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A Longitudinal Study on Pedagogical Content Knowledge: Synthesizing Research on Content, Pedagogy, and Practice

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A LONGITUDINAL STUDY ON PEDAGOGICAL CONTENT KNOWLEDGE: SYNTHESIZING RESEARCH ON CONTENT, PEDAGOGY, AND PRACTICE

In this symposium we report the results of a large-scale, multi-disciplinary research project involving three research teams comprised of math, science, and education faculty members and students on a single campus. The project was designed to investigate the effectiveness of the Learning Assistant Model for recruiting and preparing math and science K-12 teachers.

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Introduction

The goals of the Learning Assistant Model are:

1. To recruit and prepare talented math and science majors for careers in teaching
2. To improve the quality of math and science education for all undergraduates
3. To transform our undergraduate math and science courses to be student-centered and interactive
4. To transform cultures within university math and science departments to value research-based teaching as a legitimate endeavor for ourselves and for our students.

In order to achieve the goals listed above, the Learning Assistant Model uses the transformation of large-enrollment undergraduate science courses. The transformation of these courses involves creating environments in which students can interact with one another, engage in collaborative problem solving, articulate and defend their ideas, and explicitly discuss aspects of the nature of science and the nature of learning science. To accomplish this, undergraduate Learning Assistants (LAs) are hired to facilitate small-group interaction. Other nationally recognized models for peer instruction exist, most notably, Peer-Led Team Learning (Gafney & Varma-Nelson, 2007). The difference is that the LA program doubles as a teacher recruitment program. That is, *LAs make up the pool from which we recruit new K-12 teachers,* and targeted efforts to recruit LAs to teaching careers exist throughout various aspects of the program. LAs are paid a modest stipend to work 10 hours per week alongside science faculty members in various aspects of course transformation. Although the LA experience is somewhat different for each course, the experience for all LAs involves three related components:

1. *Content:* LAs meet weekly with their faculty instructors to plan for the upcoming week, reflect on the previous week, and analyze student assessment data;
2. *Pedagogy:* LAs from all departments attend a special weekly *Mathematics and Science Education* seminar where they reflect on their own teaching and learning and make connections to relevant education literature; and
3. *Practice:* LAs facilitate collaboration within their learning teams of 6-20 students by formatively assessing student understanding and asking guiding questions.

While the LA experience is valuable for students who continue on to any career, our program is specifically designed to recruit undergraduate students to careers in K-12 teaching. Thus, LAs who decide to become teachers are eligible for NSF-Funded Noyce Fellowships. As Noyce Fellows, students are required to engage in discipline-based educational research with science, mathematics, or education faculty members. Each of these research projects is closely aligned with formative assessment, research-based instructional design, or another area that we believe should be a part of standard practice for all teachers. These students present their research results at local and national conferences and are beginning to co-author papers for academic journals which summarize their collaborative work.

There is no prescribed design of what course transformation should look like. Instead, faculty members who seek and are awarded LAs must agree to: (a) use LAs to promote interaction and collaboration among students enrolled in the course, (b) meet in weekly planning sessions with the LAs who support their courses, (c) attend weekly meetings with other faculty participating in the program, (d) attend a summer preparation session for using LAs; and (e) evaluate course transformations and assess learning in their own courses. Because there is little dictation as to what a transformed course should look like, there exist several models of course transformation among our participating departments.

The LA program has grown throughout our campus and throughout the nation (Mervis, 2007; Otero, Finkelstein, McCray, & Pollock, 2006). Eight other institutions across the nation have received federal funding to replicate our program. We started the program in 2003 with the involvement of 6 faculty members working to transform 4 courses. Since then, 47 faculty members from 9 departments have used LAs and over 35 undergraduate courses have been transformed. In addition, 6 postdoctoral fellows, 11 doctoral students, 27 Noyce Fellows, and 331 Learning Assistants have been involved. Each year, the program impacts over 8,000 undergraduate students and the number keeps growing. A total of 41 mathematics and science majors have been recruited to become K-12 teachers through the LA program. Most of these students report that they did not seriously consider becoming teachers until participating as LAs. LAs who do decide to become teachers frequently report that they made this decision because they recognized teaching as a challenging endeavor, and because of encouragement and support from education, math and science faculty members. Figure 1 shows the impact of the LA program on enrollments of physics and chemistry majors in teacher certification programs. The physics and chemistry departments are specifically targeted by the LA program because these majors are traditionally underrepresented in our secondary science certification programs. The charts in Figure 1 show the difference in certification program enrollments of majors before and after the LA program began in the physics (2004) and chemistry (2006) departments.

