A College – Science Center Partnership for Science Teacher Preparation

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Abstract

This partnership between a college and a science center addresses the need to improve the recruitment and preparation of science teachers in an urban setting. We describe the integrated teacher preparation model where undergraduate science majors simultaneously participate in the City College of New York science teacher preparation program and serve as interns on the museum floor at the New York Hall of Science. We report on how graduates of our program are prepared to teach science and how they performed in the classroom. We found that the program was successful at recruiting students from the communities in which they intend to teach and successful at preparing them to teach inquiry-based science.

Introduction

The need for improved science teacher preparation has long been recognized (AAAS, 1990; Martin, Mullis, Gonzalez & Chrostowski, 2004; National Research Council (NRC), 2000a; NRC, 2010a; NRC, 2010b; NRC, 2012). Informal science centers provide families, students, and teachers rich opportunities to experience science learning in inquiry-based ways that are connected to everyday life (NRC, 2009). Research has indicated that science teacher candidates can benefit from informal science experiences and that these experiences can positively impact their pedagogical content knowledge, their views on the nature of science, and their understanding of reform-based science teaching methods (Harlow, 2012; Reideinger, Marbach-Ad, McGinnis, & Hestness, 2011). Partnerships between institutes of higher education and informal science centers have been effective at improving science education for teachers (e.g. Anderson, Lawson, & Mayer-Smith, 2006; Picciano & Steiner, 2008; Bevan & Dillon, 2010; Miele, Shanley, & Steiner, 2010), but these partnerships have not integrated preservice science teachers practicing as science educators in museum settings.

The National Council for Accreditation of Teacher Education (NCATE) notes that the traditional, primary model of teacher preparation is not able to meet the challenges facing education today (NCATE, 2010). They recommend, “creating a system built around programs centered on clinical practice” (p. 5). Science centers can provide low stakes classroom-like opportunities to practice the teaching of science utilizing inquiry. They provide a context where the practice can be focused on specific elements of the teaching of science through learner engagement with scientific activity. Such “deliberate practice” can lead to the acquisition of expert performance (Ericsson, 2008). Grossman (2008) has described this in terms of “approximations of practice” where novice teachers can practice elements of interactive teaching in settings of reduced complexities.

Modeled to an extent after medical residency training programs, a major difference between traditional preparation models and many alternative pathway teacher preparation models is the degree of emphasis on clinical experiences combined with intensive coaching and feedback. Quantitative research results about the efficacy of these models on teacher effectiveness and student achievement are scant to date. However, one of the few independent evaluations of the effectiveness of residents from an Urban Teacher Residency program suggests some promising results. The study found that graduates were more likely to remain teaching in the district after five years compared to other novice teachers (Papay, West, Fullerton, & Kane, 2011). Even more interesting was the finding that while the graduates are neither no more effective nor less effective at increasing student achievement compared to novice teachers, they out-performed veteran teachers in math by their fourth and fifth years of teaching (Papay et. al., 2011). In addition, there is evidence that teacher retention rates are higher in these programs and anecdotal evidence indicates that the infusion of the clinical component has made the learning more relevant to teacher trainees (Berry, Montgomery, & Snyder, 2008).

The collaboration described in this paper began with the recognition of the need for improved science teacher preparation utilizing improved clinical experiences, the value of developing science inquiry skills in informal learning environments, and the possibilities of leveraging deliberate practice with science instruction coupled with structured feedback and coaching. Furthermore, according to the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, the United States should double the number of underrepresented minority students who receive degrees in STEM (NRC, 2011).

The context of this project is an urban environment, where there is a majority of underrepresented minority students, and where science centers are prevalent. The pedagogical focus of our work is an inquiry-based approach to science learning. The importance of inquiry to the meaningful learning of science is well understood (NRC, 2000b, Steinberg, 2011), particularly for a diverse urban student population such as ours (e.g. Lee, Buxton, Lewis, & LeRoy, 2006).

