

Impact of a multi-institutional curriculum development project on disciplinary science faculty

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Abstract

Despite significant pressure to reform science teaching and learning in K12 schools, higher education science content courses have remained relatively static. Disciplinary science faculty have few opportunities to explore research on how people learn, examine state or national science teaching standards for K12 schools, or learn and practice research-based instructional strategies. The contrast between what is expected of future and practicing teachers in their K12 classrooms and what they experience in content and instruction in typical college or university science courses can be quite striking. This study addresses the impact of a multi-institutional collaboration among disciplinary science faculty to develop undergraduate content courses for future elementary teachers in biology and geology. We report evidence of faculty change in three key areas: (1) Knowledge and beliefs about science teaching and learning; (2) Knowledge and beliefs about K12 teachers and teaching; and (3) Knowledge and beliefs about collaborative practices of effective groups. We also describe evidence of institutional changes initiated and implemented by the faculty as a consequence of the curriculum development project.

Introduction

Despite significant pressure to reform science teaching and learning in K12 schools, higher education science content courses have remained relatively static. Disciplinary science faculty have few opportunities to explore research on how people learn, examine state or national science teaching standards for K12 schools, or learn and practice research-based instructional

strategies. The contrast between what is expected of future and practicing teachers in their K12 classrooms and what they experience in content and instruction in typical college or university science courses can be quite striking (Darling-Hammond and Bransford, 2005).

Few teacher preparation programs have yet to respond adequately to the subject matter needs of future elementary teachers. Current science distribution requirements at most colleges and universities do not provide a coherent learning experience grounded in the subject areas elementary teachers will teach. Many programs require future elementary education majors to take three “introductory” science courses from a broad menu of topics and disciplines. These courses are often survey courses that provide a superficial treatment of many topics within a discipline. Lecturing is the predominant instructional strategy used and material is covered at a rate of nearly a chapter a day. Smaller laboratory sections are often included in these courses, but are rarely aligned with the content in the lectures themselves. As a consequence, future elementary teachers are not being provided the opportunity to develop deep, conceptual understanding of relevant content, nor are they able to observe instruction that applies the recommendations of research findings on how people learn. Furthermore, variations of these courses are often adapted for inservice teachers, continuing the disconnect between content courses and the demands of elementary educators.

A major impediment to overcoming these deficiencies has been the lack of science instructional materials for use in teacher education that reflect current research on teaching and learning, particularly materials that have been studied to provide evidence of learning. A review of “reformed” introductory science content courses from many institutions across the nation revealed that though revisions led to reorganization of content, introduction of thematic approaches, or inclusion of group work and more interactive instructional approaches, few

systematically applied cognitive science research findings to their instructional design. Even fewer implemented thorough research or evaluation studies to measure the impact of the revised courses. Even when quality materials are available, to achieve positive student outcomes requires a learner-centered pedagogical approach that few higher education faculty have had the opportunity to learn and practice.

More than any other discipline group, the physics education community has applied research findings on how people learn to the design of instructional materials for teachers of science (see for example, Goldberg, 2005; Laws, 1996; McDermott, 1996). In both Life and Earth Science there are only a few examples of reformed introductory courses informed by research on How People Learn (Lawson et al., 2002; Chaplin and Manske, 2005). In most cases, these courses target non-science majors but do not focus specifically on the needs of future elementary teachers. Moreover, unlike the physics materials, the instructional materials for these courses are not commercially available.

Faced with a lack of cohesive, constructivist curricula in Life and Earth science, a group of disciplinary science faculty from five higher education institutions took on the task of developing undergraduate content courses for future elementary teachers in biology and geology. The development of these curricula required that the higher education faculty delve into the research on how people learn, study state and national science education standards, and understand the complexities of constructivist-based curriculum, instruction, and assessment. The purpose of this study was to determine the impact of the curriculum development process on participating higher education science faculty and their institutions.

