The Impact of Teaching Assistants on Student Retention in the Sciences
Lessons for TA Training

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Attrition from the sciences remains a national problem. We present results from a survey of over 2,100 undergraduates that, contrary to previous research, suggests that teaching assistants (TAs) influence student retention in the sciences in multiple ways. Multiple linear regression (MLR) and student comments suggest that TAs influence lab climate, course grades, and students’ knowledge of science careers, all of which have an effect on students’ decisions to stay in or leave the sciences. We close with recommendations for TA training, mentoring, and management to positively impact student retention.

Nationally, retention in science has become a matter of real importance, as educational institutions try to slow the sizable flow of undergraduates out of scientific fields (Campbell et al. 2002; National Science Foundation 2003; Strenta et al. 1994). Attrition in the sciences is especially problematic in the undergraduate years because approximately 40% of students who come to college intending to major in the sciences ultimately decide to major in something else (Astin and Astin 1993; Seymour and Hewitt 1997; Strenta et al. 1994). Many of those who leave the sciences are capable students with the aptitude to do well in science (Montgomery and Groat 1998; Seymour and Hewitt 1997; Tobias 1990), and the attrition problem is particularly acute for women and people of color (Astin and Astin 1993; Holstrom et al. 1997; Seymour 2002; Xie and Shauman 2003). Clearly, students have every right to change majors and explore topics they had not considered before coming to college, but it is a problem (and in this case, a national problem) if they change their prospective major because it did not satisfy their needs.

There are many hypotheses about the reasons for undergraduate attrition in the sciences, and this article explores one of them, the impact of graduate student instructors or TAs in gateway courses. The gateway course is the initial college course in the sciences taken by a first- or second-year student who expects to be a science major in college. Attrition in the sciences is especially likely in the first two years of college (Seymour and Hewitt 1997), at the time when students are still taking gateway courses.

A majority of science, technology, engineering, and mathematics (STEM) bachelor’s degrees are awarded at research and doctorate-granting universities, which employ large numbers of TAs in introductory science courses (National Science Board 2006). In fact, in the life sciences and physical sciences, TAs are responsible for more than two-thirds of the lab sections (National Center for Education Statistics 2000 as cited in Seymour 2005, p. 3; Nyquist, Abbott, and Wulff 1989; Rushin et al. 1997). As anyone who has talked with parents and incoming college students can attest, there is considerable public concern that TAs do not teach as well as faculty. In this research study, we asked: What influence do TAs have on underclass students’ plans to major in or leave the sciences?

Literature on student attrition and the role of TAs
In their groundbreaking study on student attrition, Talking About Leaving: Why Undergraduates Leave the Sciences, Seymour and Hewitt (1997)
spoke with numerous undergraduates about why they had either stayed in or switched from a science major. Overall, only 3% of students in their study who were making a switch mentioned "language difficulty with foreign faculty or TAs," and none of the students mentioned "poor teaching, lab, or recitation support by TAs" as a factor in their decisions to switch majors.

Given the significant roles that TAs play in the sciences, we were surprised by the Seymour and Hewitt findings that TAs do not influence students’ plans for a major. While students may quite obviously see the impact of the professor on a course, they may not be fully aware of the division of labor in a course: who does the grading and plans lab assignments, and how labs are managed so that everyone can have a positive experience. Therefore, our research focuses on the multiple roles, both obvious and subtle, that TAs might play in the decisions that science students make regarding a major in the sciences. We hypothesized that TAs indirectly influence the experiences of students in the sciences through the informal mentoring and role-modeling they provide and the learning environments they create in their labs or discussion sections (often referred to as classroom climate).

Research design

The survey

To determine the role of TAs in undergraduate attrition from the sciences, in January 2004, we surveyed all undergraduates at a large, Midwestern university who took at least one of the seven gateway courses for prospective majors in chemistry, biology, and physics in fall 2003 (e.g., introductory biology, general chemistry, mechanics and sound, and so on). The survey asked students about their intention to major in the sciences (or have a career in the health sciences) before the class they had just taken, as well as after they had taken the course (i.e., when they took the survey). It is important to note that this research focused on students’ plans to stay in or leave their science major, not actual retention or attrition, and it was retrospective, so it also focused on their perceived attributions for any change. To address our concerns that undergraduates may not know who takes responsibility for different parts of the course, our survey allowed students not only to choose from instructional roles (e.g., “faculty” or “TA”) but also instructional events (e.g., lab climate, course grades). The complete survey is presented in Appendix 1.

