

CLUSTER: University-Science Center Partnership for Science Teacher Preparation

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The purpose of this paper is to describe and present results from the fourth year of a five-year collaborative research project between an interactive science center and a local college. The purpose of the project is not only to recruit and train approximately 50 highly qualified science teachers who will teach in New York City public schools, but also to develop a model for science teacher preparation. This model demonstrates how university-science center partnerships can allow both institutions to leverage each other's strengths to guide and support inquiry and constructivist-based pre service teacher preparation. In addition to a description of the training model, data presented will include standardized assessments, classroom observations of project participants and comparison participants, and follow-up with graduates. Results suggest that this innovative training model has enhanced teaching skills and performance.

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INTRODUCTION

The National Research Council report, “Learning Science in Informal Environments: People, Places, and Pursuits” (2007), states that teachers need to be able to support students in developing an understanding of core ideas, assess and respond instructionally in an iterative manner, address the needs of diverse populations, and provide adequate opportunities to learn science. The report makes clear that this “represents a significant change from what virtually most active teachers learned in college and what most colleges teach aspiring teachers today (p. 6).” This statement alludes to a great challenge our colleges are facing today: meeting the need to develop teachers who can support student learning in the ways described above. Too often preservice teachers learn theory divorced from practice because institutions are not able to create coherent experiences. Darling-Hammond et al. (2005) argue that such teacher preparation programs are overly theoretical and lack the proper connections to practice.

Fieldwork and student teaching are two opportunities for preservice teachers to interact with students in ways that allow them to develop an awareness of themselves and their students as teachers and learners. In New York State, preservice teachers are required to complete only 100 hours of fieldwork and 40 days of student teaching. Fieldwork usually consists of making observations of students in learning settings and then writing a report about that experience, relating it to coursework. Student teaching involves actively working with a mentoring teacher to design and teach lessons. These required hours of fieldwork and student teaching are not nearly enough to support a preservice teacher’s development as a skilled educator, which entails designing student encounters that are embedded in science inquiry, learned over time, and draw on the knowledge that diverse learners bring to the table. The problem is exacerbated in cases where college science professors do not model student-centered teaching. Results from empirical research suggest that teacher preparation programs that weave meaningful fieldwork experiences into coursework are more effective at supporting the development of new teachers (Darling-Hammond et al., 2005). Accordingly, a number of models are being tested in which fieldwork is creatively incorporated into coursework.

The University of South Alabama, for example, tested a unique model for teacher preparation in which the amount of time teachers spent in clinical training was increased (Feldman and Kent, 2006). The goal was to weave fieldwork experiences into the courses so that preservice teachers spent more time working with students and developing effective teaching skills and dispositions. Results from the pilot program show that preservice teachers who participated in the program felt better prepared to teach diverse students upon graduation and had a deeper understanding of linking theory to practice than teachers who followed a traditional teacher training model. The teachers in this pilot also performed better in job interviews and were able to offer substantial strategies for differentiating

instruction. Overall, and perhaps most important, their level of teaching self-efficacy was higher than that of teachers who participated in the more traditional training model. The University of South Alabama model demonstrates the usefulness of creating opportunities for prolonged engagement.

Another critical area of concern in science teacher preparation is the degree to which novice teachers are able to sustain and implement inquiry-based approaches in their schools. Research has suggested that while a supportive practicum experience can strengthen preservice teachers' appreciation of inquiry-based approaches, the teachers often find it difficult and challenging to implement such approaches even *if* they perceive that to be a more appropriate strategy (Fazio et al., 2008). In their review of the research, Davis et al. (2006) similarly found that a great challenge that teachers face is the misalignment between what they learn in their teacher education program and what they experience both in their practicum and during their first years of teaching. In response to these issues, Luehmann (2007) recommends that preservice candidates have opportunities to practice teaching in informal, low-stakes settings, such as afterschool programs or camps, which are designed to engage students but not to test them. Ideally, the settings should serve populations of students similar to those where the preservice teachers expect to work. In these settings, preservice teachers can design, teach, and revise lessons without worrying about having to test the students on the material. At the same time, preservice teachers can build in thoughtful assessments for student learning as a way of designing good lessons and developing good practice. In some cases, they can teach to multiple audiences, improving their instruction each time. This allows teachers to experiment with different strategies, learn how to manage a classroom, and develop confidence in introducing topics in student-centered ways.