Context

The North Cascades and Olympic Science Partnership (NCOSP) is a National Science Foundation (NSF) funded Math and Science Partnership located in northwest Washington State. The primary goal of the partnership is to improve science teaching and learning in both the K-12 and preservice context. NCOSP includes twenty-nine disciplinary science faculty from five higher education institutions. The project is managed by Western Washington University, a regional comprehensive university (RCU) and the state's largest producer of new teachers. At this RCU, scientists from departments of biology, geology, chemistry, and physics are also faculty members in the Science, Mathematics, and Technology Education program (SMATE) where they form the Science Education Group. SMATE faculty members are actively engaged in research and teaching in their disciplines *and* science education. One-half of their time is dedicated to their work in the SMATE program where they are responsible for teaching all of the science education courses at the undergraduate and graduate level, including the elementary and secondary science teaching methods courses, supervision of science teaching field experiences for all preservice teachers, and supervision of student teaching for all future secondary science teachers.

NCOSP brought SMATE faculty together with the science faculty from neighboring community colleges based on geographic proximity to WWU and transfer student enrollment patterns. Three community colleges were selected because nearly 50% of teachers certified through the RCU begin their higher education experience at these partner institutions. A local tribal college was also included based on its proximity to the RCU, its growing interest in developing a teacher education program, and its potential to prepare diverse teachers. The

community college faculty were full partners in the design, development, testing, and implementation of the new science courses.

Study Design

The study took place over a three year period from 2004-2006. During that period, faculty were engaged in three major activities with respect to this work: (1) Professional development on science teaching and learning; (2) Curriculum development based on current research on how people learn; and (3) Curriculum implementation and approval to institutionalize the new courses.

Professional Development

Professional development was designed to develop understanding of: (1) research on how people learn (Bransford et al., 1999); (2) K12 science content standards and adult science literacy targets (AAAS, 1993; NRC, 1996; AAAS, 2001a); (3) instructional materials design (AAAS, 2001b); (4) constructivist-based pedagogy (Schulman, 1986; NRC, 1999); and (5) strategies for establishing and sustaining an effective collaborative group (Garmston and Wellman, 1999). Implementation took place in a variety of settings including regular 1-2 hour meetings of the entire faculty or specific discipline groups; half or full day experiences to explore instructional materials or new pedagogical strategies; and multi-day immersions for testing and revising instructional materials in the development process.

Year one focused largely on exploring research on how people learn and defining “big ideas” for the future courses based on K12 science content standards and adult literacy goals (AAAS, 1989; AAAS, 1993; AAAS, 2001a; NRC, 1996). Existing research-based instructional

materials were explored late in Year One and on into Year Two to understand the relevant structure of research-based materials, as well as the associated pedagogy (Goldberg et al., 2005; Laws, 1996; McDermott, 1996). Throughout Year Two, faculty worked largely in disciplinary groups to develop instructional materials and to explore and develop new skills in pedagogy and assessment. In Year Three all courses were ready to pilot in the undergraduate setting. Faculty focused on developing their pedagogical skills and revising the materials based on examination of student work and course assessments.

Professional development for faculty also resulted through adapting and implementing the curriculum materials for the NCOSP Summer Academy, a two week professional development program for inservice teachers. In August 2004, 2005, and 2006, teams of higher education faculty and experienced K12 teachers used the instructional materials with practicing K12 teachers as part of the two week academy curriculum. The Summer Academies provided an opportunity to develop and expand pedagogical skills, as well as strengthen collaboration among participating faculty and K12 teachers.

The professional development plan also specifically addressed establishing and sustaining an authentic partnership. In addition to experiences focused on doing the work, norms and principles were developed to define “how” to do that work (Garmston and Wellman, 1999). Over the course of Year One, NCOSP Leadership facilitated the development of “Principles of the Partnership” to serve as guiding principles for all aspects of the project. The principles defined the values and beliefs held within the partnership with respect to organization, collaboration, research, learning, and equity and offered observable and measurable behaviors or actions associated with each of those principles. Working groups throughout the partnership,

including the higher education faculty, informed the development of the principles and aspired to put them into practice in their ongoing interactions.