A web-based survey tool was used to create and distribute the survey. Because the survey tool allowed us to track individual responses, individuals’ responses were paired with demographic data (sex, race/ethnicity, class, and course grade) obtained from the university registrar. Out of 3,656 undergraduate students surveyed, 2,669 students responded to the survey (73% response rate). Of the 2,669 students surveyed, 2,102 were first- and second-year students (78.8% of respondents). We focused our analysis only on the underclass students (i.e., first-year students and sophomores) enrolled in the seven courses because they were not yet committed to a major. About half (46.7%) of the respondents were first-year students, and a small majority (53.3%) were sophomores. Nearly half (49.4%) were female, and only a small minority (10.2%) were underrepresented non-Asian minorities. The seven gateway courses had a total of 113 TAs teaching a total of 263 sections or labs.

A separate survey collected demographic data on the 113 TAs teaching in the sampled sections (sex, race/ethnicity, experience, and so on), as well as data on TAs’ opinions of their training. Summaries of data from both the undergraduate and TA surveys are presented in Table 1.

Data analysis

We used multiple linear regression analysis (MLR) to examine the impact of various factors on student plans for retention (independent variables are summarized in Table 1). The TA section was the unit of analysis in the regression. We ran two models. In one, called “Attrition,” the dependent variable was the percentage of a TA’s students whose interest in a science major increased, combined with the percentage of that TA’s students who started interested in a science major and stayed interested. We excluded from both models the portion of students who started disinterested in science and stayed disinterested in science (13% of the total). For statistically significant factors, qualitative comments are presented to illustrate how students attributed these factors to their TAs.

APPENDIX 1

Appendix one contains the online survey distributed to undergraduates in December 2003 and January 2004.

Survey of student decisions about science majors or careers

Please answer the following questions about your experience as a student in [course] in the 2003 fall term. The survey will take less than five minutes and all individuals’ answers will be confidential.

1. Please indicate your agreement with the following statements (choices range from “definitely not” to “definitely so”):
   a. Before the fall 2003 term, I planned to major in science, engineering, or math.
   b. After the winter 2004 term, I plan to continue enrolling in science, engineering, or math courses.
   c. Before the fall 2003 term, I planned to pursue a career in a health field (such as medicine or nursing).
   d. Before the fall 2003 term, I planned to pursue a health field.
   e. After the winter 2004 term, I plan to enroll in a science, engineering, or math course.
   f. After the winter 2004 term, I plan to continue enrolling in science, engineering, or math courses.

2. How have the following factors influenced your choice of major and/or career? (choices were, “decreased my interest in science,” “no influence,” and “increased my interest in science”):
   a. The professor for this science course
   b. The graduate student instructor (TA) for this course
   c. The environment or climate of the lecture for this course
   d. The environment or climate of this lab section
   e. My grade in this science course
   f. My grades in math
   g. Learning more about a career or major outside of science
   h. Other (please specify)

3. If your TA increased or decreased your interest in a science career or major, please explain why.

4. Any other comments?
Results
Encouragingly, the vast majority of students reported that their plans to major in science actually became more likely over the course of the term. Less than 12% of students reported a decreased interest in their decisions to be science majors (Table 1).

In regression models using TA section as the unit of analysis, there was only one statistically significant factor associated with both retention and attrition: lab climate (Table 2). Students' comments revealed that for them, lab climate encompassed a number of elements, including enthusiasm of the TA, their own anxiety levels, and how welcome they felt in the class. The comments below are typical examples of what students had to say about lab climate.