A Missed Opportunity

There is a missed opportunity in failing to use an existing resource in the community where preservice teachers can participate in prolonged engagement experiences in a low-stakes setting. Informal Science Institutions (ISIs) can serve as key partners for preservice teacher preparation. They include places such as science centers, zoos, aquaria, nature centers, arboreta, and natural history museums (Bell et al. 2009), where people learn in self-paced, voluntary, nonsequential ways. The learning in these institutions is socially constructed, occurring through interchanges between individuals and their sociocultural and physical environments (Falk, 2001). ISIs are specifically designed to demonstrate or display real-world phenomena in an environment where people can pursue and develop science interests, engage in science exploration, and reflect on their experiences through dialog with others. There is great potential for ISIs in partnership with universities and colleges to support reform-minded science teaching and learning. According to

a recent report from the Center for the Advancement of Informal Science Education, low-stakes settings such as science centers afford learners the ability to take risks and work at their own pace in following and developing their interests (Bevan et al., 2010). The report calls for the design of more effective formal-informal collaborations which leverage the strengths of each institution.

Many ISIs have floor facilitators, many of whom are teenagers or young adults, who engage visitors in science conversations. Across the United States, there are approximately 350 science centers; approximately 38% of them have a youth employment program (Association of Science-Technology Centers, 2007). Floor facilitators are trained and supported in engaging in visitor-centered conversations. The opportunity to have multiple conversations about the same exhibits with different visitors allows these facilitators to test different approaches in a low-stakes setting and to develop effective techniques for engaging students. For preservice teachers, ISIs thus have the potential to be ideal field settings.

CLUSTER – A Teacher Preparation Program

The Collaboration for Leadership in Urban Science Teaching Evaluation and Research (CLUSTER) is a National Foundation of Science (NSF) funded program in which the City College of New York (CCNY) and the New York Hall of Science (NYSCI) partnered to develop and implement a preservice secondary science teacher program. Undergraduate science students in the CLUSTER program take state-mandated education courses and work as floor facilitators, or Explainers, at NYSCI. The program aims to increase the pool of secondary science teachers prepared to implement inquiry-based science instruction. Science majors in the teacher preparation program at CCNY, who are known as CLUSTER Fellows, spend up to ten hours a week at NYSCI working as Explainers, a role which involves multiple activities; these include interacting with visitors at exhibits, leading demonstrations, and coteaching in discovery labs and afterschool and summer science programs for K-8 students. The CLUSTER Fellows interact with hundreds of visitors a day at NYSCI's exhibits. Their education coursework at CCNY is coordinated with their work at NYSCI in several ways, described further below. They also receive mentoring and supervision at NYSCI. The sequence of courses concludes with a capstone course in which students build on their coordinated activities at NYSCI and CCNY. When they have finished the program, they have completed all their requirements for science teacher certification in New York State.

Theoretical Underpinnings

Wang and Odell (2002) define reform-minded teachers as those who understand learners as unique individuals, both shaped by and dialectically shaping sociocultural

elements, politics, and ideologies. According to Wang and Odell, such teachers appreciate the diversity of students and regard teaching and learning as socially constructed. They promote collaborative inquiry and collective making of meaning. They view themselves as facilitators and knowledge transformers rather than as transmission agents. The CLUSTER partner institutions believe that teachers need to develop an understanding of teaching and learning as socioculturally situated and cogenerated through dialog and discussion, rather than as passively transmitted. CLUSTER was accordingly conceived to support teachers in incorporating reform-minded principles as a central aspect of their practice.

The guiding premise of the CLUSTER project is that in order to support students in becoming reform-minded science teachers, we have to provide them with opportunities to practice teaching in productive low-stakes settings. Preservice teachers' own schooling experiences and memories of their teachers do not always reflect reform-minded education; furthermore, their experiences during student teaching also often run counter to what they have learned about constructivist theory. Consequently, they may never have actually experienced reform-minded practices. Supporting the development of reform-minded teaching is critical both for sustaining it and for teacher retention. Davis et al. (2006) conducted a meta-analysis of 121 unique papers to document the current research on the challenges teachers face. That research indicates that teachers' experiences affect their perceptions of science and their interest and motivation to remain in science teaching. In addition, a number of studies in the last decade have shown that preservice teachers need to engage in reform-minded practices as learners in order for them to become reform-minded teachers.