Curriculum Development

The Physics for Everyday Thinking (PET; formerly referred to as Physics for Elementary Teachers) curriculum is a one-semester, research-based curriculum designed to address physics content knowledge, as well as an appreciation of the nature of science, the development of children's ideas in science, and the process of learning itself. These materials have recently been published and are commercially available for use in preservice settings.

PET is divided into multiple "cycles" that each develop 1-2 big ideas. Each cycle further develops the ideas from the previous cycles with increasing sophistication and introduces new ideas as students demonstrate the necessary prerequisite knowledge. The purpose of the cycle is clearly defined at the beginning to make the learning target explicit. A repeating sequence of experiences then begins where students are asked to record their initial ideas to elicit their preconceptions. Then, they engage in a series of activities, experiments, and simulations to generate evidence upon which to build a deep foundation of factual knowledge. Students interpret and make meaning of that evidence through summarizing questions, first individually, then facilitated either as small group or whole class discussions. This process allows them to deepen their factual knowledge, while at the same time build a conceptual framework for organizing that knowledge. Each cycle culminates with learning commentaries where students reflect on their preconceptions and their newly formed knowledge and consider how they came to develop deeper, more scientifically accurate understandings. These materials were adopted

for the physical science component of the year long course and provided a model of instructional material design that informed the development of the Life and Earth science curricula.

The faculty divided into content specialties to develop the Earth and Life science courses. To develop the curricula, faculty used a “backward design” process (Wiggins and McTighe, 1998). The process began with identification of the “big ideas” important for future elementary teachers to support student learning in science. Faculty consulted several state and national documents, including the Washington State Grade Level Expectations and Essential Academic Learning Requirements (OSPI, 2006), the National Science Education Standards (NRC, 1996) and the Benchmarks for Science Literacy (AAAS, 1993) to identify those “big ideas.” Once the big ideas were established they were fleshed out with sub-ideas pertaining to each. These sub-ideas were used to identify the key concepts critical to each curricula. The curricula were developed to specifically expose and confront common misconceptions (Driver et al., 1994; AAAS, 1993) and build a more scientifically accurate understanding of each key concept, while also establishing their connection to the big ideas.

Curriculum approval and institutionalization

At the RCU the courses were reviewed and approved by the curriculum committee of the College of Sciences and Technology, the College of Education, and the university curriculum committee. The review involved examination of detailed course syllabi and response to questions from the committees by the content faculty. The courses were approved as satisfying the general university requirements in science for the bachelor’s degree. The courses also were approved as a part of the revised course requirements for the BAEd degree in General Science and were listed as highly recommended for student majoring in Elementary Studies. The

geology and biology departments agreed to recognize the courses as satisfying prerequisite requirements for entry into the major course sequence.

At the community colleges, the courses were approved by comparable committees as satisfying the science distribution requirements for the Associate in Arts degree. The course credits also were approved to transfer as laboratory science credits towards the bachelor's degree in a four year institution.

Methods

The data were collected through the ongoing research and evaluation of NCOSP. For this study, we utilized a one-group posttest-only design that included analyses of surveys and interviews (Shadish et al., 2002) to assess the outcomes of the professional development and curriculum development experiences on the higher-education faculty. Since this research was conducted within the context of a Math Science Partnership, a variety data sets were available for analysis. The data sets were collected for a variety of evaluation purposes, only some of which directly addressed the research questions addressed in this study. However, even though some of the data were collected for other explicit purposes, evidence for the impact of the curriculum development on participating higher-education faculty was available in sections of several surveys and interviews detailed below.

Analyses of the data were primarily conducted by the NCOSP internal evaluation team and the external evaluation team at Facets Inc. Instances where analyses were conducted by parties other than the aforementioned are noted in the subsequent sections. Qualitative data, in the form of open-ended responses to survey or interview questions, were examined using thematic analyses. Thematic analysis is a process of encoding qualitative information, which can be used with any form of qualitative data (Boyatzis, 1998). Themes were generated through a

data-driven “grounded” approach, where the themes emerged from the data through careful analysis (Strauss and Corbin, 1990).