Forging a Partnership

CLUSTER (Collaboration for Leadership in Urban Science Teaching, Evaluation, and Research) is a model partnership for science teacher preparation between a college and a science center. CLUSTER was born in the common interests among science educators at City College of New York (CCNY) and the New York Hall of Science (NYSCI). NYSCI has a system where they train and work with employees to constructively support museum visitors interacting with hands-on exhibits. (These employees are called “Explainers.”) CCNY has an inquiry-based teacher certification program where undergraduates simultaneously earn a bachelor’s degree and high school science teacher certification.

CLUSTER started with a series of informal meetings focusing on a shared vision of CCNY science teacher candidates honing their skills in the teaching and learning of science on the museum floor at NYSCI. These meetings led to the plan for recruitment, collaboration, and training described below which recognized the strengths of each institution. We also focused on a process of ongoing dialogue and assessment to adapt the program as we learned.

We based CLUSTER on the premise that the synergy between formal and informal science education institutions could be more effective than traditional college-based preservice teacher preparation alone. CLUSTER is designed to leverage the opportunities available for the teaching and learning of science at a science center while connecting those experiences to formal college coursework. The science center allows students to observe and practice inquiry-based science teaching in a low stakes, high volume environment with mentoring, feedback, and coaching.

Description of Participants

A total of 61 students (“CLUSTER Fellows”) enrolled in CLUSTER. All were undergraduate science majors taking courses at CCNY. They were recruited with flyers describing the merits of CLUSTER, through faculty and staff advisement, and through a project webpage. Most were willing to explore careers in teaching science largely because of the opportunity to participate in CLUSTER. All had roots in New York City. This is particularly noteworthy as we recognize the importance of teachers being of the community in which they teach (Steinberg, 2011).

The diversity of the CLUSTER Fellows reflected the diversity of New York City and are exemplified by the following students. There were 17 who described themselves as Asian / Pacific Islander, 15 as Hispanic, and 7 as African American. (These were the 3 most often identified ethnicities.) Almost 70% were fluent in more than one language. The most frequently cited language was Spanish, followed by Chinese. Other languages included Swahili, Urdu, and Bengali.

CLUSTER Fellows also had a diversity of circumstances and trajectories. Jeanette, Laura, Isabel, and Maria (pseudonyms) were all biology majors who completed CLUSTER together, became public school science teachers at the same time, and enrolled in the same graduate school to study science education together. Brendalyz was an energetic, friendly biology major who had to tearfully withdraw from CLUSTER for personal reasons. She later became a kindergarten teacher in a charter school in Harlem. Mahmuda was a chemistry major who completed CLUSTER despite her focus on going to graduate school to study chemistry. However, after starting graduate school, she realized her main ambition was to teach so she withdrew and became a New York City public school teacher. Najeeb was a Fellow who survived war tragedy and serious illness in his native Africa. He completed a physics major with honors as well as a teacher certification program at CCNY and attended an elite graduate physics Ph.D. program. Shy by nature, participating in CLUSTER helped Najeeb grow comfortable communicating scientific ideas with others.

Description of Participant Experiences

The CLUSTER experience is summarized in Table 1. Fellows participated both as students in the CCNY science teacher certification program and as Explainers in the NYSCI Career Ladder program. At CCNY, Fellows majored in one of the sciences plus took the standard education courses and student teaching, which led to a minor in science education and secondary science teacher certification. Special sections of the education courses were established in which college instructors visited the museum to acquaint themselves with the field site. In addition, the science methods and curriculum classes were co-taught by CCNY and NYSCI staff. This took various forms, including being in the class at the same time, developing lessons and activities where students explored course content in the context of the museum, and discussing common issues of learning science on the museum floor and in the formal classroom.

Table 1 (Click on image to enlarge)

Summary of CLUSTER Fellow Experience

City College of New York	New York Hall of Science	Additional Support
Required education courses for science teacher certification	Paid internship at museum working at exhibits, demonstrations, and after school programs*	Stipend*
Student teaching	Weekly professional development sessions	Infusion of conceptual framework
Academic advising	Workshops	Reflective coaching
** Most CCNY students need to work while going to school*		

As Explainers, Fellows worked on the floor of the museum shepherding busloads of students, presenting the museum's over 400 exhibits to visitors, conducting science demonstrations for groups of visitors, and assisting in after-school programs. Explainers typically received one-hour of professional development each week from the museum in areas such as exhibit content, presentation skills, and engagement tools. Fellows were expected to work a minimum of seven hours each week as Explainers, and they averaged over 600 hours total, typically over 2 years. Additional CLUSTER program components included a semi-annual stipend, orientation sessions for new participants, and typically one Saturday workshop per semester on various topics.