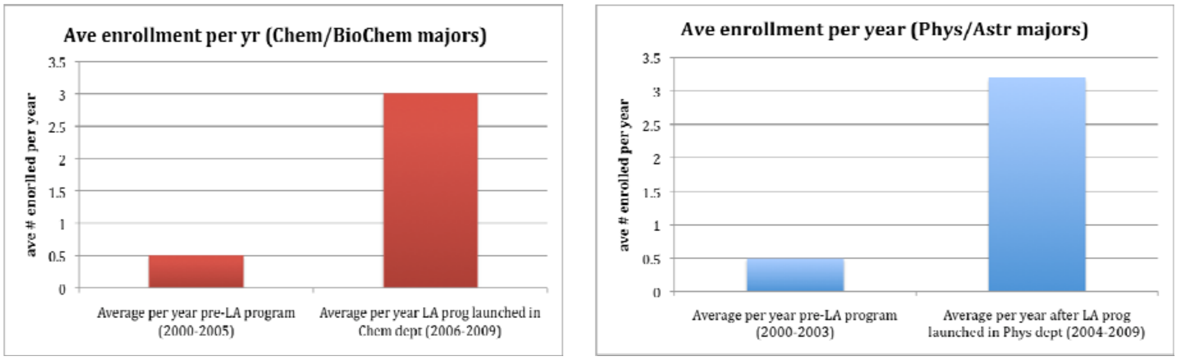

Figure 1. Physics and Chemistry majors enrolled in certification program before and after LA program began in each department

Figure 2 compares a five-year average of students who completed the secondary math and science certification program before 2005 to the number of students who completed the certification program after the LA program was in operation long enough to see its first graduates. As is evident in Figure 2, we have more than doubled the number of undergraduate mathematics and science majors who have completed our certification programs ready to teach math and science. Our program focuses on recruiting talented mathematics and science *undergraduates* to add teaching certification to their degrees (UG). Figure 2 illustrates that there has been no comparative increase in completers in the master's degree plus certification (MA+) or post-baccalaureate (PBA) programs, the other two programs that lead to teaching certification.

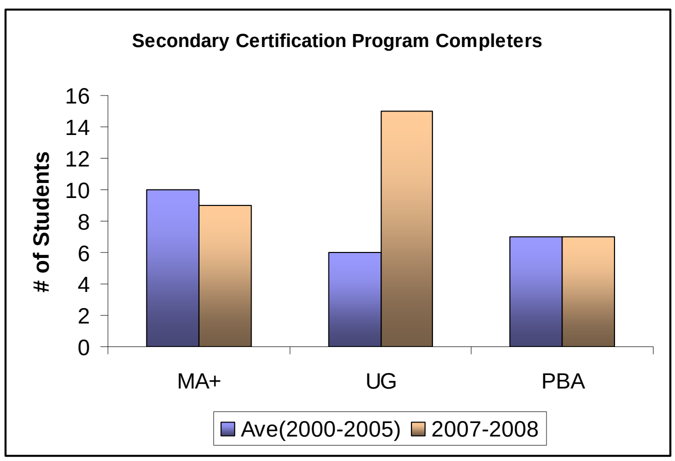

Figure 2. LAs recruited to certification program

Research Program

In 2006 our multidisciplinary team was awarded a DRL research grant from the National Science Foundation. This research project is designed to test the efficacy of the Learning Assistant model for recruiting and preparing highly effective mathematics and science K-12 teachers. Among other things, this project consists of a longitudinal study of former LAs and Noyce Fellows in comparison to other students who have graduated from the same teacher preparation project but did not receive the LA/Noyce "treatment." The research project was specifically designed to test the effectiveness of the LA model in terms of LAs' and Noyce Fellows' 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 compose three interacting research teams: the Discipline-Based Educational Research (DBER) team (investigating *content knowledge*), the Conceptions of Teaching and Learning (CTL) team (investigating *pedagogical knowledge*), and the K-12 team (investigating *knowledge of practice*). These interacting research teams investigate the research questions shown below and synthesize results on an ongoing basis.

The DBER team consists of faculty, graduate students, and Noyce Fellows from physics, chemistry, astrophysics, biology, and science education. For most disciplines, the DBER teams had to start by developing research-based instruments to measure students' conceptual understanding within their content areas. For example, the Biology Concept Inventory (BCI) has been developed by members of the DBER group in the Molecular, Cellular, and Developmental Biology (MCD Biology) (Garvin-Doxas & Klymkowsky, 2008) and will be used in future analyses of student and LA performance. Currently, the DBER team is working on activities, analogous to the tutorials in physics (see below) that can be applied to a range of MCD Biology courses. In physics, many conceptual inventories that measure students' introductory knowledge already exist and have been tested.

The CTL team consists of faculty members from the School of Education in Research and Evaluation Methodology and graduate students in Science Education and in Physics Education Research. The CTL team has been developing an instrument designed to measure the sophistication of teachers' pedagogical knowledge, and has been creating validation arguments for that instrument. The instrument, known as the Flexible Application of Student-Centered Instruction (FASCI), is discussed in more detail below.

The K12 team consists of faculty members and graduate students in science and mathematics education who investigate teacher recruitment and retention rates, visit former Noyce Fellows and LAs in their classrooms on a regular basis, interview teachers, observe their teaching using the Reformed Teacher Observation Protocol (Sawada, et al., 2002), and collect and analyze artifact packages from teachers' classrooms (Borko, Stecher, Alonzo, Moncure, & McClam, 2005).

Project Research Questions

1. DBER Team (measures content knowledge using various conceptual assessments)
   (a) How do LAs compare to other STEM majors in terms of their content understanding, beliefs about the discipline, and beliefs about learning in the discipline?
   (b) What effects can be observed on student achievement in courses that are supported by LAs?

2. CTL Team (measures pedagogical knowledge using the FASCI Instrument)
   (a) What is the effect of the LA model on the sophistication of LAs pedagogical understanding?
   (b) Does sophistication of pedagogical understanding vary by length of exposure to the LA model?
   (c) How is the pedagogical sophistication of STEM LAs different from the sophistication of STEM non-LAs who become teachers?