*The TA’s ability to make the lab atmosphere fun...definitely made doing the labs a lot easier. Furthermore, his cool attitude made it a lot easier to listen to what needed to be done, making the learning process more effective. [It increased my interest in doing a science major. (Asian male sophomore, course grade=A)*

*The lab environment was very stressful, and I often found myself frustrated and confused. This environment definitely decreased my interest in furthering a science career. (female first-year student, race unknown, course grade=B)*

Students indicated that a TA's efforts to make the lab atmosphere a positive learning environment enhanced the learning

| TABLE 1 |
|-----------------|-----------------|-----------------|-----------------|
| **Variables used in multiple linear regression modeling for TA-level analysis.** | | | |
| | **Dependent variables** | | |
| Retention score: Percentage of TA’s students moving toward, or remaining in, science | Min=0.0% | Max=100.0% | Mean=75.1% | S.D.=20.2% |
| Attrition score: Percentage of TA’s students moving away from science | Min=0.0% | Max=100.0% | Mean=11.9% | S.D.=13.6% |
| **Independent variables** | | | |
| TA characteristics | | | |
| Sex | Female: | 52 (46.0%) | Male: | 61 (54.0%) |
| Race/ethnicity | White: | 64 (56.6%) | All ID’d others: | 47 (41.6%) |
| Primary language of undergraduate education | Non-English: | 33 (29.2%) | English: | 80 (70.8%) |
| Is the TA a first-term grad student? | Yes: | 53 (46.9%) | No: | 60 (53.1%) |
| Is this this TA’s first term as a TA? | Yes: | 76 (67.3%) | No: | 37 (32.7%) |
| *TA training prepared me well; 5 pt. scale, 5=strongly agree* | Min=1 | Max=5 | Mean=3.46 | S.D.=0.91 |
| *I plan to pursue a faculty position; 5 pt. scale, 5=strongly agree* | Min=1 | Max=5 | Mean=3.22 | S.D.=1.15 |
| Student opinions of TA | | | |
| End-of-term course evaluation question: “Overall, this TA was an excellent instructor.” (TA’s average rank, 5 pt. scale, 5=best score) | Min=2.20 | Max=4.91 | Mean=3.99 | S.D.=0.63 |
| Did the TA influence your interest in STEM? (TA’s average rank, 3 pt. scale, 3=increased interest, 1=decreased) | Min=1.00 | Max=2.80 | Mean=2.06 | S.D.=0.27 |
| Non-TA factors—Averages for students in a TA’s class | | | |
| Did the professor influence your interest in STEM? (3 pt. scale, 3=increased, 1=decreased) | Min=1.20 | Max=3.00 | Mean=2.12 | S.D.=0.25 |
| Did course grade influence your interest in STEM? (3 pt. scale, 3=increased, 1=decreased) | Min=1.00 | Max=2.67 | Mean=1.91 | S.D.=0.25 |
| Did learning of other careers influence your interest in STEM? (3 pt. scale, 3=increased, 1=decreased) | Min=1.33 | Max=2.57 | Mean=2.17 | S.D.=0.16 |
| Subject and section characteristics | | | |
| How hard is the course this TA taught? (Proxy: average student grade, 4 pt. scale with 4.0 being the highest) | Min=1.87 | Max=3.54 | Mean=3.15 | S.D.=0.21 |

26 JOURNAL OF COLLEGE SCIENCE TEACHING
process and drew them to science majors. However, students who perceived a stressful and frustrating lab environment reported a decreased interest in science.

One additional factor was statistically associated with retention: math grades (Table 2). Students who commented positively on their mathematics grades indicated that they performed well in the science class and were more interested in staying in science.

My calculus TA increased my interest because he was very encouraging and motivating. Overall, my math and science classes went pretty well. (white female first-year student, course grade=A)

Three other MLR factors were not significant at the 0.05 level, but approached significance in their association with retention. They were: grade in the course, learning about other careers, and students' rating of the TA on end-of-term evaluations.

**Grade in the course**

Students' positive comments about their course grades highlighted success with difficult course material, emphasized by positive feedback and course grades that students felt were a fair reflection of their learning.

**My TA's positive response to my lab reports encouraged me to continue pursuing a career in science research.** (Asian female sophomore, course grade=A+)

Students' negative comments about their course focused on three themes. First, some students reported that they struggled with the course material and found it too difficult; they often interpreted this difficulty as evidence that they did not belong in science.

