Physics Teacher Education Coalition
Section on Teacher Preparation

A Note From the Teacher Preparation Section Editor

Chance Hoellwarth

We know that teachers teach the way they were taught. Therefore one of the most effective ways to impact how future teachers actually teach is to change the way we teach our undergraduate courses. If we, the physics faculty, want student-centered teachers who believe that teaching is an interaction, not just the transfer of information, then we need to become more student-centered ourselves. Of course, one way to do this is to incorporate more active-learning group work activities into the classroom. Unfortunately, group work requires more supervision. Groups require feedback and sometimes they need to be nudged at the right time with the right question to keep on track. The problem is that more supervision requires more time and manpower to implement; one person can only interact with so many groups at a time. However, what if I told you that there was a magic pill that could help solve this problem and potentially recruit more K-12 science teachers at the same time? That would be amazing. And amazing as it sounds, the pill exists, only it is not really a pill, it is a learning assistant program.

Learning Assistants, or LAs, are undergraduates who help teach undergraduate courses. They are like a Teaching Assistant, but probably more like a teacher's aide, since they are in the classroom with the instructor. The details of Learning Assistant roles vary by institution, but the main idea is that Learning Assistants help instructors facilitate interactions amongst their students. To a certain degree, this helps solve the manpower problem that comes along with group work. But in addition, institutions have found that Learning Assistant Programs have increased the number of physics majors pursuing teaching careers. At first glance that may seem surprising. However, if you stop and think about it, undergraduates have a very one-sided view of teaching. Giving undergraduates a chance to play the role of teacher in a more active style of learning gives them the opportunity to see how rewarding and challenging teaching can be. This, of course, is the real draw of teaching, so it isn't really surprising that this experience is a recruiter for future teachers.

The upshot of this introduction is that a Learning Assistant Program can be a valuable recruiter for future K-12 teachers. That is what this section of the newsletter is all about. In this issue you will read about the Learning Assistant programs at the University of Colorado-Boulder, University of Arkansas-Fayetteville, and Seattle Pacific University.

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The Learning Assistant model for Teacher Education in Science and Technology

Valerie Otero

The Learning Assistant model [1, 2], at the University of Colorado at Boulder uses course transformation as a *mechanism* to achieve three related goals: (1) to recruit and improve the preparation of future mathematics and science teachers, (2) to improve the education of all students enrolled in our mathematics and science courses, and (3) to engage science faculty more thoroughly in the preparation of future teachers.

The Learning Assistant model was initially developed as a part of the STEM Colorado project headed by Richard McCray in response to studies that demonstrate that a majority of our nation's youth are not performing proficiently in mathematics and science [3, 4] that many of our teachers, especially in the physical sciences, are under prepared--having neither a major nor minor in their field, [5] and that large research universities are not producing adequate numbers of mathematics and science teachers.[6]

At large research universities, few mathematics and science majors pursue careers in K-12 teaching. Those who do, typically learn about pedagogy only after they have completed most of their content courses. There is generally little or no interaction between disciplinary faculty and education faculty and between undergraduate programs designed to teach content to students and programs designed to help future teachers learn to teach that content. We regard this disconnect between disciplinary and education programs as a missed opportunity to both improve the effectiveness of undergraduate mathematics and science education and to recruit and prepare mathematics and science K-12 teachers.

The Learning Assistant Model

The Learning Assistant model is based on the premise that teacher preparation begins in the College of Arts and Sciences, where students begin their content preparation. In order to explicitly help undergraduate students integrate their content learning with their understandings of how content is learned and to encourage talented students to become teachers, we needed to establish a close collaboration between faculty members from the School of Education and faculty members from content-based departments. This collaboration was achieved through the LA model which is designed to couple mathematics and science departments',efforts to transform large-enrollment undergraduate courses with efforts to recruit and prepare talented mathematics and science majors to become K-12 teachers.

The transformation of large-enrollment courses involves creating environments in which students can interact with one another, engage in collaborative problem solving, and articulate and defend their ideas. To accomplish this, faculty members teaching in large-enrollment courses need several assistants to help facilitate small group interaction. Learning Assistants (LAs) fill this role. LAs are talented undergraduate students who are hired to facilitate small group interaction in our large-enrollment courses, and at the same time, they make up the pool from which we recruit new K-12 teachers.