3. K-12 Team (observes/analyzes practice using RTOP, field notes, and interviews)
   How do teachers who participated as LAs compare to those who did not in terms of their:
   (a) Teaching practices? Practices are observed using the Reformed Teacher Observation Protocol as well as by taking field notes and engaging in multiple interviews with treatment and control teachers.
   (b) Their K-12 students' shifts in attitudes and beliefs about mathematics and science?
   (c) Recruitment into teacher certification programs and changes in interest in teaching?

The project continues to work to collect and analyze data. Current results from each research team are summarized below.

Discipline-Based Educational Research (DBER) Team Findings

LAs' content knowledge was found to be beyond that of their peers and LAs learn content more deeply through the LA experience. Results from the Brief Electricity and Magnetism Assessment (BEMA) (Ding, Beichner, Chabay, & Sherwood, 2004) 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 44% (compared to national averages of 23% on similar instruments for traditional courses). 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 .56 (Pollock, 2006). 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.

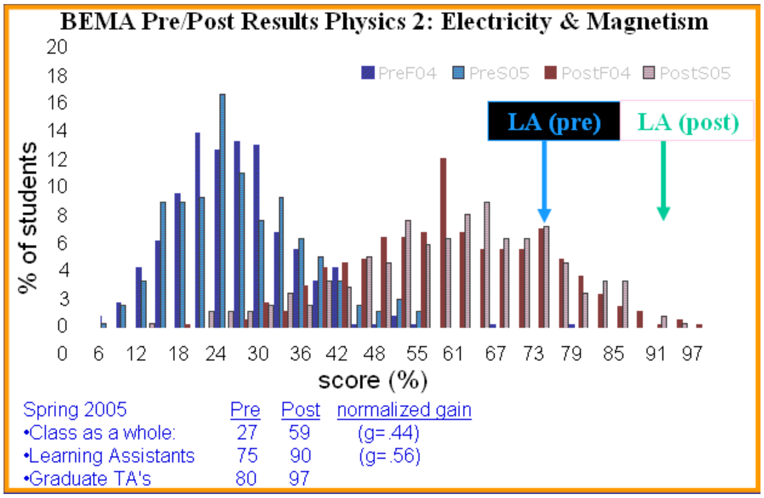

Figure 3. After one semester, LAs score as high as incoming physics graduate students.

We also observed long-term effects of course transformations on students' content knowledge in introductory courses on our upper-division majors (Pollock, 2006). The BEMA is a difficult assessment that we give pre/post in introductory Electricity and Magnetism courses. Figure 4 is a plot of BEMA scores measured for physics majors *after* completing upper-division Electricity and Magnetism.

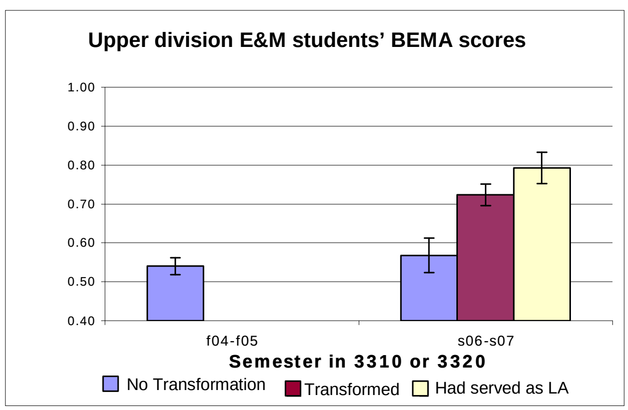

Figure 4. Longitudinal data for upper division E&M

For the first three terms of data collection (Fall 2004–Fall 2005), *none* of the students had themselves taken an LA-supported transformed freshman physics class (transformed using Learning Assistants and the University of Washington Tutorials (McDermott & Shaffer, 2002)) since we were just getting started implementing transformations. The "control group" (*n* = 75) is shown in the first bin in the figure, labeled "No Transformation" (average, 54 +/- 2%).

In the following three terms, from Spring 2006–Spring 2007, *some* of the students (*n* = 23) had come from other freshman experiences and had not had LA-supported tutorials when they were freshmen (again labeled "No Transformation"; average, 57 +/- 4%; please note this is not significantly different from this same category in the earlier bin). Next we see students labeled "Transformed" (*n* = 33); this indicates students in these *same* classes (Spring 2006–Spring 2007 combined, once again), but who had themselves taken their Freshman physics II several terms earlier at the same university in a class that was transformed using Tutorials and Learning Assistants (72 +/- 3%). The final bin is for only those students who had been LAs at some point in their career for the Physics II course (*n* = 7, average 79 +/- 4%). We thus see evidence that students' experience in an LA-supported, transformed physics course their freshman year translates to significantly improved BEMA scores at the upper division level, and that being an LA moves scores up to levels comparable to what we measure for incoming *graduate* Teaching Assistants whose average BEMA score (before teaching) is 80 +/- 4% (*n* = 15). It could be argued that there is a selection effect for the LA data. Nonetheless, the LA population is the population from which we have recruited 17 physics/astrophysics majors to become K-12 teachers (see Figure 1).

