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ATINER's Conference Paper Series
EDU2012-0112

A Staff Development Model for the Improvement of Science Content Knowledge and Teaching Practice for Elementary School Teachers

Catherine L. Tannahill
Associate Professor, Eastern Connecticut State University
Willimantic, USA

Jeanelle Day
Professor, Co-principal Investigator, Eastern Connecticut State University
Willimantic, USA

Hari Koirala
Professor, Eastern Connecticut State University
Willimantic, USA

Xing Liu
Assistant Professor, Eastern Connecticut State University
Willimantic, USA

Susannah Richard
Associate Professor, Eastern Connecticut State University
Willimantic, USA

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209
Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm

Printed in Athens, Greece by the Athens Institute for Education and Research.

ISSN **2241-2891**
6/09/2012

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Dr. Gregory T. Papanikos
President
Athens Institute for Education and Research

This paper should be cited as follows:

Tannahill, C. L., Day, J., Koirala, H., Liu, X. and Richard S. (2012) "**A Staff Development Model for the Improvement of Science Content Knowledge and Teaching Practice for Elementary School Teachers**" Athens: ATINER'S Conference Paper Series, No: EDU2012-0112.

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Catherine L. Tannahill
Associate Professor
Eastern Connecticut State University
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Jeanelle Day
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Willimantic, CT
USA

Xing Liu
Assistant Professor
Eastern Connecticut State University
Willimantic, CT
USA

Susannah Richard
Associate Professor
Eastern Connecticut State University
Willimantic, CT
USA

Abstract

This research focused on the effectiveness of a blended collaborative/cooperative staff development model (Joyce & Calhoun, 2010) as a means for providing targeted science content training to elementary science teachers (grade 3-8).

The research involved four, sequential one-year projects to increase science content knowledge and skills. The design involved an intensive two week summer workshop with on-going electronic and university based follow-up activities. Teachers were provided content, based on state and national science standards for the appropriate grade levels, by expert Arts and Sciences faculty with extension and pedagogical application by Education department faculty. Changes in science content knowledge were measured both quantitatively and qualitatively every year. For quantitative analysis, a paired t-test was used and for qualitative analysis focus group interviews were conducted. The t-tests indicated that participating teachers' science content knowledge and skills grew significantly as a result of the staff development. Focus group interviews and survey documents demonstrated that teachers felt more confident about teaching science and believed the model of staff development was successful.

Contact Information of Corresponding author:

Purpose

The purpose of this study was to investigate the effectiveness of the blended collaborative/cooperative staff development model (Joyce & Calhoun, 2010) as a means for providing targeted staff development to elementary science teachers (grades 1-8). The study took place on a master's granting university campus in New England and was funded by the state Teacher Quality Partnership grant project.

Literature Review

The cornerstone of quality learning in the 21st century is a teacher who is well versed in content, pedagogy, and technology. This requires a commitment to continuous professional learning throughout the teaching career.

Today few argue whether a teacher's knowledge of content is an essential characteristic of an effective teacher (Fallon, 2003; Hanson & Akerman, 2006; Stronge, 2002). A multitude of studies from the 1980s and 1990s researched various aspects of the connection between teacher content knowledge and student achievement (Ball & McDiarmid, 1990; Carlsen, 1987; Hashweh, 1987; Shulman, 1987; Sparks, 1998; Tobin & Garnett, 1988). Experts have recognized the first requirement for effective teaching is that the teacher understands the ideas, purposes and structures of the subject matter. Teachers must have a depth and breadth of understanding of their content in order to adapt materials and activities to student needs and to provide the necessary support to assist students toward independent learning.

A 2008 report from the Education Trust summarizes the research when it states, '*Teachers cannot teach what they do not know. Research tells us that … teachers with demonstrated knowledge of their subject areas produce stronger results with students, especially in mathematics and science'* (Ingersol, 2008, p.1).