CLUSTER was organized around a framework of inquiry-based science teaching. The framework served as a conceptual anchor for the Fellows bringing together their college and museum experiences. It was primarily derived from the 5E learning cycle and instructional model (Bybee, 1997), but it was adapted through multiple iterations based on the shared vision of CCNY faculty and NYSCI leadership along with feedback from Fellows in order to match the vision and execution of CLUSTER. The framework was composed of the following components: 1) Identifying the Big Idea; 2) Engagement Strategies; 3) Making Student Thinking Visible; 4) Introduction of New Science Ideas; 5) Reflection / Assessment.

There were also weekly small group meetings for Fellows at the museum. In these meetings, the Fellows reflected upon their experiences on the museum floor in light of inquiry-based teaching methods and other theoretical considerations emerging from their education courses. Education courses focused on student learning by constructing scientific understanding through observation and reasoning.

Fellows employed a cycle of practice-reflection-practice linked to their work at the exhibits. Typically, they would audiotape themselves at an exhibit interacting with visitors, and choose one or more of these interactions to share with and discuss in the small group. They would then utilize the suggestions they received in their work on the floor. Fellows also contributed to a CLUSTER blog site, where they continued to share their experiences and develop their thoughts on a wide range of education issues ranging from the scientific content of an exhibit to what questions to ask to working with visitors of different ages.

Our qualitative observations of these participant experiences are that the net effect was a valued community of Fellows with a coordinated and constructive set of activities. They saw value in this community, which contributed to retention (many of the Fellows were close during participation in CLUTSER and for many years after), further recruitment (most of the new Fellows had heard about CLUSTER through those already in the program), and growth as science educators (as evidenced in the section below).

Program Assessment

The assessment design addressed the general question of whether the CLUSTER program produced highly qualified science teachers in terms of their science content knowledge, pedagogical content knowledge, and classroom instructional practice. Emphasis was placed on participant preparation for implementing inquiry-based teaching strategies. The approach was a study of the growth and development of the CLUSTER Fellows. All participants were tracked from the time they started the two-year program (at approximately the beginning of their junior year) until they graduated. A subset was observed during their first year of teaching. All graduates received a follow-up survey after graduation. Not all of 61 CLUSTER Fellows participated in all assessments. The results described in this paper include all existing data and span the domains detailed below.

Science Content Knowledge

All of the Fellows were science majors in good academic standing at the time they began the program. By the time they graduated, most Fellows for whom grades were available had an overall GPA of 3.0 or better (44 of the 57). The average GPA for graduates was 3.2. In addition to their coursework, Fellow experiences at the science museum contributed to their science content knowledge. Explainers are expected to become familiar with all exhibits, so Fellows working at the exhibits were expected to learn content in science areas distant from their own majors. As Explainers learn the content of a particular exhibit, they have the opportunity to be mentored and certified by experienced museum staff who have extensive experience with that exhibit. Certification at an exhibit allows Explainers to work with visitors. If found proficient by senior staff, Explainers earn “buttons” which entitle them to a pay raise. Similarly, they could qualify to conduct one of ten regular demonstrations or several temporary ones housed in mobile carts throughout the museum, as well as lead a lab in DNA extraction. In the course of their tenure at the museum, CLUSTER Fellows earned on average one button, and qualified to teach three different demonstrations and the lab.

Science Pedagogy Knowledge

CLUSTER Fellows were given multiple pre- and post- assessments in the area of science pedagogy. These included a pedagogy multiple-choice exam that was based on the Praxis II Learning and Teaching assessment, an open-ended response to a pedagogy case study, and a lesson plan assignment. Each of these assessments and the results obtained are described below.