Conceptions of Teaching and Learning (CTL) Research Team Findings

The Flexible Application of Student-Centered Instruction (FASCI) instrument, still undergoing validation studies, is intended to measure two critical dimensions of pedagogical sophistication for science and math instruction: (a) teachers' views of students and how this translates to decision making in various contexts and (b) teachers' repertoires of teaching strategies and their tendency to apply various strategies flexibly in context. Taken together, these two dimensions (which we do not see as orthogonal) represent the FASCI construct. Our approach is to measure teachers' pedagogical sophistication on these two dimensions by scoring their responses to scenario-based items in which we attempt to "observe" their classroom practices indirectly. Up to this point, work involving the development of the FASCI has focused on theory development, item design, pilot administration, and item scoring.

Development of the FASCI Instrument

The foundation for the FASCI development has been Wilson's (2005) construct modeling approach to measurement[1]. In this approach, one begins by establishing a developmental theory for the latent construct to be measured. The instantiation of this theory is known as a construct map. Next, a set of items is designed to elicit information about how much or how little of the construct any given respondent possesses. A scoring rule is subsequently established for the anticipated item responses. After collecting data through pilot tests or field tests, patterns of scored responses across examinees and items are modeled statistically to make inferences about the location of a respondent (and item) on the construct map. The precision of the inference is evaluated by its associated estimate of measurement error. Each step of the construct modeling approach typically leads to iterative revisions for the construct map, item design, scoring rules, and measurement model. Indeed the results we present below obscure the many iterations and revisions that preceded them. In what follows we present the current state of our thinking about the FASCI instrument and its score interpretations.

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[1] This approach can also be mapped onto the "Assessment Triangle" presented in *Knowing What Students Know* (Pellegrino, Chudowsky, Glaser, & National Research Council Division of Behavioral and Social Sciences and Education Committee on the Foundations of Assessment, 2001). We start with a theory of respondent cognition (in this case, the learning progression), proceed to gather some observations of that cognition (through responses to the instrument), and use a measurement model to interpret those responses.

The construct map in Figures 5 and 6 posits two distinguishing features of teachers' pedagogical sophistication as they engage (or do not engage) in the formative assessment process. First, formative assessment depends on a teacher's attention to student ideas. This constitutes the student-centered instruction (SCI) dimension of a teacher's pedagogical sophistication (Figure 6). Second, the formative assessment process depends on a teacher's attention to student learning outcomes and use of such information to modify their strategies when these strategies do not appear to be working. This constitutes the flexible application (FA) dimension of a teacher's pedagogical sophistication (Figure 5). We would expect that the two dimensions in the construct map of pedagogical sophistication to be positively correlated since a teacher who is high on the SCI dimension is by definition one that is attentive to student conceptions and ideas, and therefore more likely to use such information to modify their instructional strategies than a teacher with a more behavioral view of teaching. As is evident in Figures 5 and 6, each dimension of the construct map is characterized by a rather small number of qualitative levels. This is not meant to suggest that more levels do not exist, only that to this point we were unable to establish additional indicators that could be used to distinguish them reliably.

Level		Respondent Characteristics
Increasing FA ↑	2	• The teacher has repertoire of strategies that can be used to facilitate student learning within a given class session. • If the teaching strategy comprised of these acts is not producing the desired result, sometimes it can be modified. • The teacher recognizes that the choice of a class activity and associated teaching strategy will depend upon variables specific to the classroom context.
	1	• The teacher has a repertoire of strategies that can be used to facilitate student learning within a given class session. • If an activity based on a particular teaching strategy is not producing the desired result, the activity can be modified by selecting a different strategy.
	0	• The teacher has a limited repertoire of strategies. • Once a particular activity has been sele cted for a class session, it is not easily modified with a different strategy.

Figure 5. Flexible Application Dimension of Pedagogical Sophistication

Level		Respondent Characteristics
Increasing SCI ↑	1	• Discussion of interactive teaching which would be *observable* to the teacher or to an outside “other.” Teacher ⇄ Students and/or Students ⇄ Students
	0	• No discussion of interactive teaching • Teacher primarily views classroom activity as way to help students make sense of new ideas. Information goes from teacher to student. Teacher → Students

Figure 6. Student-Centered Instruction Dimension of Pedagogical Sophistication

The FASCI construct map shown in Figures 5 and 6 represent our attempts to reliably measure (a) the type of instructional strategy invoked by a teacher for a given classroom session, and (b) the extent to which this strategy is modified after student learning outcomes have been assessed (whether the assessment is formal or informal). Below we discuss how we are defining and distinguishing instructional strategies, what it means for an instructional strategy to be modified, and what it means for an instructional strategy to be classified as “student-centered.”