Unfortunately, many science teachers, especially elementary science teachers, are just a chapter ahead of their students. A key conclusion of the President's Council of Advisors on Science and Technology (2010) was that '*The most important factor in ensuring excellence is great STEM [Science, Technology, Engineering and Mathematics] teachers, with both deep content knowledge in STEM subjects and mastery of the pedagogical skills required to teach these subjects well*' (p. xi).

A seminal study in 2000 looked at the status of elementary school science (Fulp, 2002). It described elementary science teachers as female and white with almost 60% nearing retirement – the last of a generation of females who were passionately interested in science but generally unable to find work in scientific fields that were compatible with family obligations. The study found that the younger teachers were often lacking in content knowledge but not in their pedagogical skills. Only 4% had undergraduate degrees in science or science education. Less than a quarter had any preparation in science education (Epstein & Miller, 2011).

A 2005 study (Rice) of the science content knowledge of elementary pre- and in-service teachers called attention to related concerns. The lack of content knowledge led to feelings of inadequacy. Elementary teachers often held the same misconceptions regarding science that their students possessed. This situation all too frequently translated to inadequate pedagogical practice.

Unfortunately, a recent study of California schools showed the situation has continued to deteriorate over the last decade rather than improve (Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011). It found that elementary science teachers were no better qualified to teach science than in 2000 and 41% of respondents felt unprepared to teach science compared to 4% in reading and mathematics (Asimov, 2007).

It is essential to understanding the complex relationships of science, society and mathematics for informed citizens to be able to relate these concepts to daily life (Manduca & Mogk, 2002). Not only must students learn these complex relationships but they must also recognize those relationships in the world around them for there to be true scientific literacy. Unfortunately, most elementary students have teachers who are unable to make these connections and, thus, unable to guide their students in making them.

This increasing emphasis on content is paired with an ever-changing expectation of the content to be taught. Newly developed content standards often ask teachers to teach students to a greater depth of knowledge than they themselves have gained in their undergraduate and professional preparation programs. Consequently, teachers must now engage in a sustained, intellectually rigorous study of what they teach and how they teach it. Demanding content standards require high-quality staff development that helps practicing educators reach this depth of understanding (Hirsh, 2003).

The characteristics of high quality educational professional development in science have been studied for five decades and are well documented (Loucks-Horsley, Stiles, Mundry, Love, & Hewson 2010). In 1996, a concerted effort produced the National Science Education Standards (NSES, 1996). A portion of these standards recognized that continued high quality science instruction needed to be supported by equally high quality, on-going professional development. These standards postulated that for teachers to be able to teach effectively they must themselves be taught in effective staff development - not just in traditional lecture mode but in the same ways that they were expected to teach their students.

In addition, quality staff development for science teachers must:

- Allow teachers to develop a deep understanding of scientific ideas and how they were formulated.
- Address problems, issues, events, and topics that are important to science, the community, and teachers.
- Provide opportunities for teachers to use scientific literature, media, and technology to broaden their knowledge.
- Allow teachers to develop understanding of the relationships of logic, reason and research to accumulated scientific knowledge.
- Support teachers in using a variety of technological tools, such as computerized databases and specialized laboratory tools (NSES, 1996)

And finally, it is essential that, '*All prospective and practicing teachers who study science participate in guided activities that help them make sense of the new content being learned, whether it comes by lecture, reading, small-group discussion, or laboratory investigation ....activities include ongoing opportunities for teachers to reflect on the process and the outcomes of their learning*' (NSES, 1996, p. 61).

In 2005, a review of publications regarding best practices, talks about inquiry, hands-on, contextual teaching and learning, collaboration, community, and reflection was published (Yager, 2005). In the introduction to that work, Yager writes:

Professional development is about ensuring that teachers continue to grow and improve. Professional development forces us to look at the acts of teaching and to discuss the effects of these acts on student learning. We have to be sure that learning does result and that it is learning with understanding and potential use – not merely an indication of students' ability to remember, repeat, and recite…..Professional development providers need to be familiar with how content strands are organize across K-12 curriculums and how major concepts and processes are seen and used in concert. ...If we focus too acutely on a single scientific discipline, and exclude concepts from other disciplines, problems result (pg. xi).