Roth and Tobin (2007) theorize that talking about practice is very different from actually teaching, and that we therefore need to address the "rift between descriptions of teaching practice and enacted teaching practice" (p. 2). As CLUSTER Fellows interact with visitors, they develop the ability to take on the role of a teacher and discover which techniques work and which are ineffective. Roth and Tobin also remind us that "practice unfolds in time, irreversibly, with its own rhythm, tempo, and directionality" (p. 7). As such, each experience with visitors becomes a new opportunity to develop practices that are anticipatory, timely, and appropriate to given situations (Roth et al. 2001). Working as a CLUSTER Fellow allows a preservice student to be both a learner and a teacher. As a learner, the Fellow guides her own inquiry, works collaboratively, and experiences hands-on activities to generate knowledge and cognition. Then, in the role of a teacher, she helps others do the same. These practices thus become second nature for a teacher to use not only in science centers, but also in any teaching environment.

Sewell's (1992) theory of structures and agency, in which each is dialectically linked to the other, is useful for investigating what makes an informal science institution a suitable setting for supporting the development of reform-minded teachers. Structures are a set of schemas, resources, and practices. Schemas are

ideas, notions, and ways of understanding the world. Some resources—such as exhibits and museum visitors—are visible; others—such as the nature of free-choice learning or comfort with hands-on teaching—are invisible. Practices are the things people do in order to accomplish a task. Agency is the power to act. The meaning of structures as dialectically linked to agency is that neither presupposes the other nor can exist without the other. Viewing the CLUSTER partnership through the Sewellian lens of structure and agency is useful because it demonstrates how the construction and use of low-stakes settings such as science centers is necessary to support students in developing reform-minded epistemologies (how one believes knowledge production occurs), ontologies (how one defines the nature of knowledge), and axiologies (how one values the way knowledge production occurs). CLUSTER Fellows work within certain structures in the program which mediate their agency development. In a low-stakes setting such as a science center, the structures include access to hundreds of interactive exhibits, weekly peer training, a framework for teaching and learning, mentors from both the science center and the university, and paid work experiences that count as field experiences, ensuring that the student can devote time to the fieldwork. The opportunity to develop strategies for engaging with a large number of diverse visitors about a variety of science topics is a great resource. These aspects of the structure are linked to agency, a Fellow's power to act. In the science center, the Fellow becomes confident, competent, and comfortable in approaching and engaging visitors and develops habits for student-centered teaching through the numerous interactions. The Fellow's agency carries from the field of the science center to the field of formal classroom teaching. Since agency is linked to structures, the Fellow has the power to mediate changes in the structures as well, possibly improving learning environments in the classroom or even throughout the school.

CLUSTER Preparation Model

As the partnership between CCNY and NYSCI has developed, we have realized that there were certain support structures that needed to be woven into the model, and that we needed a heuristic (a teaching framework) to connect the college and science center experiences to each other and to the nature of scientific inquiry. The model requires not only the CCNY coursework and the activities at NYSCI, but also a coach who can help students make connections between what they are learning and how they are applying it to interactions with visitors. We also have a blog where students can share and respond to challenges and successes with visitor interactions. This blog is coupled to reflective practice activities where students use audiotapes and videotapes to document their interactions. We also added quarterly whole-group workshops, where we have the opportunity to provide models of inquiry-based teaching, answer administrative questions regarding registering for courses and student teaching, and address issues of preparing students to apply for

Table 1. The CLUSTER training model at a glance.

CCNY	NYSCI	Additional CLUSTER support
<ul style="list-style-type: none"> • 5-course NYS certification sequence in science education, including student teaching • Capstone course: “Project Learning in Science and Science Museums” 	<ul style="list-style-type: none"> • Paid Internship: 7–10 hrs/wk., minimum 150 hours • Work in 4 settings: Demos, labs, after-school programs, exhibits • Weekly Explainer training sessions 	<ul style="list-style-type: none"> • CLUSTER coach • Use of videotapes, audiotapes, and blogs in on-going reflective coaching groups • 4 Saturday workshops per year • Infusion of constructivist teaching framework both in CCNY classes and in coaching at Hall

teaching positions. Table 1 describes the CLUSTER model at a glance.