We define a “strategy” as a teaching act chosen purposefully to engage students with the content or skills they are expected to learn. So while all strategies are acts of instruction, not all acts necessarily constitute instructional strategies as we are defining the term. For example, the use of humorous anecdotes by a teacher can go a long way towards establishing a classroom environment that is conducive to learning, but we would not characterize this as an instructional strategy in and of itself. Treagust (2007) distinguishes six categories of instructional strategies commonly used in science teaching:

1. Demonstrations
2. Explanations (e.g., telling students the answer, interactive explanations)
3. Questioning (e.g., dialog, debate, discussion, use of wait-time)
4. Representations (e.g., concrete, verbal, mathematical, visual, symbolic, gestural)
5. Group and Cooperative Learning (e.g., jigsaw, peer-tutoring, group investigations)
6. Inquiry (e.g., exploration, conceptual invention, conceptual expansion)

All teachers have a potential repertoire consisting of these different instructional strategies. While any given classroom activity will usually involve some combination of strategies, one will usually be most prominent. Treagust (2007) presents the categories above as existing on a continuum from “teacher-centered” to “student-centered,” with demonstrations being the least student-centered and inquiry being the most student-centered. For FASCI responses, we say that an instructional strategy has been modified when the respondent articulates a shift in emphasis within a given item response from one instructional strategy to another (i.e., from a demonstration to questioning). The key criteria we use for determining whether a strategy is student-centered is whether the strategy is being used to implement a classroom activity that enables students to be actively engaged with the concepts at hand, and that provides an opportunity for student to express their developing ideas and conceptions.

The FASCI construct map represents an initial hypothesis about the factors that distinguish teachers that are more sophisticated in their knowledge about teaching from those that are less sophisticated. The next step in developing an operational instrument was to create items capable of eliciting information about what teachers do (and the reasons why) when they are in the formative assessment cycle.

Designing Scenario-based Items

A construct map is a first step in operationalizing hypothesized characteristics of teachers with different levels of strategic knowledge. The items on a survey instrument are the means by which information about a given respondent's location on the construct map is elicited. In the present assessment context the optimal choice of items to pose—both in terms of content and format—is not at all straightforward. Our approach has been to develop standardized items that present teachers with a variety of classroom-based scenarios. For each scenario, we provide three prompts that allow teachers to elaborate on their instructional decisions. The general structure for each item is shown below.

> Step 1: Present a classroom scenario that involves a specified learning activity. The scenarios should vary to the extent that they appear more student-centered or teacher-centered.
>
> Item Prompt (a) asks: How might this activity facilitate student learning?
>
> Step 2: Present information hypothetically elicited from the learning activity posed in the scenario that represents a potential obstacle to student learning.
>
> Item Prompt (b) asks: Describe both what would you do and what you would expect to happen as a result.
>
> Item Prompt (c) asks: If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

The item below illustrates how the template above is applied:

> Students are working in groups of four to discuss a conceptual question you provided them at the beginning of class.
>
> a) How might this activity facilitate student learning?
>
> As the activity proceeds, one group gets frustrated and approaches you—they've come up with two solutions but can't agree on which one is correct. You see that one solution is right, while the other is not.
>
> b) Describe both what would you do and what you would expect to happen as a result.
>
> c) If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

While we have developed a total of 15 different scenarios, the pilot testing of the FASCI that we discuss below contains only the following five:

Scenario 1) Students are working in groups of four to discuss a conceptual question you provided them at the beginning of class.
Scenario 2) You are working out an example problem up on the board.
Scenario 3) You have just finished giving a lecture on a complicated topic.
Scenario 4) You have given your students a quiz to assess their understanding of a difficult topic.
Scenario 5) In talking with one of your students you discover that they have a misconception[2] about a central topic presented in that week's class. You attempt to address the misconception by having a one-on-one conversation with the student.

The following contextual constraint is given at the beginning of each scenario: "Please assume (unless it is otherwise specified) that you are teaching a high school course in physics, chemistry, biology, earth science or math to a class of 25-30 students." The use of these classroom scenarios is intended to make it harder for respondents to provide what they consider to be the desired answer. In addition to these scenario-based items, a set of background questions are included about a respondent's academic background and previous teaching experiences[3]. Many of the scenarios used in the FASCI instrument were inspired by the actual experiences recounted to us by Learning Assistants through interviews. All scenarios were written by a team of faculty, graduate students, and K-12 teachers with expertise in both measurement and science education. The qualitative analysis of the item responses and subsequent scoring of those responses inform our judgments about how the FASCI can be used to distinguish teachers with different levels of pedagogical sophistication. Scores resulting from the ratings of these responses were analyzed using an Item Response Theory approach (Lord, 1980) in order to obtain estimates of each

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[2] Although we recognize the potentially problematic nature of using the term "misconception" rather than "alternative conception" or "prior ideas," we chose to use it in this particular item because it reaches a larger audience of respondents when interpreted in its colloquial meaning.
[3] We have found that it takes the average respondent about 30 minutes to complete the most recent version of the FASCI.

respondents’ pedagogical sophistication. Score reliability is high for the Flexible Application dimension but work is still needed to fully develop a reliable construct for the Student-Centered Instruction dimension.

Pilot Study

In the 2007-2008 pilot test of the FASCI instrument, 65 individuals responded to the 5 scenario-based tasks on the current version of the instrument (Talbot & Briggs, 2008). Of these 65, 28 were female and 37 were male. The majority (n = 43) of respondents were undergraduate Learning Assistants (LAs) at our university. Two respondents in the sample were Noyce Fellows within the Learning Assistant program (Otero, 2006). Faculty Experts from the School of Education and the STEM departments were also included in the sample (n = 3). It should be noted that these faculty are known as exemplary teachers and committed educational researchers and therefore are not typical faculty. Graduate students from STEM departments who were teaching assistants for undergraduate courses and labs were also included in the pilot sample (n = 8). A sample of practicing K-12 science teachers from local area schools (n = 8) was also surveyed. One respondent did not disclose their group affiliation. Mean self-reported teaching experience for the entire sample was 4.5 years (SD = 8.6 years). Table 1 summarizes this and other relevant descriptive information for the sample.