These elements can be encapsulated in one of the most widely recognized staff development models: the Collaborative/Cooperative Model (Joyce & Calhoun, 2010) and provide the foundation for our projects. This model is based on the belief that '*teachers who think and study together can make positive changes that, moreover, can make a serious difference in student learning in a relatively short time'* (Joyce & Calhoun, pg.62). The objective is to '*organize groups… to learn from one another's' repertoires…and build their stock of professional tools*' (p.63) and is based on three premises: collective action increases positive, learning of selected knowledge and skill, and implementation of this learned knowledge and skills. This development of a learning community, brought together to increase their own knowledge base, to learn from each other with the ultimate purpose to enhance student learning is a synergistic process.

This study relied heavily on prior research for its structure. The projects incorporated direct content instruction supported by additional hands-on inquiry activities. Content was identified in collaboration among higher education faculty, district liaisons, and participating teachers. Throughout the project there was collaboration among the faculty and participants and among the teachers from the various school districts. Two or more participants from each school were recruited to build self-supporting instructional teams. This collective energy increased the positive perception of the process, often increase the learning of the participant selected knowledge and skills, and increased the implementation of these learned knowledge and skills (Joyce & Calhoun, 2011).

Methodology

Participants

Spanning a series of four grants, 139 elementary and middle school teachers, predominantly grades 1-6, participated in a series of one year grant projects. Districts were asked to send teams of teachers and support personnel such as Special Education and Second Language teachers and aides. A total of 20 school districts participated with two involved for all four projects and four districts for three years. Participants came from districts with varying diversity and economic capabilities but all districts recognized a need for increased science content knowledge for elementary teachers.

Faculty

Faculty from Environmental Earth Science, Astronomy, the physical sciences and Biology from the School of Arts and Sciences, and Education faculty from the School of Education and Professional Studies were involved. All participating faculty members were tenure track and varied from assistant to full professors with active research agendas. Two Arts and Sciences and three Education faculty members participated in all four projects. The studies occurred on a master's granting university campus in New England and were funded by the state Teacher Quality Partnership grant project.

Design

The design was the same for each of the four projects. There was an introductory workshop lasting between seven and ten days with follow-up activities during the academic year. At the request of the participants, the workshop began within a few days of the end of the regular school year and ended by July 4. At the elementary level, the science content focused on the natural world: concentrated in life sciences, physical sciences and cosmology. These then were the topics studied during the workshop. Scientific processes, procedures and thinking were woven throughout the content.

The project was a collaborative effort of public school districts, a liberal arts public university, school district administrators, teachers and university faculty. Initial grant parameters focused on increasing science content knowledge for teachers. While districts self-selected to participate and identified the general area of need (elementary science content), interested participants were surveyed to identify specific science content areas based on new state curriculum standards. Each year involved different standards and different content topics based on the participants' needs and grade level involvement.

Education faculty took these survey results and worked with professors in geology, environmental earth science, biology, astronomy and physics to identify specific content and the depth appropriate for the identified grade levels. Although the Arts and Sciences faulty were knowledgeable in their content area, their teaching expertise was with post secondary and not elementary students. Education faculty assisted with interpretation of standards in terms of curriculum content at the elementary level. They also assisted with identifying the depth and breadth of the content needed by elementary students. However, the content was developed and presented by faculty from Arts and Sciences as meaningful adult learning opportunities. They were teaching their content to adult learners who were to use that content as appropriate for their own elementary students.