The Teaching Framework

In order to serve as the conceptual glue between the coursework and the science center experiences, we created a teaching framework based on the 7E Model. The framework is simply a heuristic for the CLUSTER Fellows to use as they learn how to design teaching experiences and reflect on their strengths and weaknesses in teaching. The parts of the framework are as follows: identifying the big idea, engaging the learner, assessing prior knowledge, introducing the big idea, and assessing the learner for the big idea. This framework is used by the Fellows to improve their strategies for interacting with visitors at exhibits. It is also used as a foundation for course assignments and projects. Since the faculty at the college and the museum work collaboratively, the Fellows are learning to think and reflect about teaching with the framework in mind. For example, as they consider writing their lesson plans, they are asked to identify the big idea, describe a strategy for engaging the learner, and so on. When the coach works with the Fellows, the framework is useful in analyzing audiotaped interactions between a visitor and the Fellow. While everyone recognizes that teaching is never a prescribed step-by-step process, the framework becomes an effective strategy for developing habits of mind that are applicable in formal and informal teaching settings.

Research Goals

The research aims of this project are primarily two-fold: first, to document the growth of the Fellows as they proceed through the program; second, to compare

Table 2. Status of CLUSTER Fellows as of October 1, 2009.

Status	N	%
Active	28	44%
Graduated – Track A	8	12%
Graduated - Track B	4	8%
Withdrawn	23	36%
TOTAL	63	100%

KEY: Graduated – Track A: full Cluster graduate. Completed certification sequence at CCNY and met Hall requirements. Graduated – Track B: partial CLUSTER graduate. Partially completed CCNY requirements and/or NYSCI requirements Withdrawn: either withdrew from program voluntarily or was asked to leave.

their progress to that of a comparison group. The data comes from several sources: standardized assessments, open-ended assessments, and classroom performance observations. The Fellows were evaluated and compared several times: at program entry, during student teaching, at program completion, and one year after graduation.

METHODOLOGY

Participants

The participants in this study were 63 undergraduate science majors enrolled at CCNY in the CLUSTER program. This group included students who were uncertain about pursuing a career in education but who were encouraged to explore that possibility by joining CLUSTER. While this approach lowered the retention rate, it has also allowed the program to recruit outstanding science teacher candidates. The students were of varying ethnicities. Table 2, below, presents information on the CLUSTER participants as of October 2009. Approximately 44% are currently active participants and 20% have graduated. Eleven of the 12 graduates are teaching. Seven are teaching in New York City public schools, two in private schools, and two in informal science institutions. The twelfth graduate completed all elements of the program and remained interested in education but elected to pursue graduate work in physics. Track A graduates have completed all elements of the CLUSTER program, while Track B graduates have not completed all elements of the program.

Table 3 compares the CLUSTER Fellows' and the comparison participants' demographic measures. One of the research challenges was the difficulty in finding a suitable comparison group of undergraduate science education majors, since relatively few such groups exist. Therefore, a comparison group of convenience was selected; the participants are from New York City alternate certification teaching programs such as the New York City Teaching Fellows program. In that program, candidates receive an intensive summer training and then are placed immediately in the classroom as full-time teachers. These students pursue their

Table 3. Demographics of the CLUSTER Fellows and the comparison group as of October 1, 2009.

	CLUSTER		Comparison	
	N	%	N	%
Gender				
Men	28	45	18	26
Women	35	55	52	74
Ethnicity				
White, Non-Hispanic	4	8	35	50
Black, Non-Hispanic	4	6	15	21
Hispanic	16	25	16	23
Asian/Pacific Islander	26	40	4	6
West Indian	4	6	–	–
Other	4	15	–	–
Science Concentration				
Biology	37	59	55	79
Chemistry	14	22	5	7
Earth Science	3	5	7	10
Physics	7	11	3	4
Undecided	2	3	–	–
Total	63	100	70	100

Master's degree over two years while teaching in New York City schools. Their training focuses on scientific inquiry and classroom experience. It is, however, a highly compressed program, and there is no institutional partner at which candidates can teach in low-stakes settings before becoming responsible for their own classrooms. It is also important to note that the CLUSTER graduates and the comparison graduates differ in some significant ways. CLUSTER Fellows are recruited while they are sophomores or juniors in college, while the comparison students are all college graduates, many from prestigious undergraduate universities; some had already completed an advanced degree. Many were also career changes who had worked in the business world. As indicated in Table 3, the CLUSTER Fellows are split more evenly between men and women, more ethnically diverse, and more widely represented among the science concentrations than the comparison graduates.