Pedagogy multiple choice assessment and case study. The pedagogy multiple choice assessment and case study were adapted from the Praxis pedagogy and learning test that is used by many state education agencies in the United States to make decisions regarding the licensing of new teachers (Educational Testing Service, 2005). The areas assessed come from educational psychology, human development, instructional design, assessment, and other teacher preparation topics (Educational Testing Service, 2005). For our purposes, a sample test from Cracking the Praxis (Stewart & Sliter, 2005) was adapted to include 24 multiple-choice questions and one case history.

The 24-item pedagogy multiple-choice assessment was scored as the percentage correct. CLUSTER Fellow scores increased from 43 +/- 17 percent on the pretest to 63 +/- 16 percent on the posttest.

The pedagogy case study described a high school science class in which a subset of students had a variety of learning issues. Each open-ended response was graded from 0 to 2, as outlined by Education Testing Service. A rating of “0” to a question response indicates that the student demonstrated “little knowledge of pedagogical concepts, theories, facts, procedures or methodologies relevant to the question” and “failed to respond appropriately to the question.” A rating of “1” indicates that the response demonstrated “some knowledge” of the above and was appropriately responsive to one part of the question.” A rating of “2” indicates that the response demonstrated “strong knowledge” of the above and was appropriately responsive to all parts of the question. The three scores were then summed, for a possible total score of 6. CLUSTER Fellow scores increased from 1.9 +/- 1.1 on the pretest to 3.9 +/- 1.4 on the post-test.

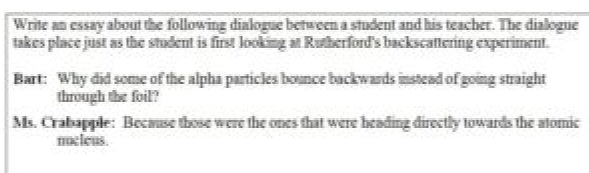
Lesson plan analysis. Similar to the PRAXIS II assessment, Fellows were given 30 minutes to write a lesson plan corresponding to their area of concentration (biology, chemistry, earth science, or physics) that would allow students to master some of the competencies required to answer a question on a the New York State exit exam. The lesson plans were graded by an external consultant who is a science educator with extensive expertise in reviewing lesson plans. Plans were rated according to a modified rubric adapted from Newmann, Secada, and Wehlage (1995). The final capsule lesson plan rating ranges from 1 to 4.

CLUSTER Fellow scores increased from 1.8 +/- 1.0 on the pretest to 2.9 +/- 0.83 on the posttest. CLUSTER Fellows' post-lesson plans were much more accomplished than their pre-lesson plans, building in group work, inquiry-based learning, and assessment of prior knowledge. However, the post lessons did not always include activities that were more student-centered. In addition, while the lessons included assessment of prior understanding, the lessons did not adjust for those understandings.

Teacher-Student Discourse Analysis

The Teacher-Student Discourse assessment, developed for this project, is shown in Figure 1. Twenty-four Fellows completed this assessment both before and after participation in CLUSTER. Each essay about the fictitious dialogue was interpreted through two dimensions relevant to science education. For each of these two dimensions, student responses were scored on a 4-point scale, with "1" being the lowest score and "4" being the highest.

Figure 1 (Click on image to enlarge). **Teacher student dialogue assessment given to CLUSTER Fellows prior to and after their CLUSTER experience.**



Write an essay about the following dialogue between a student and his teacher. The dialogue takes place just as the student is first looking at Rutherford's backscattering experiment.

Bart: Why did some of the alpha particles bounce backwards instead of going straight through the foil?

Ms. Crabapple: Because those were the ones that were heading directly towards the atomic nucleus.

The first dimension is "awareness of instructional practice." Did Fellows recognize that Ms. Crabapple is not providing Bart with the opportunity to figure out the answer scientifically, but rather is acting as a passive provider of information? A score of 1 indicates that the Fellow's response focused on more explanation being needed. A score of 4 indicates that the Fellow identified that Ms. Crabapple is simply stating an answer without guiding the student to a proper understanding through reasoning and interpretation. The average Fellow score on this dimension increased from 1.29 +/- 0.75 to 2.79 +/- 1.1.