Since the program began in 2003, we have recruited 18 LAs to teacher certification programs, most of whom have reported that they did not consider teaching as a career until participating as LAs. The most common reasons reported for making the decision to become a teacher were recognizing the complexities of teaching and encouragement and support from mathematics and science faculty.

The Difference

The differences between the LA model at the University of Colorado at Boulder and other standard models for undergraduate teaching assistants are (a) our focus on teacher recruitment and preparation, (b) a special seminar targeted at helping LAs integrate content, pedagogy, and practice, (c) a collaborative educational research program designed to evaluate the effects of the LA model, and (d) the involvement of mathematics and science research faculty in the recruitment and preparation of future teachers.

Course Transformation and the Role of LAs

LAs are paid a modest stipend to work approximately 10 hours per week in various aspects of course transformation. Approximately 60 LAs are hired each semester to work in six mathematics and science departments: Physics; Astrophysical and Planetary Sciences; Molecular, Cellular and Developmental Biology; Geological Sciences; Chemistry; and Applied Mathematics. Specific courses that have been supported by LAs are listed in Table 1.

Table 1. Learning Assistant supported Courses

Department	Courses
Applied Mathematics	APPM 1350: Calculus I for Engineers APPM 1360: Calculus II for Engineers APPM 3310: Matrix Methods APPM 3570: Applied Probability GEEN 1340: Calculs I (semester 1 of a 2 semester sequence) GEEN 1345: Calculs I (semester 1 of a 2 semester sequence)
Astrophysical and Planetary Sciences	ASTR 1010: Introductory Astronomy ASTR 1120: General Astronomy Stars and Galaxies ASTR 2000: Ancient Astronomies
Chemistry	CHEM 1021: Introductory Chemistry CHEM 1111: General Chemistry CHEM 4411: Physical Chemistry/Biochemistry Applications 1
Geological Sciences	GEOL1010/1030: Introduction to Geology
Molecular, Cellular, and Developmental Biology	MCDB 1111: Biofundamentals MCDB 1041: Fundamentals of Human Genetics MCDB 2150: Principles of Genetics MCDB 4650: Developmental Biology
Physics	PHYS 1010/1020: Physics of Everyday Life I and II PHYS 1110/1120: General Physics with calculus PHYS 2130: Modern Physics for Engineers

There is no dictated design of what course transformation should look like. Instead, faculty members who request LAs must (1) use LAs to promote interaction and collaboration among students enrolled in the course, (2) meet in weekly planning sessions with the LAs who support their courses, (3) attend biweekly meetings with other faculty participating in the program, (4) attend a summer session targeted at building a community of university faculty, high school teachers, and future teachers, and (5) actively evaluate transformations and assess learning in their own courses. Because there is little dictation as to exactly what a transformed course should look like, there exist several models of course transformation among our participating departments. For example, one of two models of transformation in the physics department utilizes the University of Washington's *Tutorials in Introductory Physics* [7] in recitation sections each headed by one graduate TA and one undergraduate LA. The Tutorials involve conceptually-based group problem-solving activities which are based on research in physics education. LAs who work in *Tutorial* sessions formatively assess student understanding, ask guiding questions, and facilitate collaboration within groups. These

tutorial sessions are supplemented by weekly lectures which are made interactive through infrared response systems and collaborative peer instruction (Mazur, 1996). Average normalized learning gains in these courses, as measured by conceptual instruments such as the Force and Motion Conceptual Evaluation [8] range from 40% to over 60% [9], far above the learning gains measured for traditional courses (23%) [10].

A different model for course transformation is used in the Applied Mathematics department. In weekly LA-led problem-solving sessions, each small group of students uses a 2-ft × 3-ft dry-erase board to collaboratively construct problem solutions. A more radical form of transformation is found in the Astrophysical and Planetary Sciences department where one lecture per week is replaced by *Learning Team* sessions headed by the LAs. In this model, enrolled students are assigned to one of several learning teams each headed by an LA who facilitates collaboration among groups as they analyze real astronomical data and generate and compare models to fit these data.

Although the LA experience is somewhat different for each course, the experience for all LAs involves three related activities: (1) LAs facilitate collaboration among learning teams by formatively assessing student understanding and asking guiding questions; (2) they meet weekly with their faculty instructor to plan for the upcoming week, reflect on the previous week, and analyze assessment data; and (3) LAs from all departments attend a special *Mathematics and Science Education* seminar where they reflect on their own teaching and learning and make connections to relevant education literature.