Data Collection and Analysis

Many sources of data were used during the course of this study. However, the data discussed in this article includes only pre- and post-standardized assessments

and teaching observations. Standard quantitative approaches were used in the data analysis, which was limited because of the small sample sizes involved. The standardized assessments include a variety of measures that were adapted from standardized teacher certification tests in pedagogy, science content, and lesson planning. Pre-tests were administered as students entered their education programs, and post-tests were administered upon graduation. The science content test, pedagogy test, and content-based lesson plan are based on the Praxis II assessments. The Praxis series of tests is used by many state education agencies in the United States as part of the process of licensing of new teachers (Educational Testing Service, 2005). The Praxis II PLT exam is designed to assess a beginning teacher's knowledge of a variety of subjects, including educational psychology, human development, instructional design, assessment, and other teacher preparation topics (ETS, 2005). For purposes of the project study, the science content assessments were adapted from the XAMonline preparatory guides.

In order to assess classroom teaching, an instrument was designed to focus upon the implementation of inquiry- and constructivist-based science instruction. The observer was asked to rate specific elements of the teacher's performance, such as skill at engaging student interest and at making student thinking visible, or the extent to which the students were allowed to construct their own understanding.

Findings

The results thus far indicate that the museum-university partnership has facilitated the development of science teachers in a number of key areas. Specifically, the CLUSTER Fellows perform well on a variety of standardized and performance assessments, despite having less academic and teaching experience relative to the comparison participants. In some instances, their performance is clearly stronger than the comparison participants' and some other comparison teachers' as well.

CLUSTER Fellows Compared to Other Candidates/Teachers

Table 4 displays the mean scores from a classroom observation instrument designed to focus on the implementation of inquiry-based science instruction. The observer has extensive experience with student and full-time teachers. As described above, he was asked to rate specific elements of the teacher's performance, such as skill at engaging student interest and at making student thinking visible, or the extent to which the students were allowed to construct their own understanding. Possible ratings ranged from 0, if an element was not observed at all (for example, when the lesson had no discernable big idea), to 4, if an element was implemented with great skill or to a high degree.

Table 4. Comparison of CLUSTER Fellow student teachers and comparison participants: classroom observation.

Scale: 0 (low) to 4 (high)

Observed skill	CLUSTER Fellows (n = 9)	Comparison participants (n = 6)
Level of skill in communicating the lessons's "big idea"	2.6 (.40*)	2.9 (.66)
Level of skill in engaging student interest	2.6 (.45)	2.3 (.82)
Level of skill in probing for students' prior knowledge, understanding	2.4 (.53)	2.3 (1.03)
Level of skill in assessing student acquisition of knowledge and skills	2.4 (.71)	2.3 (.94)
Level of skill in allowing students to construct their own understanding	1.8 (.48)	1.8 (.56)

* Standard deviations

As seen in Table 4, both groups scored highest in communicating the lesson's big idea, and lowest in allowing students to construct their own understandings. The comparison participants did better than CLUSTER Fellows in communicating the lesson's big idea, and CLUSTER Fellows did better at engaging student interest and assessing student understanding. The two groups scored the same, on average, in probing for prior knowledge and allowing students to construct their own understandings.

The second analysis draws on the observer's experience in supervising science student teachers over the years. In addition to data from the observation instrument presented above, the observer also coded his observations—of the 15 students he observed for this study and of 13 others whom he had observed in previous years—on the elements related to effective science teaching listed in Table 5. Table 5 presents the results of this analysis and includes two additional comparison groups: other student teachers with no prior teaching experience, and experienced teachers in the Master's program.

Table 5 shows that, in all three areas, CLUSTER Fellows outperformed the other student teachers with no formal teaching experience. They also outperformed the comparison participants except in the area of classroom control. While half of the other student teachers with no formal teaching experience experienced classroom control difficulties during their first observation, only 25% of the CLUSTER Fellows did. None of the other student teachers used inquiry strategies successfully or asked students to explain their own thinking, while 25% of the CLUSTER Fellows used inquiry strategies successfully, and 38% of them asked students to explain their own thinking. The CLUSTER Fellows used inquiry successfully more than the experienced teachers did, and, of the four groups, were second only to the experienced teachers in asking students to explain their own

Table 5. Comparisons of first observed lessons: CLUSTERS and others.