Table 1.
Descriptive Characteristics of the FASCI Pilot Test Sample

		LA (n = 43)	Noyce (n = 2)	K-12 (n = 8)	Faculty (n = 3)	Grad Students (n = 9)	Entire Sample (N = 65)
Mean Age (SD)		20.33 (2.50)	22.5 (0.71)	46.25 (5.75)	57.0 (11.53)	24.44 (3.25)	25.85 (11.48)
Gender	Male	53%	50%	50%	100%	67%	57%
	Female	47%	50%	50%	0%	33%	43%
Mean Years Teaching Experience (SD)		1.22 (2.33)	5.00 (5.66)	15.75 (6.30)	30.33 (17.50)	1.67 (1.58)	4.53 (8.59)
Recent Subject Area Taught	Astronomy	9%			33%		8%
	Biology	12%					8%
	Chemistry	12%		13%			9%
	Earth Science		50%			11%	3%
	Physics	46%		87%	33%	89%	55%
	Other	14%	50%		33%		11%
	Not reported	7%					6%
Race	Native American	2%					1%
	Asian	7%					5%
	Hispanic	7%		12.5%		11%	8%
	White	84%	100%	75%	100%	89%	85%
	Not Reported			12.5%			1%

We purposefully chose our sample in order to gather a heterogeneous set of respondents. We hypothesized that novice teachers (such as LAs) would have a limited repertoire of instructional strategies compared to more experienced teachers such as practicing K-12 teachers or Faculty Experts. Similarly, we expected novice teachers such as graduate students in the STEM disciplines to be less student-centered in their instructional approaches as compared to more experienced K-12 teachers and Faculty Experts.

Preliminary results are shown in Figure 7, which displays the combined FA and SCI scores for these five different populations. As shown in the figure, Noyce Fellows and Faculty experts score highest on the Flexible Application dimension, and LAs score higher on student-centered instruction dimension. This is not surprising since LAs are typically constrained somewhat in what they are expected to do with their learning teams and in most cases do not have full control of the learning-team classroom environment. Work on the FASCI, and dissemination of it, will continue through the life of the research grant. A Phase II Noyce Teaching Scholarship grant will enable us to increase the size of our Noyce Fellow sample.

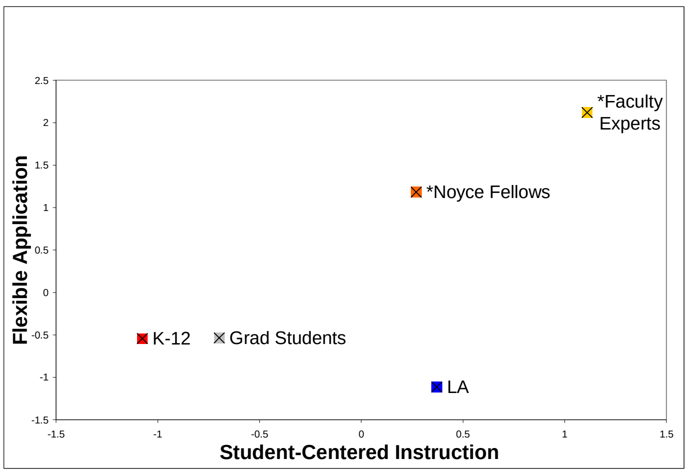

Figure 7. Group locations on the two-dimensional FASCI construct

Future Work

Our current and future work focuses on three areas: 1) We are examining the extent to which the FASCI needs to be content-specific in order to obtain reliable results. The current FASCI scenarios are content-neutral within the sciences (i.e. the respondent is free to frame the scenario in any science topic of their choosing—it is not constrained). A new physics-specific FASCI is currently being piloted alongside the existing version in order to investigate the possible threat to validity posed by the existing content-neutrality of the scenarios. 2) We are also currently pilot testing a new partially constrained version of the FASCI instrument which still uses the scenario-based item structure. 3) We are also working with the K-12 research team to observe the actual practice of teachers and compare that data to FASCI scores from those teachers in a further effort to establish a validity argument for the FASCI. To that end, we have developed a FASCI observation protocol which is based on the FASCI survey instrument.

K-12 Research Team Findings

A team of graduate students and faculty members (most of whom were K-12 teachers at one time) visit former LAs' K-12 classrooms and observe their teaching. We also observe a control group of teachers who were certified through the same program but did not have the Noyce/LA "treatment." Each teacher is observed three times throughout a year and each observation consists of two researchers evaluating teaching practice using the Reformed Teacher Observation Protocol (RTOP; Sawada, et al., 2002). At the end of each observation, the two researchers discuss their scores. All of the researchers who go out into the field and make observations have attended over 10 hours of training using the instrument and the entire group reached a high level reliability in scoring their preliminary observations.

Data Collected

In fall 2007, we identified LA teacher candidates who had found teaching positions in math and science and also identified potential non-LA (control) teachers who had graduated in the same year. We were able to secure participation from eight former LA students and four non-LA students, split evenly among math and science candidates (see Table 2).

