Who Is Responsible for Preparing Science Teachers?

Valerie Otero,1* Noah Finkelstein,2 Richard McCray,2 Steven Pollock2

At the University of Colorado at Boulder, involving students in the transformation of science courses raises the visibility of science teaching as a career and produces K–12 teachers well-versed in science.

Teachers knowledgeable in both science and pedagogy are critical for successful math and science education in primary and secondary schools. However, at U.S. universities, too many undergraduates are not learning the science (1–3), and our highest performing students are choosing fields other than teaching (4). With a few exceptions [such as (5, 6)], universities convey that teaching kindergarten to 12th grade (K–12) is not a career worthy of a talented student (7). Two out of three high school physics teachers have neither a major nor a minor in the discipline (8), and the greatest teacher shortages are in math, physics, and chemistry. The shortages of teachers with these majors have likely contributed to the poor current outcomes (9) for math and science education [supporting online material (SOM) text].

The first of four recommendations by the National Academies for ensuring American competitiveness in the 21st century was to “increase America’s talent pool by vastly improving K–12 science and mathematics education” (9). Teacher preparation is not solely the responsibility of schools of education. Content knowledge is one of the main factors positively correlated with teacher quality (10), yet the science faculty members directly responsible for teaching undergraduate science are rarely involved in teacher recruitment and preparation.

The Learning Assistant Model

At the University of Colorado (CU) at Boulder, we have developed a program that engages both science and education faculty in addressing national challenges in education. Undergraduate learning assistants are hired to assist science faculty in making their courses student centered, interactive, and collaborative—factors that have been shown to improve student performance (1–3). The program also recruits these learning assistants to become K–12 teachers. Thus, efforts to improve undergraduate education are integrated with efforts to recruit and prepare future K–12 science teachers.

Since the program began in 2003, we have transformed 21 courses (table S1) with the participation of 28 science and math faculty members, 4 education faculty members, and 125 learning assistants. The learning assistants support and sustain course transformation—characterized by actively engaged learning processes—by facilitating collaboration in the large-enrollment science courses (fig. S1). The program also increases the teacher-to-student ratio by a factor of 2 to 3 (SOM text). Without learning assistant participation, such courses tend to be dominated by the lecture format. Faculty members new to course transformation are supported by faculty that have experience working with learning assistants (SOM text).

About 50 learning assistants have been hired each semester for courses in six departments: physics; astrophysical and planetary sciences; molecular, cellular, and developmental biology (MCD biology); applied mathematics; chemistry; and geological sciences. The learning assistants are selected through an application and interview process according to three criteria: (i) high performance as students in the course; (ii) interpersonal and leadership skills; and (iii) evidence of interest in teaching. Learning assistants participate as early as the second semester of freshman year and as late as senior year. Learning assistants differ from traditional teaching assistants (TAs) in that learning assistants receive preparation and support for facilitating collaborative learning.

Learning assistants receive a modest stipend for working 10 hours per week in three aspects of course transformation. First, learning assistants lead learning teams of 4 to 20 students that meet at least once per week. Learning assistant–led learning teams work on collaborative activities ranging from group problem-solving with real astronomical data to inquiry-based physics activities. Second, learning assistants meet weekly with the faculty instructor to plan for the upcoming week, to reflect on the previous week, and to provide feedback on the transformation process. Finally, learning assistants are required to take a course on Mathematics and Science Education that complements their teaching experiences. In this course, co-taught by a faculty member from the School of Education and a K–12 teacher, learning assistants reflect on their own teaching, evaluate the transformations of courses, and investigate practical techniques and learning theory (SOM text).

Through the collective experiences of teaching as a learning assistant, instructional planning with a science faculty member, and working with education faculty, learning assistants develop pedagogical content knowledge, which is characteristic of effective teachers (11). The skills that learning assistants develop are valuable for teaching at all levels and in many environments. Those learning assistants who consider K–12 teaching as a career are encouraged to continue and are eligible for NSF-funded Noyce Teaching Fellowships (fig. S2).

Results of the Learning Assistant Program

The learning assistant program has successfully increased the number and quality of future science teachers, improved student understanding of science content, and engaged a broad range of science faculty in course transformation and teacher education.

To date, 125 math and science majors have participated as learning assistants and 18 of

<table>
<thead>
<tr>
<th>Undergraduates enrolled in science teacher certification programs</th>
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<tr>
<td>Physics and astrophysics</td>
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<tr>
<td>MCD biology</td>
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<td>Chemistry</td>
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<td>Geoscience</td>
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More students enticed into teaching. The learning assistant (LA) program at CU Boulder improved recruitment of undergraduate students into K–12 teacher certification programs relative to the undergraduate recruitment rates noted for 2004 to 2005 without the learning assistant program. Chemistry and geoscience joined the program in 2006, and so have not yet recruited students into teaching certification programs. N.A., not applicable.
them (6 math and 12 science) have joined teacher certification programs. These learning assistants have an average cumulative grade point average (GPA) of 3.4, higher than the typi-
cal 2.9 GPA for math and science majors who express interest in teaching (12). In physics at 
CU Boulder, the average GPA for majors is 3.0, and it is 3.75 for learning assistants.