Annual Partnership Survey

The goal of the partnership survey instruments was to measure the partnership itself at various points in time, to understand how it was evolving, to measure its success in targeted aspects, and to look for evidence of sustainability. The partnership survey measured changes in understanding of individual roles within the partnership, beliefs and practices related to learning and teaching, and communication patterns within and across institutions and stakeholders. Partnership surveys were administered to faculty in November 2005 (response rate 33%) and December 2006 (response rate 77%).

Faculty Interviews

Interviews with ten faculty members from among the participating institutions of higher education were conducted initially in 2004 and again in 2007. The first interviews were conducted while the courses were still in the development stage. Survey questions focused on issues related to faculty knowledge and beliefs related to the content of the course, as well as their ideas about effective collaboration. The second interviews were performed after the courses had been through one year of pilot testing and examined issues of sustainability.

Facilitator Surveys

Facilitator Surveys were administered to higher education faculty each year in preparation for and throughout the summer academies provided for inservice teachers. These

surveys provided data on faculty knowledge and beliefs about teaching and learning, teachers and schools, and effective partnerships. The surveys administered in summer 2005 (92% response rate) and summer 2006 (72% response rate) were used for this study.

Math and Science Partnership Management Information System

These data were gathered from the NSF-MSP information database on all participating higher education faculty involved in NCOSP. The data were collected from a questionnaire administered by NSF that each faculty member filled out at the end of year regarding their involvement in MSP activities and how those activities have affected them as professionals in education. Two questions concerned knowledge gained through participation in NCOSP, and to what extent NCOSP related professional development had an impact on the faculty member's ability to perform his or her institutional responsibilities. These questions were analyzed qualitatively for salient themes over the course of three consecutive school years (2003-04, 2004-05, 2005-06).

Analysis and Findings

The data were analyzed for evidence of faculty change in three key areas: (1) Knowledge and beliefs about science teaching and learning; (2) Knowledge and beliefs about K12 teachers and teaching; and (3) Knowledge and beliefs about collaborative practices of effective groups. We also looked for evidence of institutional change initiated and implemented by faculty as a consequence of the curriculum development project.

Science teaching and learning

Data from the multiple sources strongly suggest that participation in curriculum development and pilot testing influenced faculty attitudes and beliefs about science teaching and learning. One component of the annual partnership survey examined beliefs and practices related to learning and teaching. In Year One, of eleven respondents, nine faculty at four different institutions cited increased awareness of constructivism and science education research as a result of participating in partnership professional development activities. Six indicated that they had effected some changes in their own undergraduate classrooms (primarily in terms of focus on “big ideas,” more inquiry, and group work). At this stage of the process, changes in belief were cited much more frequently than actual changes in practice.

In the second partnership survey, faculty reported further increases in their knowledge of science teaching and learning and also described specific changes in their own classroom practice. Of 24 respondents to the survey, 17 faculty representing all five institutions reported that “participation in NCOSP (had) significantly influenced (their) beliefs and practice related to science learning and teaching.” When asked to elaborate, three main themes were evident in the open-ended responses: (1) understanding of how people learn, specifically the importance of eliciting preconceptions and supporting metacognition; (2) appreciation of fostering conceptual understanding and favoring depth rather than breadth; and (3) recognition of student inquiry and its relevance in the science classroom. The following two quotes provide examples of comments consistent with these themes.

My 'traditional' lecture chemistry class has become much more focused on developing a conceptual understanding on the part of the students. This is a shift away from the primary focus being on the facts. The intent is that by shifting this focus, the students will gain a much better and lasting understanding of the material.

I have really come to see the power of guided inquiry - both as a facilitator in the summer academies and in teaching my own course. I've come to a much greater respect for very structured inquiry in learning science concepts. This has led me to be more clear about the purposes for different kinds of inquiry...