The Mathematics and Science Education Seminar

The Mathematics and Science Education seminar is jointly conducted by a faculty member from the School of Education and a K12 teacher. In this course, new LAs reflect on their own teaching practice, reflect on the transformations of the course in which they are working, investigate relevant educational literature, and engage in in-depth discussions about their own teaching and learning. Seminar readings and discussions include topics such as discussion techniques, learning theory, cooperative learning, student epistemologies, metacognition and argumentation, self-explanations and tutoring, multiple intelligences and differentiated instruction, the nature of science and mathematics, national standards, teaching with technology, and qualities of an effective teacher. Students in this course try out new ideas each week in their learning teams and report their results in seminar. In many cases, LAs provide guidance to one another regarding managing issues that typically arise in their learning teams. Each week, LAs complete online reflections on their teaching and the learning of the students in their learning teams. In addition, throughout the semester LAs turn in two reflective essays that integrate the education literature with their own teaching and learning experiences. LAs often report that by studying and reflecting on student learning, they have become better learners themselves. At the end of each semester, LAs in the seminar present a poster session attended by their lead instructors, School of Education faculty, University of Colorado administrators, graduate students, and their peers. Each LA or small group of

LAs present a poster that focuses on aspects of the LA experience that influenced their thinking both as a learner and as a teacher.

Focus on Teacher Recruitment

Although the LA experience (represented in Figure 1) is valuable for undergraduates who continue to any career, our program is specifically designed to actively recruit talented undergraduate students to careers in teaching. Therefore, a student can continue to be an LA for a second semester only if he or she shows commitment to finding out more about teaching. This may be evidenced by taking an education course or participating in an early K-12 field experience. LAs can be hired for a third semester only if they have been accepted to a teacher certification program at which time they are eligible for NSF funded Noyce Teaching Fellowships of up to $10,000 per year. [11] As Noyce Teaching Fellows, students can become Lead LAs who mentor novice LAs, participate in the development course educational technology, or work with mathematics, science, and education faculty conducting educational research.

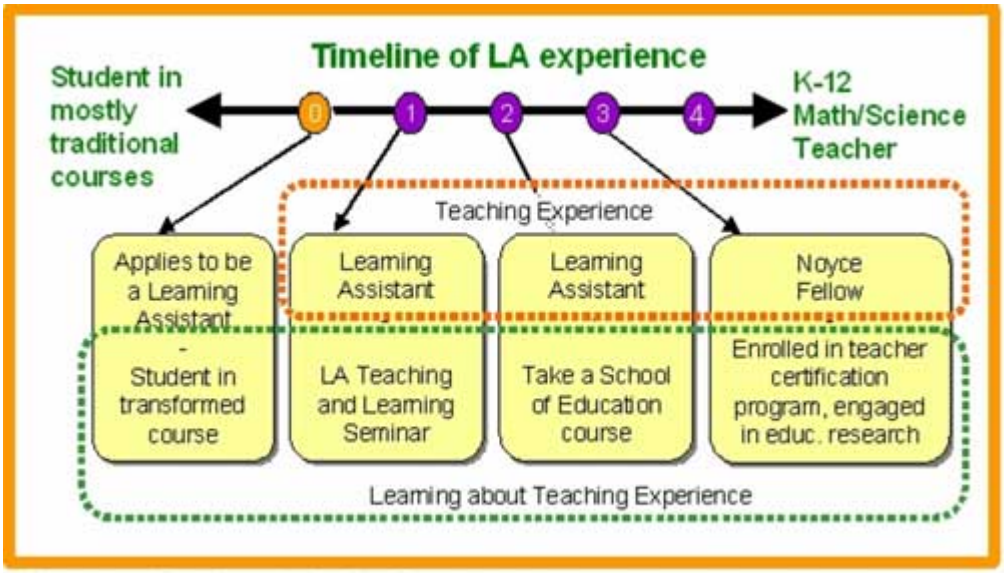

Figure 1. Timeline of the LA Experience

Faculty members who use LAs evaluate their own course transformations by systematically investigating student learning in their courses. In some cases this involves the design or modification of assessment instruments to measure students's levels of conceptual understanding of the content of the course. This type of research and development has been conducted by individual faculty members since the beginning of the STEM Colorado program in 2003. However, a coordinated research program to test the effectiveness of the LA model on multiple levels will officially begin in Fall 2006.