The learning assistant program improved recruitment rates to science teacher certification
programs over preexisting rates (see table on page 445). Before the learning assistant
program, about two students per year from our targeted science majors enrolled in certifica-
tion programs. Nationwide, about 300 physics majors each year are certified to teach (13).
Thus, even small improvements in recruitment rates could have an impact on the pool of avail-
able teachers, particularly in the state of

Learning assistants improve student learning.
Pretest and posttest FMCE results for CU students in
a transformed course with learning assistants. The
pretest median is 24% (±1%) (n = 467); the
posttest median is 85% (±1%) (n = 399). Arrows
indicate posttest average (mean) scores for (a)
students nationwide in traditional courses with pretest
scores matching those of CU students, (b) students
in a CU course that features educational reforms but
no learning assistants, and (c) students in the CU
course transformed with learning assistants (arrow
shows the mean of the brown bars).

Colorado (14). Most of the learning assistants
who decided to become teachers report that
they had not explored teaching as a career until
participating as learning assistants. Factors
that led to decisions to become teachers include
recognition of teaching as intellectually
challenging and positive attitudes among
participating faculty (7).

Development of Content Knowledge
Each of the participating departments demonstra-
tes improved student achievement as a
result of the learning assistant program
(15–17). The transformation of the introdzc-
tory calculus-based physics sequence provides
an example. These courses are large (500 to 600
students), with three lectures per week imple-
menting peer instruction and personal response
systems (17, 18). The learning assistant pro-
gram has provided enough staff to implement
student-centered tutorials with small-group
activities (19). Learning assistants and TAs
train together weekly to circulate among stu-
dent groups and ask guiding questions. The
number of applicants for learning assistant
positions in physics is currently 50 to 60 per
term for 15 to 20 positions.

We assessed student learning with the Force
and Motion Concept Evaluation (FMCE) (20)
and the Brief Electricity and Magnetism
Assessment (BEMA) (21). In transformed
courses, students had an average normalized
improvement of 66% (±2% SEM) for the FMCE
test (see chart, left), nearly triple national aver-
age gains found for traditional courses (3, 22).

With the BEMA exam, the average normalized
learning gains for students in the transformed
courses ranged from 33 to 45%. National aver-
age gains are not yet available for this new BEMA
exam. The normalized learning gains for the
learning assistants themselves average just
below 50%, with their average posttest score
exceeding average scores for incoming physics
graduates. In a different model, students
enrolled in a physics education course can opt
to participate as learning assistants for additional
credit (23). These students make gains twice that
of their peers who do not opt to participate as
learning assistants. Students who engage in
teaching also demonstrate increased understand-
ing of the nature of teaching and improved abili-
ties to reflect on their understanding of teaching
and learning (23) (table S2).

Impact on Faculty
Faculty members participating in the learning
assistant program have started to focus on educa-
tional issues not previously considered.
Faculty members report increased attention to
what and how students learn. In a study of fac-
culty response to this program, all 11 faculty
members interviewed reported that collabora-
tive work is essential, and learning assistants
are instrumental to change (7). One faculty member
notes: “I’ve taught [this course] a million times.
I could do it in my sleep without preparing a
lesson. But [now] I’m spending a lot of time
preparing lessons for [students], trying to think
‘Okay, first of all, what is the main concept that
I’m trying to get across here? What is it I want
them to go away knowing?’ Which I have to
admit, I haven’t spent a lot of time in the past
thinking about.” This type of statement is com-
mon among those who engage in course trans-
formation for the first time (SOM text).

Sustaining Successful Programs
The learning assistant model can be sustained
and modified for a variety of institutional envi-
ronegms. Another longstanding successful
model, the UTeach program at the University of
Texas (5) has demonstrated that it is possible
to internally sustain educational programs for
science majors. These and other model pro-
grams bring together partners who each have a
vested interest in increasing the number of
high-quality teachers and the number of math
and science majors, as well as improving
undergraduate courses.

Implementation of a learning assistant pro-
gram requires local interest from faculty in the
sciences and education, as well as administrative
backing and funding of a few thousand dollars per
learning assistant per year (SOM text). The cost of
a learning assistant is less than one-fifth that of a
graduate TA. Learning assistants may also receive
credit in lieu of pay. Another model is to fund
learning assistant stipends from student fees.

With collective commitment, education can be
brought to greater visibility and status, both for
students considering teaching careers and for fac-
tulty teaching these students (SOM text). As scien-
tists, we can address the critical shortfall of K–12
science teachers by improving our undergraduate
programs and supporting interest in education.

References and Notes
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Supporting Online Material
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