Of the 17 faculty members who reported that participation in NCOSP significantly influenced their beliefs, six specifically described changes they had made in their approach to undergraduate teaching. Significantly, faculty reported these changes in the context of their overall approach to teaching, not just in the new Earth or Life Science courses. As one faculty member stated:

I'm much more conscious of the role of learner pre-conceptions and metacognition in my own teaching. I've made changes in most of my classes to account for these.

Data reported in the NSF Management Information System were consistent with those reported in the annual partnership surveys. When asked to “briefly describe (i.e., one paragraph) any knowledge or experience that you gained through your participation in MSP—and how this knowledge influenced your instruction or research during the school year,” faculty reported increases in their knowledge and skills in five main areas: (1) Inquiry-based model of science teaching and learning; (2) “How People Learn” and current research in pedagogical techniques and how to incorporate these best practices in the classroom; (3) Instructional strategies, specifically questioning strategies, and how to elicit student pre- and misconceptions and teach to those conceptions in an effective and lasting way; (4) Curriculum development and how to structure the classroom for maximum student learning; and (5) Assessment and how to use assessment-driven instruction. A summary of these responses is provided in Table 1.

Table 1. Areas of increased knowledge and experience reported by faculty through the NSF Management Information System.

Year	N	Number of respondents indicating an increase in knowledge of:				
		Inquiry-based teaching	How people learn	Instructional strategies	Curriculum development	Assessment
03-04	33	9	7	6	6	
04-05	32	10	7	7	7	6
05-06	26	8	11	2		6

Here again, faculty comments provide additional insight into how the knowledge they developed throughout the curriculum development and implementation process promoted changes in the teaching practices. These two comments reflect the impact of the curriculum development process on faculty practice:

“Building the ‘Big Ideas’ list has led me to reconsider what is really important to cover. Learning about ‘How People Learn’ has allowed me to begin incorporating new and more effective pedagogies into my classroom.”

“After a careful reading of ‘How People Learn’ I have re-structured my classes to incorporate a larger element of meta-cognition.”

The two comments below demonstrate that the curriculum implementation process continued to support changes in instructional practice.

“I am better able to emphasize inquiry learning in my own teaching. I ask more questions and provide fewer direct answers.”

“Because of the MSP we have developed a new sequence of science courses specifically targeted at pre-service elementary teachers. Because of my involvement in this project, I am now involved in the teaching of the physical science course in this sequence. This course is using a research based curriculum and employs best practices in instruction. This has been a fantastic opportunity to learn what it takes to teach science right.”

During the second and third years, as the curricula were being piloted and revised, several faculty noted that they had an improved knowledge of assessment, and specifically how to use

assessment to drive instruction. The following quote offers one example of how improvements in questioning strategies allowed faculty to better assess student understanding.

“My approach to teaching in fall 2005 is radically different. I am much more in tune to questioning strategies and to the use of assessment in guiding instruction than ever before.”

Facilitator surveys administered at the end of the Summer Academies also demonstrated that the faculty had gained important insights into how people learn and a clearer understanding of the importance of the design of the instructional materials. On the 2006 survey, twelve of thirteen faculty respondents agreed with the statement “I gained important new insight into how people learn” (mean response 3.3 ± 0.6 on a 4 point scale) and all thirteen agreed with the statement “My Academy experience will have a significant impact on my work” (3.5 ± 0.5 on a 4 point scale). Follow up surveys administered following the 2006 summer academy continued to reveal the same trends. Of the 14 faculty who responded, all indicated that the academy experience would have lasting effects on their work in their institution. The most powerful experiences were reported as further insight into how people learn (3 faculty), practice with inquiry-based learning (3 faculty), and honing questioning skills (3 faculty). Reports of changes in classroom practice triggered by the academy included more student-centered learning in which preconceptions and student ideas were more explicitly addressed (3 faculty) and a greater emphasis on questioning rather than telling (3 faculty).

Survey results were supported by comments collected in individual interviews. Of ten faculty interviewed, nearly every faculty member said she/he had learned more about learning and teaching and had incorporated new strategies and practices aligned with how people learn (especially inquiry labs, questioning, and listening and addressing students’ ideas) in other courses they were teaching.