The LA-TEST research project

The NSF-funded Learning Assistant model for Teacher Education in Science and Technology (LA-TEST) research project [12] was designed to test the effectiveness of the LA model specifically in terms of LAs' development of content knowledge, pedagogical knowledge, and their practice in K-12 schools. Faculty members from education, mathematics, and science, K-12 teachers, graduate students, and Noyce Fellows comprise three interacting research teams: the Discipline-Based Educational Research (DBER) team, the Conceptions of Teaching and Learning (CTL) team, and the K-12 team. These interacting research teams investigate teacher recruitment rates as well as the research questions shown in table 2 and synthesize results on an ongoing basis.

Table 2. Research Questions for the LA-TEST project

DBER: Content Knowledge	CTL: Pedagogical Knowledge	K-12: Teaching Practice
(a) What effects can be observed on student achievement in courses that are supported by LAs? (b) How do LAs compare to other mathematics and science majors in terms of their content understanding, beliefs about the discipline, and beliefs about learning in the discipline?	(a) What is the effect of the LA model on the sophistication of LA pedagogical understanding? (b) Does sophistication of pedagogical understanding vary by length of exposure to the LA model? (c) How is the pedagogical sophistication of LAs different from the sophistication of non-LAs who become teachers?	How do teachers and teacher candidates who participated as LAs compare to those who did not in terms of: (a) Practicum-based coursework (b) Their teaching practices (c) Their own studentsЖ(K-12) attitudes and beliefs about mathematics and science (d) Retention and attrition rates

Preliminary Results

Recruitment

Since the program's inception in 2003, 28 faculty members from 6 mathematics and science departments have used LAs to transform 23 courses; 125 mathematics and science majors have participated as LAs (18 LAs have enrolled in teacher certification programs); and 4 education faculty have been involved in this process. LAs recruited to teacher certification programs have an average cumulative GPA of 3.4, well above the average GPAs for mathematics and science majors at our university. Table 3 compares enrollments in certification programs in the state of Colorado and enrollments at the University of Colorado at Boulder (not including LAs) to the numbers of students that

have been recruited to certification programs through the LA program. In table 3, 6 of the 7 mathematics majors recruited through the LA program are from Applied Mathematics, a discipline traditionally underrepresented in our certification programs but specifically targeted through the LA program. The departments of Chemistry and Geological Sciences joined the program in mid-2006, so it is not surprising that the LA program has not yet recruited any students from these majors.

Table 3. Undergraduate students enrolled in teacher certification programs

Major	State of Colorado* (2004-2005)	University of Colorado Boulder Not including LAs (2004-2005)	Recruited from LA Program (2004-2006)
Physics	5	1	5
Astrophysics	0	0	3
MCD Biology	0	1	3
Mathematics	162	14	7
Chemistry	14	0	0
Geosciences	11	0	0

*Data from 18 colleges and universities with 10,869 candidates, 385 science majors

These data are evidence that the LA program has some effect on recruiting mathematics and science majors to teaching careers.

Content Knowledge

LAs' content knowledge is beyond that of their peers and LAs learn content more deeply trough the LA experience. For example, results from the Brief Electricity and Magnetism Assessment [13] given to students enrolled in second semester introductory physics show average pre-test score of 27% for enrolled students and an average post-test score of 59%, with an average normalized gain of 0.44. The LAs who had taken the course the prior semester had pre-test score (the beginning of the semester of working as an LA in this course) of 75%, higher than their peers' post-test scores. More interesting is the fact that LAs' average post-test score (at the end of one semester of being an LA) was 90%, with an average normalized gain of 0.56. [14] Thus, LAs developed their content knowledge as a result of teaching as an LA. Similar results are being found in other LA-supported courses and this is the subject of ongoing research.

Pedagogical Knowledge

LAs tend to view their students in terms of their students' *learning processes* rather than in terms of whether a student is good or bad or whether they do or do not understand the material. Our studies show that while faculty and teacher candidates tended to view students in terms of the learning process they also viewed their students in terms of whether the students do or do not understand, and in terms of whether they are good, bad, lazy, smart or dumb. Results are summarized in the table 4 below.

Table 4. Views of students by faculty, teacher candidates, and LAs

View of Students	Specific statements indicating view	Faculty (% of codes)	Candidates (% of codes)	LAs (% of codes)
Learning Process	Students are trying to learn, are constructing understandings, must articulate/defend ideas	39	39	81
Condition of Student	Students want to learn/do not want learn, get it or they donŢ, have misconceptions	30	61	17
Property of Student	Students are smart/dumb, good/medium/bad, have/do not have ability, lazy/do least they can	30	0	2

The results shown in table 4 may indicate that LAs have a greater sensitivity to the struggles of learning mathematics and science among their peers. This may be an indication that there is great value in beginning the teacher preparation process early in students' undergraduate careers rather than waiting until they have decided to become teachers of students who are much younger and more inexperienced than themselves.