We refer to the second dimension as “backwards science / forward science” (Arons, 1976). In this dialogue, the teacher’s response suggests that the scientific reasoning for the phenomenon should be understood prior to the observation that leads to the understanding of that very phenomenon. Here a score of “1” indicates that the Fellow failed to recognize that the teacher is providing a response by assuming that which she is trying to prove rather than engaging in the scientific process of theory building with the student. A score of “4” indicates that the Fellow recognized that the teacher’s response should include promoting building an inference based upon the observed phenomenon. The average Fellow score on this dimension increased from 1.29 =/- 0.55 to 1.79 =/- 0.83.

The second dimension was more difficult for the students and was not a topic explicitly covered anywhere in the Fellow experience. The scores on both dimensions can be combined to create a summed score for both pre and post. The summed score improved from 2.58 to 4.58.

Exhibit Audio Tape Analysis

Audio-tapings of Fellows “explaining” at one exhibit were made in order to explore their growth in the program. The Light Island Exhibit consists of a table with several light sources and objects that can be manipulated: a mirror, a prism, lenses, and colored filters. Its purpose is to demonstrate light absorption, transmission, reflection, and refraction. Fellows taped themselves as they interacted with visitors at the exhibit, using an unobtrusive voice activated audio taping device that clearly recorded the Fellows and less clearly recorded the visitor. Fellows shared their tapings with their coaching groups, and discussed ways of improving their performance.

The purpose of these tapings was to see if there were noticeable changes in Fellows’ interactions with museum visitors, particularly in the use of skills related to inquiry-based science instruction. The children they interacted with were completely free to leave the exhibit at any time, and many did so after only a few minutes. The first recording was made within the first two months of starting in the program, with additional tapings approximately every six months thereafter.

We analyzed the first and last recordings of all 19 Fellows who had recordings that were at least eight months apart. The average time between tapings was 15-months. Transcripts were analyzed blindly (dates and names removed). They were coded for ten inquiry strategies that were related to the CLUSTER framework. These ten strategies span inquiry approaches critical to instruction and connected to the framework given at the beginning of this paper. Scores were given on a scale of 1 (not at all employed) to 3 (employed to a high degree).

Table 2 details the ten science inquiry strategies and the first and final coding means. The difference in the means of eight of the ten strategies reached statistical significance. The largest improvements were seen in relating the exhibit to the learner’s life or to the wider world (number three) and in the use of comprehensible discourse, suitable to the age and language ability of the learner (number six).

Table 2 (Click on image to enlarge)

Mean Ratings for Discrete Strategies

First and Last Audio Tapings (n=19) Rating Scale Ranged From 1 – Not at all employed to 3 – Employed to a high degree			
To what extent to the Explainer:	**1st taping mean**	**Final taping mean**	**Significance (p value) of T-test (2-tailed)**
1. Successfully draw the learner in and make them feel comfortable.	2.32	2.63	.03
2. Probe for prior knowledge.	1.74	2.26	.02
3. Relate the exhibit to the learner's life or the wider world.	1.53	2.32	.00
4. Provide explanations of science facts that are clear and accurate.	1.84	2.16	.16
5. Let the learner lead, give them choices about what to do.	1.42	1.79	.19
6. Use discourse that is comprehensible, and suitable to the age and language ability of the learner.	2.11	2.74	.01
7. Listen carefully to the learner, and follows up on their comments or questions.	1.79	2.26	.00
8. Ask the learner to make a prediction about what will happen.	2.16	2.21	.72
9. Ask the learner to describe what they see.	1.89	2.11	.00
10. Frame the conversation with a "big idea."	1.68	1.79	.00
Sum of 1 – 10 above	**18.47**	**22.26**	**.00**

In the course of the program we hypothesized that participation may have a positive effect on the ability of English Language Learners (ELL's) to communicate orally in English. Of the Fellows in this sample, 4 of the 19 were classified as ELL's. The scores of the 4 showed improvement in the majority of categories. Given the language intensive nature of the taped interactions, these findings provide some support for the contention that the relatively intensive interactions in English at the exhibits, particularly over longer periods of time, can contribute to an improvement in the ability of ELLs to foster scientific inquiry in English.