With participants representing multiple grade levels and with the science standards crossing multiple grade levels, participants were able to place their particular needs relative to the scope and sequence of the overall elementary science curriculum. For example, Chart 1 shows the standards from one summer's workshop with Chart 2 shows the corresponding schedule. The standard number represent the grade level year that topic is covered with a more detailed descriptor. Standard 3.2 is related to organisms and is addressed during the 3rd grade. Children learn that plants and animals adapt both structurally and behaviorally to survive in different environments; 4.3 on the role of water in shaping the earth is taught in 4th grade; etc.

As the schedule in Chart 2 illustrates, mornings were devoted to developing or deepening content knowledge and the afternoon focused on pedagogical content knowledge. Each morning Arts and Sciences faculty presented the selected content, generally through direct instruction but also with field trips to illustrative locations. Science and Education faculty typically ate lunch with the participants. During lunch, communities of learning were built through discussion of morning content with occasional presentations of on-going academic research by the science content faculty. This served to reinforce the connection of theory to practice.

Afternoons were devoted to the same content theme as mornings delivered through hands-on pedagogical models appropriate for use with elementary students. These were developed and taught by combined teams of Education and Arts and Sciences faculty although the Education faculty led the afternoon activities with the Science faulty assisting and providing clarification and content reinforcement. The premise guiding the afternoon activities was that the teachers needed to learn using materials and pedagogical strategies that they could apply to their own classrooms. During follow up activities the participants discussed the challenges and successes they faced in implementing this new knowledge and skills. Periodic fieldtrips to the University Arboretum, the University Planetarium, local geologic sites and local museums provided opportunities for actually application and observation of science content. These same opportunities were available for scheduling for school field trips as well.

Data collection

Each year between twenty five and thirty participants were given a pre- and a post-workshop assessment based the standards and the derived workshop content. The pre-test was administered on the first morning and the post-test given on the last afternoon. Questions frequently required explanation and extended understanding such as:

- List two major concepts about light. Provide one example of application.
- How do energy and nutrients move through food webs?
- How does radiant energy affect the earth's climate?

The same experts graded both the pre- and post-tests to ensure consistency.

While internal evaluation occurred each year, outside evaluators reviewed a series of staff development projects for the state for three of the four years. Internal assessment also included focus group interviews with participants and Arts and Sciences Faculty. The Outside evaluators interviewed all involved faculty but also included some open ended questions for participants regarding overall satisfaction.

Data Analysis and results

As shown below, each year the analysis indicated that the difference between the pre- and the post-test means in participating teachers' science content knowledge was statistically significant (see Table 1).

Each year the standard deviation for both pre-and post-tests are high indicating a diverse group of teachers in terms of their science content knowledge. This created a challenge for differentiating instruction. It is interesting that the standard deviations for post-tests are smaller than the standard deviations for pre-tests. This indicates that many teachers who demonstrated a lack of content knowledge in the pre-test were able to gain the science content knowledge relatively fast.

As the table indicates, the teachers' science content knowledge improved each year as a result of the workshop. Generally the greatest gains in knowledge were by the elementary school teachers (grades1-6). The Year 2 participants (grades 7-8) were more likely to have had more formal prior content preparation. Based on the overall results, it was found that the collaborative/cooperative model of staff development is a successful method to increase science content knowledge and skills.

Anecdotal evidence

Interviews were conducted with participating faculty and with participants at the end of each project. Reviewing transcripts, interview summaries and comments from the outside evaluators' survey data found four consistent threads:

- Participants indicated greater confidence in their ability to teach science.
- Collegiality and collaboration opportunities were valued.
- Participants were consistently satisfied with their professional development experience.
- The higher education faculty involved in the projects also reported an impact.

Although self-efficacy was never a part of the internal assessment, from the beginning of the projects, participants stated they had more confidence in their ability to teach science. In Year 2 one teacher responded:

> *It gave me a new confidence to have all that background information, it helps when you're getting up in front of a group of kids that are just little guns loaded with questions - not that you have to know all of the answers, I've never felt like I had to have the answer, I'm not afraid to say let's find out. - but it allowed me to enhance the lessons with a little background information.*

A first year participant commented that she had a greater appreciation of her place in the scope and sequence of science instruction and felt respected by others in the educational process.