Summary

The LA model integrates the development of content knowledge, pedagogical knowledge, and practice for all participants by beginning the teacher preparation process early in students' undergraduate careers and by involving mathematics and science faculty in this process. Although we recruit approximately 15% of the LAs who participate in this program to teacher certification programs, the experience is valuable for students who move on to any career. The participation of mathematics and science research faculty in the active recruitment of teachers has led to departmental cultures that encourage rather than discourage teaching as a legitimate and valuable career option for our most talented mathematics and science students.

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Undergraduate Learning Assistants at the University of Arkansas:
Formal classroom experience, preparation for a variety of professional needs

Gay Stewart

Undergraduate Learning Assistants (LA) have been a valuable addition to the physics program at University of Arkansas. Learning assistants have improved our instruction, involved more faculty in teacher preparation issues, and attracted more people into physics teaching. When we embarked upon an NSF supported curriculum development project, it became clear that the first and greatest need for sustaining educational reform was for our future faculty to be prepared to be as professional about their roles as educators as their roles as researchers. Our focus at first was to add these kinds of activities to the graduate program, with the same sort of mentoring that accompanies the development of research skills, without extending the time needed to complete a degree. Our undergraduates going to graduate school said that they would like some of this same support. This led us to pursue undergraduate involvement in the program. The results of bringing these talented and highly motivated undergraduate students into a teaching apprenticeship have been wonderful for the undergraduates and their students! (We added more detailed information on some of the official coursework to the catalog to support the program. This is available at http://www.uark.edu/depts/physinfo/pfpf/pfpf.html. Choose the "resources" link from the page.)

Our learning assistants get course credit, not pay. It had to be something we could implement without added cost. The most common course taken is PHYS 400V---Lab and Classroom Practices in Physics. It can be tailored for anywhere from one to three credit hours. One hour would be spent doing the readings and participating in discussion. Sometimes a student will simply observe teaching, planning on doing the actual teaching the following semester. The discussions focus on the pedagogy and the presentation of curricular materials used in class. Laboratory and demonstration techniques illustrating fundamental concepts are acquired through participation in the classroom as an apprentice teacher. Weekly readings are from physics education research literature. The classroom time gives experience in using classroom methods that are measurably effective in promoting student learning. The course is tailored on an individual basis for the undergraduate students. Typical topics covered include preparation for classroom presentations, testing and grading, addressing student alternative conceptions, effective use of classroom demonstrations and interactive classroom techniques.

For three hours of credit, a student would participate in the same pre-semester activities as the incoming graduate students, four full-day meetings on topics essential to classroom experience, with 10-25 pages of reading per day. For the remainder of the semester, a

one-hour meeting each week is used to discuss the week's reading (20-25 pages). Then, they take primary responsibility for teaching their own lab-practicum session. Their performance in class is observed. In the beginning, observations are used to provide feedback. The results of the observations as the semester progresses do factor in to the course grade. This full workshop is only held in the fall at our institution, so it takes careful planning on the part of the advisers to make sure students who may want to take the course in the spring have the opportunity to participate. Graduate teaching assistants coming into our institution in the spring semester are not allowed to teach in one of the reformed courses unless they have already had this or similar extensive preparation. For those students, the preparation workshop takes place the following fall. Our institution has a number of upper-division lab-based courses that require grading and technical support, giving us appropriate alternative assignments.

It is best if the faculty member supervising the PHYS 400V internship is actually teaching the course of which the internship is a part, or working in close collaboration with the instructor of the course. Then, much of the discussion of pedagogical issues associated with the teaching internship is covered in the weekly teaching assistant preparatory meetings for the course. Preparing for and holding the weekly meeting to discuss the readings does add a time commitment to the supervising faculty member. At some institutions instruction for this course, which sometimes has as many as five undergraduates, could count as part of the teaching load. A small "cheat" is to only officially offer the course in the spring semester, whether the students do their internship in the fall or the spring, allowing the enrollment to be large enough to count as a class. At UA this is still impractical, as small (<14) classes for undergraduates are recognized as service, and not counted toward the teaching load. However, this is in part made up for by the fact that the graduate student, who would normally teach the lab being used for course credit by the undergraduate, can spend that time primarily grading or proofreading course materials. The TA is available as needed for the LA, but relieves some of the grading load associated with the course on the instructor. Our experience is that very early on, the TA often feels unnecessary in the course, as the LAs bring so much enthusiasm, and often talent!