Analysis of these recordings was complicated by the wide range of visitors with whom Fellows interacted at exhibits, particularly in terms of age. Almost all of the ratings focused on the extent to which the Fellow was able to engage the visitor in meaningful conversation about the exhibit. Very young visitors were generally unable to participate at this level through no fault of the Fellow, and hence recordings of interactions with 4 and 5-year olds routinely received lower ratings than did those involving older visitors. In spite of limitations such as this, ratings improved as the Fellow persisted in the program, and the longer between tapings, the larger the improvement.

Classroom Observations

Six CLUSTER graduates were observed four times each in their secondary science classrooms by the same college supervisor who had observed them as student teachers. Table 3 compares their classroom performance 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 teaching. CLUSTER graduates continued to show improvement in their classroom practice through their CLUSTER experience and into their first year as teachers.

Table 3 (Click on image to enlarge)

Mean Ratings From Classroom Observations

Classroom Observations (n=6) Rating Ranged From: 1 = Unacceptable to 4 = Exemplary			
Area	1st student teaching observation	Final student teaching observation	First year teacher observation
1. Positive classroom management	2.83	3.17	3.75
2. Students propose/evaluate explanations	2.33	3.00	3.50
3. Focuses on major concepts and principles	2.40	2.67	3.25
4. Students design, conduct, & report investigations	2.33	2.67	2.67
5. Uses student explanations, predictions to assess understanding	2.33	3.00	3.50
6. Successfully communicates the lessons' big idea	2.67	2.83	NA
7. Allows students to construct their own understandings	0.17	1.83	2.00
8. Engages students' interest in science	2.50	2.50	2.75
Summary Evaluation Score	2.37	3.11	3.43

CLUSTER Graduate Status

Fellows who graduated having completed the full CLUSTER program are referred to as Track A graduates. Fellows who graduated having partially completed the CLUSTER program are referred to as Track B graduates. (Track B graduates successfully completed their Bachelor's Degrees, but did not complete all of the education courses which lead to teacher certification.) There are 22 Track A graduates and 39 Track B graduates. Table 4 shows follow up status of Fellows from each track. Results are based on a follow up survey and individual interviews.

As indicated in Table 4, the vast majority of the CLUSTER graduates for whom we have information became educators or intend to become educators. Nineteen became teachers of record in urban classrooms. In addition, six graduates went on to work in other education-related jobs such as a tutor in a non-profit, a high school science teaching assistant specialist, and an educator in a science museum. Of the remaining graduates for whom we have information, seventeen were either looking for teaching positions or have explicitly indicated that they intend to pursue a teaching position in the future. Most of these participants were in graduate school after graduating CLUSTER. Only two CLUSTER graduates indicated that they do not intend to pursue a career in education.

Table 4 (Click to enlarge image)

Cluster Fellow Graduate Status

Graduate Status (n=61)			
Area	Track A	Track B	Total
Teacher of record in urban classroom	14	5	19
Educator, not teacher of record in urban classroom	1	5	6
Seeking teaching position / intends to teach	5	12	17
Does not intend to teach	0	2	2
Unknown	2	15	16
Total	22	39	61

Conclusions

The CLUSTER model was developed to address the need for highly qualified inquiry-based science educators for and from diverse urban communities. Its major innovation was to bring together a public undergraduate college program and an informal science center. This allowed for strategic implementation of meaningful clinical experiences with inquiry education through execution of repeated low stakes deliberate practice.

Our results indicate that the program succeeded in the development of an experience that gave participants the necessary foundation and tools to implement inquiry-based science education. We have found that the model recruits quality candidates into science teaching, that the candidates recruited are from the communities in which they intend to teach, that participants have the opportunity to develop effective science teaching strategies, and that graduates perform well in the classroom. We believe that the model of informal-formal education partnership is an effective way to support science teacher recruitment and preparation, and many of the elements above can be implemented even with a more limited partnership. This model is transferable to other institutions, and matches emerging trends in science teacher education.

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