Both participants and faculty noted opportunities and outcomes related to growth in collegiality and collaboration, not only teacher to teacher, faculty to faculty but also teacher and faculty. The common lunch opportunity appears several times in comments. The Year 2 focus interviews had two faculty members mentioned it with one saying, '*Yeah I think the lunches were a real highlight, and they made a connection between the teachers and staff*' and a second faculty member added '*I* *think those lunches were great cause you really got to know what they were interested in accomplishing .... And I just got to develop relationships which was (sic) important.*' That same year a participant commented '*The availability of the staff during lunch to ask them more questions was nice*' and another added: '*What I thought would be neat, is to have one of the professors come to one of our schools ....*' Another participant commented that '*it was a good chance to network with other teachers from different districts ...'* (Year 2). Arts and Sciences faculty initiated collaborative activities with Education faculty members. A particularly gratifying comment said '*perhaps the most useful outcome from this funding activity has been the long term professional relationship that has been forged with faculty in education. This has resulted in several collaborative efforts for funding, as well as a better understanding of the needs and interests across disciplinary lines in relation to shared committee work'* (Year 3).

Focus group interviews and outside evaluator reports consistently reported a high degree of customer satisfaction with the design and delivery of the projects. In Year 3, three different participants noted that they attended based on information from teachers who had attended in the past. By the last project, the majority of participant recruitment was being done by previous attendees. A simple response in Year 4 was '*Your (sic) doing well. Thank you.*' Consistently throughout the projects, participants noted an appreciation of the professional atmosphere of the workshops. The time during morning and afternoon breaks and the working lunches seemed like professional conferences. Several participants commented about their treatment as fellow education professionals by faculty and also frequently commented about having easy access to the same materials.

An unintended consequence appeared to be the impact on the Arts and Sciences faculty who were involved. During focus interviews, they were routinely asked what impact participating in the projects had on them. While they indicated greater collaboration with Education faculty both in activities and advisement of pre-certification students, the comments about the projects' impact on their teaching was surprising. In Year 4 one faculty wrote '*This partnership has strengthened interactions between education and arts and science faculty in several ways. For example, greater awareness of state educational standards by earth science faculty has improved advising for students planning to become teachers.*' The second year, one faculty commented '*I think it actually gave me a different perspective ... and helped me to kind of see a little bit about what students were coming in with.*' In Year 3 two Arts and Science faculty provided some detailed information about changes it had made in their teaching strategies for several different courses. They mentioned everything from use of '*newly prepared materials such as three dimensional maps (anaglyphs) to hands-on instructional activities.*' Another commented that '*Collaborations with social science education faculty have reinforced the importance, in my mind, of connecting aspects of science to the ways in which people interact with the earth.*'

Conclusions

As a result of these four single year grant projects, a number of significant conclusions can be drawn confirming prior research.

First, analysis of pre- and post test data show this is an effective model for increasing science content knowledge for elementary teachers. Every year participants demonstrated significant gains in content knowledge. With the knowledge gain was an increased confidence in their ability to teach science has occurred.

Second, recruiting teams of instructional staff from participating schools appears to foster dialogue about the teaching of science and provides a sense of where their instruction fits within the large scope of science content. The teams provide mutual local support for testing and implementing ideas and techniques. Team members did not need to be from the same grade but could be instructional support personnel such as special education and instructional aides.

Third, providing materials similar to those used during the professional development activities facilitated classroom implementation. It appeared that placing materials at each school rather than locating them at a central site made it easier access. Those with easier access were more likely to use the materials.

Additional anecdotal evidence indicated an unexpected consequence. Teaching strategies for content faculty from Arts and Sciences appeared to be impacted by participation in these projects. They reported increasing their use of hands-on activities and authentic applications not only with successive workshop participants but also with their college classes. Several times they reported using materials developed for the workshops with university students.