Table 2.
Year 1 K-12 cohort experience and content area

	Science	Math
LA	4	4
Non-LA (control)	2	2

Of the 11 former LA students that we contacted, 2 declined to participate because they were not currently teaching and the other did not return phone calls or email. Of the 13 non-LA students we contacted, 6 did not respond to multiple invitations to participate, and 3 declined to participate. The three control teachers who replied to our invitation, declined to participate due to concerns about committing to a research study during their first year of teaching. District approval for current and future teacher participation was secured for each participant in addition to permission from school principals to conduct research at the school site.

Since participation in this study was voluntary, we assume that the difficulty in recruiting or eliciting replies from potential control teachers might have been due to a lesser commitment to research in teaching and learning among non-LAs. This is in contrast to the LA students who were immersed in such studies during their undergraduate experience and had ongoing contact with math, science and education faculty over several years. All were paid a small stipend for participating in the research project.

Given the complexity of classroom-based research and the many variables that could be examined, we first developed a coding scheme that included a set of primary variables that could be examined across all data sources. These Constructs of Interest are:

1. Assessment practices (methods and conceptions)
2. School Context (perception of support from colleagues and administrators)
3. Construction of knowledge (i.e., teachers conceptions of how students learn math/science)
4. Teacher background (including LA and teacher education experiences)
5. Teacher self-efficacy (i.e., perceptions of and responses to problems of practice)
6. Views of students (how they regard student diversity, readiness to learn, students' struggles)
7. Lesson Design/Planning (regard for student prior knowledge, inquiry, content)

Secondary and tertiary codes have also been developed to elaborate different aspects of these constructs of interest, exemplified in the various data sources. Since the research questions and related coding scheme call for an examination of teachers' conceptions and practices, the data sources selected drew from a blend of interview protocols, survey instruments, classroom observation protocols and sampling of classroom artifacts. The data sources used in Year 1 of this study are as follows:

Table 3.
K-12 research: Year 1 data sources

Teacher Conceptions	Teacher baseline interview Observation interview Reformed Teaching Observation Protocol FASCI responses and scores
Teacher Practice	Scoop notebook Reformed Teaching Observation Protocol
Students' Conceptions	Colorado Learning Attitudes Science Survey (adapted for secondary school use)

Baseline interviews were conducted with all teachers upon their entry into the study. Three interviews were conducted over the phone and the rest were conducted in person, at their school site. Three classroom observations were conducted for 10 participants, which included use of Reformed Teaching Observation Protocol (RTOP) and the observation interview[4].

To support the collection of classroom artifacts, we video-taped and processed DVDs that included an overview of artifact notebook procedures for teachers in order to provide an additional resource for teachers for future reference (and for out-of-state participants). Each artifact notebook includes teacher lesson plans, assessments, assignments, and reflections about lessons over a period of one week. Notebooks were collected from 11 of the 12 participating teachers. We also plan on reviewing the field notes and artifacts embedded in the RTOP for evidence of teachers' conceptions of inquiry and student learning.

The Colorado Learning Attitudes Science Survey (CLASS; Adams, et al., 2006), which had been used with LAs during their undergraduate experience, was reformatted so that it could be

[4] Two math participants (one LA, one non-LA) had teaching assignments in South Dakota and Vermont. They agreed to participate in all phases of the data collection with the exception of classroom observation.

administered in paper-and-pencil format. Math and science versions of the CLASS were developed, and the language was also adapted so that it could be used with middle grades and high school students. Spanish translations of the math and science CLASS were also developed. Eleven participating teachers administered the CLASS to one class of their students.

Status of data collected

Some preliminary results are shown in Table 4. The numbers are still small for this study mainly due to the amount of time it takes to get full school and district approval for work in the individual K-12 classrooms. We expect greater numbers and more types of data in the upcoming year.

Table 4.
Reformed Teacher Observation Protocol Scores

Group	Math	Science	Overall Mean
LA (*n* = 8)	68.3	42.1	49.6
Control (*n* = 4)	36.0	41.5	39.6

All RTOP data has been translated into an Excel file and summarized as descriptive statistical data for the LA and non-LA groups. We are also re-aggregating the ratings for the 25 RTOP prompts to match the constructs of interest. Using the standard protocol for analysis, preliminary analysis of RTOP data suggest that the LA group (n_{obs} = 21, mean = 49.9, SD = 21.4) is more likely to engage in inquiry-oriented classroom practices than the control group (n_{obs} = 9, mean = 39.0, SD = 14.7). However, it is worth noting that these differences, while large, are not statistically significant comparisons when contrasting the 95% confidence intervals for each group's mean. The relatively low numbers of participants in each group, especially the control group, limit our ability to make statistical inferences.

Students' Interest in Teaching Careers

We studied the effect of the program on students' interest in teaching careers by comparing LAs' interest in teaching careers to a matched sample of students. In this part of the study, we used three sources of data to investigate interest in teaching as well as changes in other factors not reported here. First, we collected demographic and survey data on students' interests in, and predispositions toward, teaching from 3 years of Learning Assistant recruitment sessions that are held mid-semester each semester (*n* = 592). Of the students who attended the session, some applied to be LAs and some did not apply. Of those who applied, some were accepted and some were not (see Figure 8). The second source of data was a follow-up survey that was administered online. The follow-up survey investigated teaching interest among those who participated as LAs and those who did not. The total number of online follow-up surveys collected was 231. A third source of data (not reported here) was the actual application forms from students who applied to be LAs (*n* = 474).