Some LAs have asked for the opportunity to take the instructor role in one of our two big weekly discussion sessions that go with the course (officially, they are lectures). We choose a topic several weeks in advance. They bring in their discussion outline, reading quiz questions, end of class summary quiz questions, and examples for review at least a week in advance. The careful preparation that has gone into these in every case is amazing. My own course notes contain several cases of such student work. Then, the instructor sits in on the student's lesson, to provide assistance if needed, but to allow an opportunity for helpful discussion afterwards to allow the student to become an even better instructor. This is amazingly useful if it can be scheduled for a day following a trip or proposal deadline for the instructor, when he or she would be less than at best anyway.

Sometimes our undergrads who get truly serious about teaching will take a graduate level course: Internship in College or University Teaching, PHYS 574V. The internship is a

supervised experience in an organizational setting for students interested in education. We consider the internship as an important part of the preparation of a competent professional in the field. Research clearly shows that learning a subject does not adequately prepare one to teach it. Our learning assistants get excellent teaching evaluations from their students. They also often report a significant improvement in their own understanding of the material they are presenting.

Students who go on to graduate programs at other institutions often communicate with us about their teaching assignments, and how much more effective they feel they can be based on their experiences in such a supportive atmosphere. Students who have done this internship and gone on to graduate school have been successful in their studies. Some students, including a few engineers, decided that the teaching was what most interested them, and this has been a rich pool for recruiting future high school teachers.

While the mentoring associated with such an endeavor is not trivial, it is well worth it to a department and an institution (and, frankly beyond that!) These students go out into whatever career they are going to pursue with a much better appreciation of how to communicate science. It is easy as a faculty member to forget just how far out we are on the tail of the normal distribution academically, and that most students don't think like we do. Building the awareness of how to successfully facilitate learning is vitally important if we are going to improve teacher preparation, impacting not just the preparation of the future teachers, but the future teachers of teachers!

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Creating and Sustaining a Teaching and Learning Professional Community at Seattle Pacific University

Lane Seeley and Stamatis Vokos

I. Introduction

It is sometimes remarked that the modern university is a collection of independent departments united by a common physical plant. The Physics Department at Seattle Pacific University views this state of affairs as an unfortunate symptom of specialization rather than a desired feature of academic life. An authentic collaboration between a university's Physics Department and School or College of Education, enriched through close ties with partner school districts, can align all major forces that feed (or starve) the professional trajectory of a science teacher. Putting together and sustaining such collaboration is inevitably time-consuming. Yet, the rewards for the Physics Department can be great as can be the positive impact on the continuum of science teacher preparation and enhancement. This article outlines two facets of collaboration at Seattle Pacific University-among faculty (physics and education) and among students (physics majors, minors, non-majors, and preservice teachers). Due to lack of space, this article does not address a third important area of collaboration, namely among teaching professionals (preservice and inservice teachers, school administrators, and university faculty (including resident master teachers)).

II. Collaboration Among Faculty

In 2002, the most senior member of the Physics Department had been at SPU for four years. In 2003, the Department was awarded a NSF CCLI (Course, Curriculum and Laboratory Improvement) grant, *Adapting and Implementing Research-Based Curricula in Introductory Physics Courses at Seattle Pacific University*. This grant has supported a complete restructuring of all introductory physics courses at SPU, both calculus- and algebra-based. We have integrated elements from exemplary research-based curricula, including *Tutorials in Introductory Physics* (Physics Education Group, University of Washington), *Activity-based Physics* (Physics Education Research Group, University of Maryland) and *Real Time Physics* (University of Oregon, Tufts University, and Dickinson College).

This adaptation process has resulted in significant gains in student understanding on several measures. The fractional increase in student learning gains on national assessment instruments such as FCI, FMCE and CSEM is between 50% and 80%. Similarly, analysis of student performance on dozens of written research-based questions given before and after special instruction suggests strong improvement in student learning in several topical areas. Such fine analysis has also suggested topics with which students still

struggle after instruction and modifications to the curricular materials that are necessary for a better match with our students's needs.

