with Owen Astrachan is experimenting with a similar program:

www.cs.duke.edu/cseducation/undergrad/utasignup.html

A former Stanford section leader named Mike Scott said such good things about the program that Elaine Rich and Roger Priebe were convinced to create a similar program at UT/Austin:

<http://www.cs.utexas.edu/users/scottm/USL.htm>

Georgia Tech has a similar program.

References

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