Limitations and Future Research

Unfortunately with a series of single year projects with differing grade levels, varying participating districts, and revolving teacher participants, no opportunity existed to truly measure either fidelity of implementation or the impact of this professional development on student learning. All information regarding implementation and impact on student learning resulted from anecdotal responses.

Based on results of these projects several additional areas of research are apparent. There is a need for longitudinal research as to the retention of content as well as application of the pedagogical strategies introduced. Impact on student learning also needs further study. Additional research into the efficacy of this model in other content areas such as mathematics, social studies and English language arts for elementary teachers could be beneficial. Exploration of this model for new teachers (within the first three years) might assist in teacher retention since the interdisciplinary approach to elementary teacher training has largely been abandoned in the United States in favor of requiring a single content major.

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Chart 1: State Science Standards

3.2 – Organisms can survive and reproduce only in environments that meet their basic needs.

Plants and animals have structures and behaviors that help them survive in different environments.

4.3 – Water has a major role in shaping the Earth's surface.

Water circulates through the Earth's crust, oceans, and atmosphere.

5.3 – Most objects in the solar system are in a regular and predictable motion.

The positions of the Earth and moon relative to the sun explain the cycles of day and night, and the monthly moon phases.

6.1 – Materials can be classified as pure substances or mixtures, depending on their chemical and physical properties.

Mixtures are made of combinations of elements and/or compounds, and they can be separated by using a variety of physical means.

Pure substances can be either elements or compounds, and they cannot be broken down by physical means.

Chart 2: Sample Schedule.

Week 1					
	Monday 6/21	Tuesday 6/22	Wednesday 6/23	Thursday 6/24	Friday 6/25
8:00 -11:45		Elements/Mixtures/ Compounds		Land/Water Interactions	
	*Welcome *Pre-Test	*Content on Elements/ Mixtures/ Compounds	*Inquiry Activities on Elements, Mixtures & Compounds	*Content with activities on Land/Water Interactions	*Inquiry Activities using Water Kit
	*Lunch	*Lunch	*Lunch	*Lunch	*Lunch
1:00 -4:00	*Literacy & Content	*Literacy Connections & Technology Integration	*Team-Based Science Strategies on Elements, Mixtures & Compounds	*Content Seminar with activities on Land/Water Interactions	*Team-Based Science Strategies & Technology Integration
Week 2					
	Monday 6/28	Tuesday 6/29	Wednesday 6/30	Thursday 7/1	Friday 7/2
8:00 -11:45	Earth/Moon/Sun		Adaptations		Wrap-Up
	*Content Seminar	*Content Seminar	*Content Seminar	*Literacy Connections & content integration	*Literacy Connections & content integration
	*Lunch	*Lunch	*Lunch	*Lunch	*Lunch
1:00 -4:00	*Earth, Moon & Sun Kit activities	*Team-Based Science Strategies with Technology Integration	*Inquiry Science: Water Plants Activity *Webquest design project (grade level & content specific groups)	*Technology project sharing Wrap-up	*Wrap up *Post-Test *Focus group interview

Table 1. *t*-test for Pre- (in parentheses) and Post-test Science Scores for Teacher Quality Partnership Projects

Year	N	*M*	*SD*	*t*	*p*	Significance
Year 1: Gr. 5th & 6th	19	76.45 (56.09)	20.67 (20.08)	6.2585	0.0000069	p<.001
Year 2: Gr. 7th & 8th	23	83.2 (64.1)	20.2 (30.5)	3.74	0.000566	p<.001
Year 3: Gr. 6th, 7th, & 8th	19	72.7 (63.09)	20.17 (26.95)	1.7689	0.04699	p<.05
Year 4: Gr. 4-8	25	78.0 (63.0)	25.3 (33.9)	1.8371	0.0393	p<.05

Pre-test Means and Standard Deviations are within parentheses.