Element	CL (8)	OST (6)	CG (6)	ET (7)
Lack of classroom control skills interfered with lesson	25%	50%	0%	14%
Featured successful use of inquiry strategy	25%	0%	17%	57%
Students asked to explain their own thinking	38%	0%	17%	57%

Key: CL – CLUSTER Fellows OST – other stud. teachers CG – comparison participants ET – experienced teachers

thinking. The observer also noted anecdotally that the CLUSTER Fellows were clearly more comfortable working with young people than the other novice student teachers that he observed were.

The final comparative analysis presents the average scores on the standardized pre- and post-tests of six of the CLUSTER track A graduates and 18 comparison graduates. The average age of the six CLUSTER graduates is 25.5; the youngest is 24 and the oldest is 28. The average age of the 18 comparison graduates is 30.5; the youngest is 25 and the oldest is 51. In addition, at the time of graduation, the comparison graduates had completed their Master's degrees and therefore had a much more extensive background in human development, pedagogy, curriculum, and methods. They also had had two years of full-time classroom teaching, as opposed to the CLUSTER graduates, who had had only one semester of student teaching.

As seen in Table 6 below, the comparison participants had much higher scores, both upon program entry and at graduation, on the pedagogy multiple-choice test; this result is not surprising, given that the comparison group had completed more undergraduate courses in such subjects as psychology, human development, and education. Upon program entry, the scores of the comparison participants were also higher on the pedagogical open-ended case studies. In part, this may reflect stronger writing skills on the part of the comparison students since this group did not include English Language Learners. However, at graduation, the average scores of the CLUSTER Fellows on the case studies were higher than the comparison group. The Fellows were able to identify and recommend more appropriate classroom strategies in response to the scenarios in the case studies. The comparison participants performed better at entry on the lesson plan assessment, but at graduation the Fellows performed slightly better. In addition, the CLUSTER Fellows showed much more growth on the science content test, whereas the comparison participants' scores on that test actually declined. That may in part reflect the fact that the Fellows are still taking formal coursework in science and are continuing to be exposed to science and teaching science at NYSCI.

While it is difficult to make comparisons with small sample sizes, it is impressive that with less formal coursework and real-world experience and, at the point of post-testing, much less teaching experience (the comparison participants

Table 6. CLUSTER Fellows and comparisons' pre- and post-scores on assessments.

Assessment	CLUSTER Fellows-pre- mean (SD) N = 6	CLUSTER Fellows-post- mean (SD) N = 6	Comparison participants-pre- mean (SD) N = 18	Comparison participants- post-mean (SD) N = 18
Pedagogy – multiple choice	35.50 (13.28)	56.67 (4.95)	61.11 (12.45)	69.67 (11.94)*
Pedagogy-case studies	1.33 (1.14)	4.67 (1.00)	2.46 (1.11)	3.86 (1.06)
Lesson plan	1.17 (.45)	3.00 (.71)	1.63 (.81)	2.91 (.83)
Science content	58.33 (17.91)	72.00 (12.01)	74.53 (13.59)	70.41 (12.89)

* $p < .05$ (significant results from independent t-tests conducted between post-scores of Fellows and comparison participants)

had spent the previous two years working full time in the classroom), the CLUSTER Fellows kept at pace or outscored the comparison participants on three of the four post-assessments.

Longitudinal Growth of CLUSTER Graduates

Six CLUSTER graduates began full-time teaching in New York City public secondary schools during 2008–2009. As part of CLUSTER follow-up on the support of these teachers, the same college supervisor who had observed them as student teachers observed them in the classroom twice during the year. As student teachers, the graduates were observed using a protocol consisting of two parts: the standard protocol used for all science education student teachers at the college, and a second protocol that highlighted elements of the CLUSTER constructivist framework for teaching science. Table 7 focuses on a subset of the questions (8 out of 15) that relate most closely to the specific goals of the CLUSTER program. The final rating, Summary Evaluation Score, is calculated by averaging the 15 individual ratings of the college section of the observation protocol. It is therefore a good global measure of the observer's impressions of each teacher. Because of the small number of CLUSTER graduates being discussed here (6), no statistical tests were conducted. Table 7 compares the average ratings for the six CLUSTER graduates at three points in time: when they began their student teaching, when they finished their student teaching, and in the spring of their first year of full-time teaching. A notable trend is visible in these ratings: all improve over time, with the exception of two instances where there is no change (there is no change in the rating of "engages students' interest in science" between the first student teaching observation and the final student teaching observation, and there is no change in the average rating of