In addition to gains in conceptual understanding our curricular renovation has dramatically impacted the learning environment in our introductory classes. Students are now expected to take an active role in every aspect of their learning process. A majority of class time is devoted to small group activities in which the students work closely with peers and instructors to construct and test models and wrestle with new ideas. In this context students are forced to practice articulating scientific ideas and listening critically to the ideas of their peers.

Ongoing collaboration among all physics faculty has been a crucial ingredient of the program. In an environment in which individual faculty members have the freedom to structure their classes in almost any way they wish, agreement on the goals of each course and the common ways to work toward these goals have by now created positive student expectations about all introductory physics courses at SPU. A telling sign is that by the end of the first quarter of each three-quarter sequence the overwhelming majority of students consider the research-based materials as an indispensable part of their learning experience in physics.

Very early in the planning process for adopting new curricular approaches, Department members invited science education faculty to contribute to the design of a new learning environment in physics. Those initial discussions helped to establish the Physics Department as a credible voice on teaching and learning on campus. Since that time physics and education have developed a substantial collaboration, at a scale that is unequaled in Washington State.

The collaboration between Physics and Education spawned successful grant requests to private foundations. As a result SPU received ongoing funding to partially support a Resident Master Teacher who plays a pivotal role in guiding the Department's ongoing efforts in teacher education and enhancement and who now serves as a Teacher-In-Residence for our participation in PhysTEC. Working on grant-funded projects only deepened the collaboration among the disciplines. In 2005, the Physics Department leveraged this close working relationship with Education to secure a major additional NSF grant. In four years, the Department went from offering zero professional development opportunities for teachers to now offering professional development for teachers in several partner school districts, including several hundred K-8 teachers in south-central Washington.

This Departmental climate of collaboration (both within and outside) did not escape the attention of the central administration. Within a few years, the Department was awarded (a) a new tenure-track faculty position when the science education position in the School of Education was vacated due to retirement and (b) a University-funded postdoctoral position to help new PhDs become immersed in results of research on the learning and teaching of physics so as to have a future impact on Christian higher education. Physics

faculty were also invited twice to present to the Universityx Board of Trustees results of the Departmental efforts to improve student learning. Such results were also presented at a retreat on assessment of student learning for all SPU faculty and figure prominently in the University's national communications campaign. Collaboration among faculty (physics and education) is the centerpiece of these efforts.

III. Collaboration Among Students

Restructuring our curriculum to increase student engagement brought with it a significant challenge: the need to decrease the student to instructor ratio. The solution of this problem provided an ideal context for recruiting students for future teaching careers.

The single biggest obstacle to small group learning at the college level is the intensive instructor time that is required. Each one of the curricula that we adopted is designed to be most effective with a student to instructor ratio of no more than 10:1. We have addressed this challenge by leveraging the collective talents of our students. In the first year of implementation of the new instructional approach we made do with a suboptimal number of Teaching Assistants who were prospective teachers enrolled in the MAT program at SPU. We quickly recognized that despite our best intentions, the whole program would sink or swim on the shoulders of our Teaching Assistants. Since SPU does not have yet a graduate program in physics, we have been utilizing undergraduates who (a) have participated in the reformed courses and (b) have shown a special willingness to help others understand the material. Since those early attempts, we have been developing a cadre of Learning Assistants (LAs), who are the true core of the physics program at SPU.

Our LAs serve, alongside the course instructor, as facilitators of guided small group learning. LAs receive either credit or monetary compensation for their participation. During a typical week LAs: attend one or two 80-minute preparation sessions; assist in one to three 80-minute tutorial sessions; perform up to two hours of homework grading; and read seminal articles from the physics education literature.

Our perspective toward developing a professional community among the LAs, which is intentionally centered around learning, is grounded on results from research on the nature of effective professional development of teachers (Darling-Hammond, 2000; Garet, 2001; Hawley, 2000; Kennedy, 1998; Loucks-Horsley, 2003; Mundry, 1999). Research suggests that high quality professional development programs pay attention to three things: (a) the deepening of content knowledge for teaching (Ball & McDiarmid, 1990; Kennedy, 1997; McDermott, 1990), (b) intentional development of a learning community (Borko, 2004, 1992; Grosmann, 2001), and (c) emphasis on the study of artifacts of classroom discourse.