Although I struggled with this class greatly, I very much enjoyed it as I love [the discipline]. However, my seeming incapability to understand it has rendered it impossible for

### TABLE 2

Factors associated with TA's retention score (Model A) and attrition score (Model B): Summary of multiple linear regression results.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Model A: Retention¹</th>
<th>Model B: Attrition²</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA characteristics</td>
<td>Beta</td>
<td>SE</td>
</tr>
<tr>
<td>TA's sex (female)</td>
<td>.002</td>
<td>.040</td>
</tr>
<tr>
<td>TA's race/ethnicity (all others)</td>
<td>.018</td>
<td>.048</td>
</tr>
<tr>
<td>TA's primary language of undergraduate education (Non-English)</td>
<td>-.058</td>
<td>.058</td>
</tr>
<tr>
<td>Is the TA a first-term graduate student? (yes)</td>
<td>-.077</td>
<td>.042</td>
</tr>
<tr>
<td>Is this the TA's first term as a TA? (yes)</td>
<td>.091</td>
<td>.045</td>
</tr>
<tr>
<td>&quot;This TA was an excellent instructor&quot; rating from students</td>
<td>-.262</td>
<td>.042</td>
</tr>
<tr>
<td>&quot;My TA training prepared me well&quot; rating by TA</td>
<td>.086</td>
<td>.024</td>
</tr>
<tr>
<td>&quot;I plan to pursue a faculty position&quot; rating by TA</td>
<td>-.037</td>
<td>.019</td>
</tr>
</tbody>
</table>

What non-TA factors influence student interest in a science major?

<table>
<thead>
<tr>
<th>Factor</th>
<th>Beta</th>
<th>SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA influences interest</td>
<td>.026</td>
<td>.124</td>
<td>.873</td>
</tr>
<tr>
<td>Professor influences interest</td>
<td>-.097</td>
<td>.126</td>
<td>.534</td>
</tr>
<tr>
<td>Lecture climate influences interest</td>
<td>-.140</td>
<td>.169</td>
<td>.407</td>
</tr>
<tr>
<td>Lab climate influences interest</td>
<td>.368</td>
<td>.127</td>
<td>.026*</td>
</tr>
<tr>
<td>Course grade influences interest</td>
<td>.248</td>
<td>.106</td>
<td>.065†</td>
</tr>
<tr>
<td>Math grades influences interest</td>
<td>.338</td>
<td>.125</td>
<td>.009**</td>
</tr>
<tr>
<td>Learning of other careers influences interest</td>
<td>.188</td>
<td>.130</td>
<td>.076†</td>
</tr>
</tbody>
</table>

Subject and section characteristics

<table>
<thead>
<tr>
<th>Factor</th>
<th>Beta</th>
<th>SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>How hard is the course this TA taught? (average student grade) (avg. student grade)</td>
<td>.164</td>
<td>.134</td>
<td>.243</td>
</tr>
<tr>
<td>Chemistry course? (yes)</td>
<td>-.009</td>
<td>.058</td>
<td>.953</td>
</tr>
<tr>
<td>Physics course? (yes)</td>
<td>.171</td>
<td>.073</td>
<td>.302</td>
</tr>
</tbody>
</table>

1 Positive beta indicates increasing retention, negative indicates decreasing retention.
2 Likewise, positive beta indicates increasing attrition, negative indicates decreasing attrition.
3 Biology course is the excluded category.

R² = .451 Adj.R² = .304
R² = .302 Adj.R² = .115

³ p < 0.10  * p < 0.05  ** p < 0.01
me to major in [it], sadly enough. (female first-year student, race unknown, course grade=B+)

Second, other students reflected on the grading climate, commenting on the stressful nature of an instructor's expectations, the course curve, or the lack of encouragement.

Although I do not wish for the university to lower their standards for students, [the course], along with most of the other science courses offered at the university, can be the most discouraging and unmotivating courses offered. I realize this class is a weeder class and it definitely shows! (white female sophomore, course grade=A+)

Finally, a third group of students pointed to dissatisfaction over the grading process due to unclear assessment standards.

I felt that the TA should give you at least an idea of how you're doing in the class before you receive your grade. ... They should at least give you an idea or talk with you on how they feel you can improve your lab reports rather than just returning them with no notes or comments or anything. (Hispanic female sophomore, race=C, course grade=B+)

Learning about careers
Students who learned of summer opportunities, internships, and the flexibility of career choices reported that they were more likely to pursue a career in the sciences. We should note that the corresponding question on the survey actually addressed learning about careers outside of science, but student comments clearly indicated that learning about careers within science was important too.