Table 7. College supervisor's observations (n = 6).
Scale: 4 = exemplary; 3 = acceptable; 2 = developing; 1 = unacceptable

Area	1st student teaching observation	Final student teaching observation	Final first-year teacher observation
Positive classroom management	2.83	3.17	3.75
Students propose/evaluate explanations	2.33	3.00	3.50
Focuses on major concepts and principles	2.40	2.67	3.25
Students design, conduct, report investigations	2.33	2.67	2.67
Uses student explanations, predictions to assess understanding	2.33	3.00	3.50
Successfully communicates the lessons' big idea	2.67	2.83	NA
Allows students to construct their own understandings	0.17	1.83	2.00
Engages students' interest in science	2.50	2.50	2.75
Summary Evaluation Score	2.37	3.11	3.43

“helps students to design and conduct their own experiments” between the end of student teaching and the spring of their first year as teachers). It may be that the graduates who are now employed as full-time New York City teachers find it difficult to enact and expand upon all aspects of inquiry-based teaching as they conform to curriculum requirements and other context limitations (see the “Observer’s reflections” below).

Observer’s reflections

Despite the overall improvement over time in the above ratings, the college supervisor who observed the CLUSTER Fellows, both as student teachers and as first-year teachers, notes that he actually saw less implementation of inquiry activities during their first year in the classroom than he had when he observed them as student teachers. He attributes this to the much broader demands confronted by teachers of record than by student teachers:

I do not find this backsliding at all surprising... Last year, their lessons were planned and hands-on equipment assembled with the help of their cooperating teachers, they were receiving daily feedback and modeling, and they had part-time schedules with few classroom responsibilities beyond actually teaching the lessons. This year, they are working full time and unassisted, handling extensive administrative burdens, planning every lesson (and perhaps trying to learn new science content themselves) for a full complement of

classes that may include multiple courses and in some cases unfamiliar curricula, all while devising tests, grading papers, preparing report cards, dealing with guidance issues, and so on. In addition, they know that . . . their future may depend on demonstrating to their principals and their peers that with little or no external help, they can maintain order in their rooms and keep up with the calendar. Thus, it is easy to understand why they might choose to stick to the kinds of lessons that make the smallest demands on their preparation time, energy, and classroom management skills. The good news is that this setback is probably temporary. Their understanding of (and hopefully their preference for) the inquiry approach is still there, and a year or two from now, when they are more accustomed to the workload and the curriculum, and feel more confident of their own skills, there is every reason to expect that they will begin to use more inquiry, and, because of their training, use it successfully. (The Center for Advanced Study in Education, 2009, p. 22)

Again, these findings are based on small numbers of participants and the impressions of one observer. However, the considerable experience of the observer gives us great confidence in the accuracy of the data, and the general trend across all of these ratings is clear. It seems reasonable to conclude that their participation in CLUSTER may be responsible for these differences.

DISCUSSION

Future science teachers learn science in college classrooms, which do not necessarily model scientific inquiry. Their actual field experiences are limited and generally provide little or no opportunity to observe and practice exemplary science teaching. Therefore, it is difficult for them to create and implement inquiry-based lessons. In urban public schools, it is often teachers who are not from the community who teach science classes. They struggle with managing classrooms and connecting to their students. The result is that the existing model of science teacher education is in need of reform, particularly in urban settings.

CLUSTER is a university-science museum partnership model intended to address the need for recruitment and preparation of future science teachers for urban schools. The students who attend CCNY are typically products of the New York City public school system and reflect the city's ethnic diversity. Future teachers are therefore recruited from the community in which they will eventually teach. As part of their college experience, they work in a museum setting in which scientific inquiry is natural and spontaneous. They interact with visitors of all ages about engaging in scientific activities. There is opportunity to repeat, practice, reflect, and enjoy all in a low-stakes environment.

As anticipated, the Fellows' experiences at the museum have enhanced their confidence with their communication skills, understanding of scientific inquiry, and enthusiasm for teaching. However, the training model has undergone significant refinement over time due to the Fellows' inability to make connections between their work at the museum and their university course work.