Critical Elements of the SPU LA Program - At first glance, the LA program has many similarities to a more common 'teaching assistant' model in which senior students assist

the introductory students with their use of laboratory equipment. We believe it is important to recognize that the role of LAs is different in a number of critical ways:

> LAs are explicitly trained in the pedagogical techniques they are expected to utilize. They are taught to recognize and elicit student difficulties and guide students in the development of their own working understanding through a process of progressive questioning. Instructors model teaching through questioning during preparation sessions in which LAs work through the materials as learners. Special emphasis is given to specific prevalent and problematic student ideas during these training sessions.
>
> The curriculum used in our program is very different from standard laboratory curriculum both in methodology and objectives. Each of these curricula focuses primarily on building conceptual understanding rather than measurement techniques. Where a traditional lab TA provides an available reference for students and a source of technical expertise, an effective LA must fully engage the students and guide their learning trajectory.

SPU LA Program Attributes - Student gains on standardized assessment instruments attest to the impact of our LA program on student learning. We also have accumulated qualitative evidence that the LA program is having a significant positive impact on the LAs themselves. The most obvious measure is the popularity of the program. In 2002, we had one peer instructor. This past fall we had 21 students attend an organizational meeting for the program! This was a substantially greater number of LAs than we needed (or could accommodate easily) but we included all interested students because we came to realize that this opportunity is an important piece of the undergraduate education of all students who cross our department doors and a wonderful recruiting tool, both for the physics major and a career in science teaching.

Despite the fact that serving as an LA is difficult work and can be intimidating, students seek out these roles because they have come to embrace inquiry-based instruction and they want to participate in this style of discourse both as learners and instructors. LAs also clearly view the experience as a way to further deepen their understanding. In fact, we have had a significant number of pre-med students serve as LAs in part because they see it as a good way to prepare for the MCAT. LAs overwhelmingly express what many professors have come to recognize, "I never really get these concepts until I need to help someone else understand them."

We believe that the LA program allows us to structure our introductory courses in a way that is more accessible to students who have a strong aptitude for teaching but might not immediately gravitate toward a physics major. Small group activities increase the participation level of students who are careful, reflective thinkers rather than quick problem solvers. In addition, group learning rewards talents that are not often recognized in standard lecture courses such as critically listening to peers and carefully articulating

scientific ideas. These skills are important in many vocational pursuits and obviously crucial to effective teaching.

It is important to note that nearly half of our LAs are not physics majors. A common characteristic among our LAs is a strong interest and an apparent aptitude for teaching. We expect that the LA experience of non-majors who pursue teaching careers makes them more inclined to include physics as one of the subjects they feel prepared to teach in an effective way.

We also have strong evidence that the LA program has increased the level of interest in teaching among both physics majors and minors. Through their participation LAs come to regard teaching as an intellectually rigorous and rewarding pursuit. They recognize that content knowledge is not sufficient for teaching and have the opportunity to appreciate the roles pedagogical content knowledge and curricular content knowledge play in effective teaching. Many of our physics majors who participate in the LA program go on to undertake undergraduate research projects in curricular evaluation, adaptation and development. Recently our newly rejuvenated SPS chapter received a Marsh White Award to support outreach activities to local high schools.

Remaining Challenges - There are many challenges that must be overcome to successfully implement an LA program. These include funding, faculty participation, and course restructuring to make LAs an integral part of the learning process (not just laboratory supervisors). Strategies for overcoming these challenges may differ significantly with the size, priorities and culture of individual departments. In our case, these challenges were overcome largely thanks to the universal commitment of all members of the Physics Department and the constructive relationship and strong support of university administrators.

One challenge that we continue to confront in our LA program is the complexity of scheduling. All LAs should attend the corresponding preparation session before they teach that material in the classroom. For efficiency we hope that every time an LA attends a preparation session, she has the opportunity to teach that material at least once. With two distinct tracks of introductory physics, each with multiple sections and multiple LA-led activities each week, coordination has proven to be a big challenge! Beginning next fall we plan to begin holding preparation sessions where one faculty member will supervise several groups of students each working through distinct topics. With four of these sessions per week we expect this will lend significantly greater flexibility to our training protocol.

We have also encountered a somewhat unexpected challenge of balancing community with professionalism. On the one hand we want to encourage learning environments that are informal, relaxed, and collaborative. On the other hand, we want to call our learning assistants (many of whom are juniors) to a high degree of responsibility and professionalism. These two goals are certainly not contradictory; however, achieving both has proved to be quite challenging.

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