“I think almost any time I make a decision about some instructional practice in my classes, I almost always am thinking of the tenets described in HPL... I spend a fair amount of time soliciting students’ ideas...I actually have incorporated two new inquiry style labs where the investigation is open ended and doesn’t have a ‘right answer’...”

“I do a lot more questioning rather than telling...in my lecture-based calculus type classes; I do more inquiry labs in my lab section...I don’t feel as compelled now to cover as much material, I certainly value the depth of the material—the depth of knowledge more than the scope...It has taken away a little of my guilt in doing things that I kind of have always felt were the correct way—the right to do things—you felt pressure to sit in a lecture mode. I don’t feel that pressure any more.”

Together, these findings demonstrate that the professional development plan, the development of the Life Science and Earth Science curricula, and the implementation of these curricula with both preservice and inservice teachers led to substantial changes in faculty understanding of how people learn and constructivist-based pedagogy.

K12 teachers and teaching

Data from both the annual partnership survey and from the NSF Management Information System indicated that faculty were more aware of the needs and challenges of preservice and inservice teachers. In response to the open-ended question, “Please briefly describe (i.e., one paragraph) any knowledge or experience that you gained through your participation in MSP—and how this knowledge influenced your instruction or research during the 2003-04 school year,” two to four faculty specifically cited working with K12 teachers as formative to their experience over the three years the survey was administered. Data from the partnership survey supported this observation. When asked, “Please tell us about the changes you have experienced in your thinking, knowledge and practice. If there are specific ‘partners’ or

partnership activities that have been influential in those changes, please elaborate,” faculty cited interactions with K12 teachers as important. As one faculty commented:

Interacting with the teacher leaders has been the most important learning experience for me. Seeing content from their perspective has helped my classroom practice immensely. Developing professional relationships with them has be very important.

When specifically asked about collaborations with NCOSP colleagues (e.g. faculty, teachers, and administrators) that were significant, four of the 24 respondents cited K12 teachers or Teachers on Special Assignment.

During the multi-day immersions to prepare for the Summer Academy, faculty frequently cited the participation of K12 teachers as one of the most valuable components of the planning sessions and offered recommendation for more and greater involvement of teachers. In facilitator surveys, 10 of 13 respondents strongly agreed with the statement “I gained important new insight into K-12 education” (mean 3.7 ± 0.6 on a 4 point scale). Of 14 faculty describing the most powerful or useful experiences of their summer academy work, two specifically cited work with K12 teachers. As one faculty stated,

It was great to work with the K12 teachers – especially in terms of their thinking about the scientific method, geology, etc. This was also a great opportunity to network and see/hear how science is done in the K12 classroom.

Additional analyses from the partnership survey and faculty interviews suggest that despite valuing these connections in the moment, communication across groups outside actual events remains infrequent. During interviews, all ten faculty members interviewed expressed that they have enjoyed and learned from K-12 teachers during the summer academy and would like to continue interacting with them. As one faculty member stated:

“I absolutely love working with all these different people...it has been a new lease on my professional life...we get so isolated that it has given me ways to share ideas and add to

the collective pot whenever I can...I'd like that part to [continue to] happen but I would also like to be able to follow some support connections with the (K-12) teachers..."

However, several cited a lack of time as a significant barrier to maintaining and extending there relationships once back in the regular work setting. A few individuals observed that there would need to be funding to provide release time if higher education faculty and K12 teachers were to genuinely work together throughout the year.

Collaborative practices of effective groups

In Year One, both the partnership survey and the Summer Academy facilitator survey suggested that not all faculty felt that all partners were listened to or treated equally, that communication was inadequate, and that decision-making processes were not clear or shared. Efforts to define principles of collaboration, develop shared values, and implement collaborative norms led to substantial increases in participant satisfaction with group interactions and perceptions of openness and respect across individuals and institutions. An observation protocol aligned with the principles of the partnership was developed to assess group interactions against established criteria. Initial analyses suggest that these principles are becoming "norms" within the groups. In facilitator surveys administered in association with the Summer Academy in Year 2 and Year 3 the majority of faculty expressed a high degree of satisfaction with interactions among co-facilitators, responsiveness of management to individual needs, and overall communication and decision making.