The class increased my interest in working in a laboratory environment and finding out what it's really like to run your own experiments. (African-American female sophomore, course grade=A+)

Students' end-of-term rating of their TA
Surprisingly, TAs who received high end-of-term course evaluations from students were more likely to have lower levels of student retention than TAs with low evaluations (though the differences are not statistically significant). The reasons for this trend are unclear.

None of the MLR factors associated with TA demographic characteristics had a significant effect on the model. Neither TA gender, race, English language training, or experience appears to significantly impact student choices about major. Likewise, course difficulty (as measured by average student GPA across the course) had no impact on student plans.

Discussion
Seymour and Hewitt (1997) report that undergraduates do not identify their TAs as a reason for switching majors. Our findings are similar to theirs in that undergraduates do not attribute the TA as a major cause of their change in plans for a science major. However, undergraduates in our study did identify a number of factors that educators know are affected by science TAs: most importantly, the lab climate, but also course grades, and learning about careers. Similarly, math grade was important for retention, although it is a factor more within the domain of math instructors.

Training and mentoring TAs to aid science retention
Although science TAs were not directly implicated as a factor in students' academic planning, they likely influence those factors which were found to be significant, most notably, lab climate, learning about other careers, and aspects of course grades. If TAs could positively influence these factors, then they could conceivably have a dramatic influence on students' plans to stay in or leave the sciences. How can we better train and support TAs? We make the following recommendations for science TA training programs:

1. Sessions on issues of retention
We recommend that TA training programs enlist novice TAs in discussions of best practices for retention. The authors of this study were able to find only one paper directly addressing TA training for retention (Bolgiano and Horton 1993). While not specifically aimed at science disciplines, and not directly assessed, the one-hour retention training program described in the paper was viewed positively by TAs. Following from the example presented by Bolgiano and Horton, training on retention for science TAs might include presentations on science retention data from their own institution, presentations of national retention figures and disparities, discussions of the undergraduate experiences of the TAs in training, and case studies on why students leave and why they stay.

2. Sessions on the role of the TA in fostering a positive lab climate
Pearson (1991); Galvin (1991); and Cano, Jones, and Chism (1991, pgs. 87-94) describe a number of best practices for TAs seeking to create a classroom climate that is inclusive and supportive for all students, regardless of gender, race/ethnicity, or background. Science TA training programs should include discussions of lab climate, the best use of lab groups, the experiences of underrepresented students in the lab, and how to handle domineering and uncooperative students.

3. Sessions and readings on the role of the TA in modeling possible science careers
Visible connections to the real world and potential careers appear to be an important hook for students in introductory courses. TAs can be excellent role models of possible careers in science fields. TA training programs should involve discussions of what influenced the TAs themselves to enter science, what resources exist to guide students in career choices, and how to talk about alternative careers in science with their students. Another possibility is to have TAs occasionally teach the lecture class, not just the discussion
section or lab. Guest lectures give the TA some experience in the lecture environment, and allow them to show students their own research and experiences as scientists (Gaither 1994).

4. Sessions and readings on making explicit grading standards and procedures and communicating to students how they are doing in the course

While TAs often do not control the grading policies of a course, they often have some discretion in how they grade individual assignments. At the very least, TAs control how students are made aware of and comfortable with those policies. Student comments revealed that by explicitly discussing expectations for the course and individual assignments, TAs can eliminate much of the uncertainty that causes grade anxiety.

Finally, we would like to note that TA training should not be viewed simply as basic training designed to get TAs through their first term of graduate teaching. In order for training to transfer to classroom practice, it is likely that continual follow-up, practice, mentoring, and advanced training is necessary (Notarianni-Girard 1999; Shannon, Twale, and Moore 1998). Therefore, TA trainers and faculty developers should consider ongoing mentoring and training throughout a TA’s career. We also note that the principles discussed should be equally useful for faculty managing large introductory courses with TAs. Weekly course meetings represent an ideal venue to train TAs to retain science students.


Tobias, S. 1990. They’re not dumb, they’re different: Stalking the second tier. Tucson, AZ: Research Corporation.


References


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