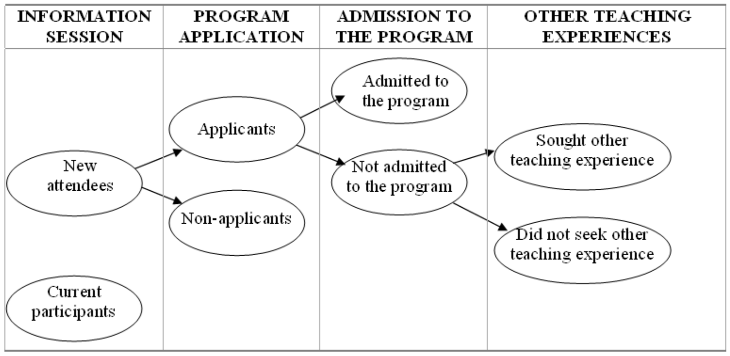

Figure 8. Populations studied in the recruitment study.

Altogether, 59% of information session attendees applied to the program. 36% of all applicants (not all of whom attended the information session) were admitted to the program.

There was no significant difference between the applicants and non-applicants in terms of their interest in teaching careers as measured by a multiple choice question on the information session survey. Mean scores for teaching interest were essentially the same for the two groups, but the standard deviation of these scores is significantly different, showing a wider spread for non-applicants. Also, applicants were significantly more likely than non-applicants to indicate that seeking a teaching experience was their reason for attending the information session in the first place, as measured by a separate question on the survey. We compared changes in interest in teaching careers among students who completed both the information survey and the online follow-up survey. A total of 90 pre-post responses were collected: 51 from students who participated as LAs, 32 from non-participants who did not seek any other teaching experience, and 7 from non-participants who sought a teaching experience outside of the LA program. We conducted a one-way ANOVA on change in teaching interest among the three groups of respondents. The results are shown in Figure 9.

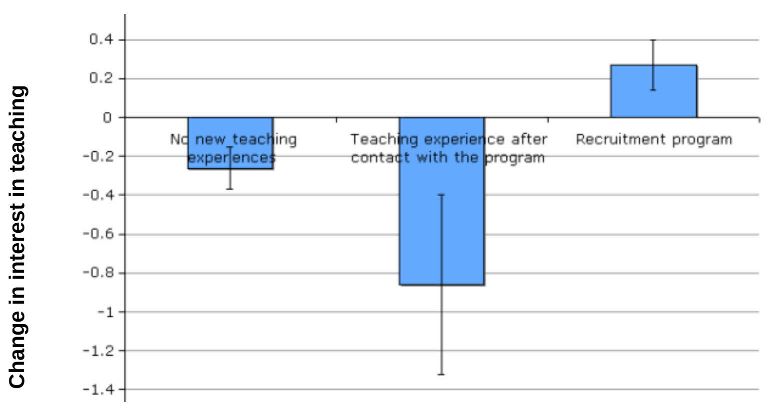

Figure 9. Interest in teaching results from 3 years of data.

In Figure 9, the leftmost bar shows students who attended the information session, did not serve as LAs and who did not seek new teaching experiences after applying to the LA program, the middle bar shows students who attended the information session, did not serve as LAs, and did seek out and engage in other teaching experiences. The right-most bar shows students who attended the information session and served as LAs. Figure 9 demonstrates that students who served as LAs increased their interest in teaching whereas those who attended the information session but did not serve as LAs actually decreased in interest in teaching. The LA program thus may enhance interest in teaching above and beyond other teaching experiences.

Contribution to Research on Science Teaching

One of the grand challenges in science education is measuring the effects of instructional transformations on content-centered programs and on teacher preparation programs. We have taken advantage of our lively, multi-disciplinary group to measure effects of transformations at various points in the teacher professional continuum, beginning when students are enrolled in introductory science courses and just starting to consider teaching as a career option and extending into their first few years of teaching. The comprehensive study presented here shows promise in meeting the challenge of understanding how pedagogical content knowledge (Shulman, 1986) is developed and manifested in the classroom. Our research also seeks to distinguish not *if* a teacher preparation program is effective, but *which aspects* of a multi-disciplinary Learning Assistant program lead to effective teaching in K-12 schools. Instead of focusing on a single measure of pedagogical content knowledge, the research presented here attempts to investigate various aspects of prospective and practicing teachers' learning experiences. This approach to understanding teacher learning is empirically based and exploratory in the sense that the research is grounded in the experiences of prospective and practicing teachers. We have attempted to remove biases associated with what *we think* pedagogical content knowledge might look like. That is, instead of measuring an a priori construct of pedagogical content knowledge that we assume to understand, our study seeks to describe teacher knowledge and to make inferences about its development and use in the classroom, in efforts of constructing a vision of pedagogical content knowledge.

Other work associated with this program seeks to investigate the effect that the Learning Assistant program has on the development of university research faculty members' own teaching and awareness of issues and research in education. In this symposium, we look forward to significant audience interaction and reactions to our work, and we will provide time for discussion among attendees about future directions for and replications of large-scale programs such as this one.

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