Institutional change

A number of institutional changes have occurred as a consequence of partnership activities. A year-long science course sequence with common curricula and assessments is now offered as a general undergraduate requirement at all partner higher education institutions. Faculty across all institutions collect student work and assessment data on these courses and collaboratively address evidence of learning and curriculum revisions needed based on student data. At the RCU, the course sequence is “highly recommended” and treated as a “requirement” for elementary education majors. Enrollments for each course in the sequence increased each quarter at each institution during the pilot year. Enrollments for 2006-07 are higher, with maximum numbers reached at several sites.

Despite encouraging enrollment trends, one or more of the courses is sustainable at several institutions largely through the efforts of the faculty members who were part of the course development team. Except for temporary, part-time hires, there was little mention of additional instructors (not part of the developer group) coming on board to teach the courses. Some faculty express concern about the long term sustainability of the courses without increasing the number of faculty involved. One faculty noted,

“We are going to have a problem at this college finding teachers who are interested in teaching [the new course] and can teach it...because it is so different from the standard old design...There is not a very big population of higher ed. teachers in our community college arena ...who could do it without support...”

Moreover, while the Life science seems sustainable at the RCU and one of the community colleges, the other campuses report difficulties with managing equipment and organisms to get predictable results and with handling lab logistics and set ups without a dedicated lab assistant or

technician. One instructor suggested going with simulations on the computer to address these problems.

In some cases the original design of one or more courses is being modified in order to exist within the department. Some faculty indicated that they anticipate even more “adaptation” in the future, especially if revisions were not done collaboratively for the existing course materials. Several suggested producing guidelines that would support these courses in ways that are consistent with each other at their core, but with mutually agreed upon modifications that could be made locally in each institution to ensure sustainability.

General Conclusions and Implications

In multiple surveys and interviews, faculty reported a deeper understanding of constructivism and how people learn, especially the importance of preconceptions and metacognition. They also reported a greater appreciation of conceptual understanding and focus on big ideas, as opposed to factual recall. Finally, they described increased knowledge of inquiry-based teaching, particularly the use of questioning strategies to foster and assess student understanding. This new knowledge promoted changes in classroom practice, including increased elicitation of student preconceptions and greater emphasis on questioning rather than telling.

Faculty also reported increased awareness of and appreciation for K12 teachers and teaching. Through work on the summer academies, faculty became more cognizant of the needs and challenges of preservice and inservice teachers. Several faculty cited their work with K12 teachers as one of the most important parts of their summer academy experience. However, both

surveys and interviews indicated that time was a barrier to sustained collaboration between higher-ed faculty and K12 teachers.

In addition to changes in individual faculty, the curriculum development process has led to institutional changes on each higher education campus. The full course sequence, including the new Earth and Life science courses are now officially approved courses offered that meet campus general undergraduate requirements and, at the RCU, are required for elementary education majors. These courses are a significant departure from the introductory courses previously taken by elementary education. Despite these changes, the ability of the campuses to sustain these courses depends heavily on the faculty who developed the courses unless additional faculty are provided the training necessary to teach them with the same pedagogical approach.

The data strongly suggest that the curriculum development and implementation process, and the associated professional development experiences, had a profound impact on participating faculty. The knowledge and beliefs they developed about teaching and learning through reading published literature, designing instructional materials, and collaborating with their K12 and higher education peers combined to generate significant improvements in their classroom practice. Though institutional changes were also observed, it is unclear whether these changes have penetrated deep enough within the participating departments to exist independent of the faculty directly involved in the curriculum development process. Future efforts to engage additional faculty members in professional development experiences and, perhaps, in co-teaching the courses may be important vehicles for extending the change process to this “second tier” and ensure the longevity of these courses at each site.

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