One modification has been the introduction and continued use of a unifying, clearly delineated teaching framework that facilitates connections between what the CLUSTER Fellows are learning in class and their interactions on the museum floor. Another major improvement in the model has been the use of audiotapes of the Fellows' interactions with museum visitors. During regular group meetings, the Fellows reflect on their practice as they play their audiotapes. The reflection and discussion about teaching practices is often continued in the blogs and social networking site that all Fellows participate in. In addition, the CLUSTER model has impacted the training for all Explainers at the museum. During workshops on science content at the museum, CLUSTER Fellows now build bridges between their own science learning and what they have learned about how to teach science.

Even with these features, there are still challenges that need to be navigated. How can Fellows transfer what they have learned in an open, exploratory, activity-based museum environment to a prescriptive, test-driven school environment? How can we help Fellows transition from working with small numbers of visitors who choose to spend a few minutes at an exhibit to teaching a captive group for a full class period? How can the model best prepare students to be urban science teachers when they have so many other demands on their time, such as completing science course requirements for their majors, and in some cases, working at other jobs, commuting, and parenting?

While preliminary, the results suggest that CLUSTER has positively impacted the recruitment and training of science teachers, particularly in an urban setting. CLUSTER Fellows are New York City college science students who, without the opportunity to participate in the CLUSTER program, may not have considered careers in teaching. They learn about interactive science settings, grow comfortable talking to large and small groups, and become reflective practitioners. They benefit from being part of a community of preservice science teachers. CLUSTER is an example of a preservice training program that has leveraged the wealth of opportunities that an informal science museum has to offer with respect to science teacher training.

As full-time teachers, CLUSTER Fellows experience the same challenges that all new urban teachers face, but they have a strong foundation on which to draw and build. Their relative success at engaging students, making connections, and focusing on student thinking is encouraging in light of the pressures they face as full-time teachers in New York City schools. The CLUSTER partnership has hopefully given the Fellows a strong indoctrination in effective, constructivist, and inquiry-based pedagogy that can withstand contextual assault.

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REFERENCES

- Association of Science-Technology Centers. (2007). *ASTC sourcebook of statistics & analysis*. Washington DC: Author.
- Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments: People, places and pursuits*. Washington, DC: National Research Council of the National Academies.
- Bevan, B. (with Dillon, J., Hein, G. E., Macdonald, M., Michalchik, V., Miller, D. et al.). (2010, March). *Making science matter: Collaborations between informal science education organizations and schools. A CAISE Inquiry Group Report*. Washington, DC: Center for Advancement of Informal Science Education (CAISE).
- The Center for Advanced Study in Education. (2009). *CLUSTER Advisory Board Report Year 4, 2009*. New York: Author.
- Darling-Hammond, L., Hammerness, K., Grossman, P., Rust, F., & Shulman, L. (2005). The design of teacher education programs. In Darling-Hammond, L., & Bransford, J. (Eds.), *Preparing teachers for a changing world* (pp. 390-441). San Francisco: Josey-Bass.
- Davis, E., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, 76, 607–651.
- Educational Testing Service (2005). *Praxis II Test Preparation*. Retrieved from <http://www.ets.org/praxis>
- Fazio, X., Melville, W., & Bartley, A. (2008, March). *The role of the practicum experience in supporting secondary pre-service teachers implementing inquiry-based science*. Paper presented at the annual international conference of the National Association of Research in Science Teaching, Baltimore, MD.
- Feldman, P. & Kent, M. (2006). A collaborative effort: Bridging theory and practice in pre-service preparation. *The New Educator*; 2, 277–288.
- Falk, J. H. (Ed.). (2001). *Free-choice science education: How we learn science outside of school*. New York: Teachers College Press.
- Luehmann, A. (2007). Identity development as a lens to science teacher preparation. *Science Education*, 91, 822–839.
- Roth, W. M., Lawless, D. V., & Masciotra, D. (2001). Spielraum and teaching. *Curriculum Inquiry*, 31, 183–207.
- Roth, W. M., & Tobin, K. (Eds.). (2007). *Science, learning, identity: Sociocultural and cultural-historical perspectives*. Rotterdam: Sense.
- Sewell, W. H. (1992). A theory of structure: duality, agency, and transformation. *American Journal of Sociology*, 98, 1–29.
- Wang, J., & Odell, S. J. (2002). Mentored learning to teach according to standards-based reform: A critical review. *Review of Educational Research*, 72, 481–546.