

HANDS-ON PHYSICAL SCIENCE FOR IN-SERVICE TEACHERS

J. McDONNOUGH and S. McKELVEY
School of Education, Virginia Commonwealth University
Richmond, VA 23284

A. BASKI and D. LEWIS
Dept. of Physics, Virginia Commonwealth University
Richmond, VA 23284

Abstract

We have developed an outreach program designed to improve the physical science teaching of upper-level elementary teachers in the City of Richmond. This program begins with an intensive, two-week summer graduate course for participating in-service teachers. The course is based on ten hands-on activities related to Virginia's *Standards of Learning* in physical science. During the school year, physics faculty and undergraduate assistants deliver these lessons to the teachers' classes. This paper reports on the impact of the program on the teachers' content knowledge and self-efficacy in teaching science. Based on analysis of pre- and post-tests and a feedback questionnaire, the program successfully assisted the teachers in augmenting their science content knowledge and confidence to teach science.

Introduction and Review of Literature

Significant challenges face school districts, teachers, and parents in order to meet the educational goals of the No Child Left Behind legislation, the *National Science Education Standards*, and the *Virginia Standards of Learning (SOL)* [1,2]. According to a National Survey of Science and Mathematics Education, "Elementary teachers are lacking in content preparation, especially in the physical sciences." [3] In addition, a Virginia study shows that of the seven science SOL strands, third and fifth grade elementary school teachers have the least confidence in teaching the physical science strand with topics on force, motion and energy [4]. There is a dire need to improve the delivery of physical science education in our primary and secondary schools. Most elementary school teachers have had minimal training in the physical sciences, but they are now expected to teach science to their students so that they can pass standardized exams. To do this effectively, pre-service and in-service teachers must be exposed to educational experiences that build their content knowledge of physical science in the context of sound instructional practices. This paper reports on the impact of the Virginia Commonwealth University (VCU) Outreach program on the content knowledge needed to teach SOL-related physical science topics by in-service elementary teachers.

The quality and quantity of science taught to elementary school students is strongly influenced by their teachers' confidence, attitude, and knowledge level [5-8]. Thus, it is essential that pre-service and in-service programs address the need to produce elementary teachers who possess strong pedagogical content knowledge (PCK). Shulman has described PCK as the transformation of content knowledge from the mind of the teacher into instructional practice [9,10]. A teacher's PCK is in a constant state of flux as he/she progresses along the continuum from the pre-service experience into practice and beyond. To produce teachers with high pedagogical content knowledge in science, the National Science Foundation (NSF) and National Research Council (NRC) have recommended that university teacher preparation programs do the following: 1) *integrate* content and methods courses; 2) form *relationships* between education and science departments and the K-12 sector; 3) introduce *experiences* that help pre-service teachers prepare for teaching science; and, 4) provide opportunities for pre-service and in-service teachers to *interact* [11,12].

Teaching science for young students to learn with understanding requires that teachers understand child development, pedagogical and assessment alternatives, and scientific conceptual and procedural knowledge [5,6]. In the emerging paradigm, educating an effective teacher of science is coming to mean much more than presenting innovative ways to teach science. Effective teacher education and professional development cannot be limited to brief workshops presenting "bags of tricks," or one-semester methods courses or summer institutes. Practicing teachers need a sound conceptual understanding of introductory science and a transformation of their perspective on the learning of science. Since the constructivist perspective on science learning recognizes that science knowledge is not something the teacher transfers to students, the professional development of elementary teachers of science should move teachers toward developing a constructivist perspective. Teachers' knowledge of teaching is not found in textbooks, or "experts"; rather, knowledge about teaching science is personally created and socially mediated as elementary teachers make sense of their teaching worlds in light of prior knowledge of teaching, learning, and curricular approaches [5].

The assessment of an effective teacher preparation or professional development program in science must measure changes in the teacher's level of pedagogical content knowledge, which includes content knowledge and self-efficacy beliefs. Self-efficacy beliefs are a teacher's judgment of his/her capability to effectively teach [13,14]. According to Fulp, elementary school

teachers who evaluate their self-efficacy at teaching a variety of topics rank themselves as being least qualified to teach physical science [15]. Given that studies have documented that strong self-efficacy beliefs are linked to high student achievement and increased student motivation, it seems reasonable to design and measure learning experiences that enhance teachers' self-efficacy [16].

Instruments developed to measure self-efficacy include the Teacher Efficacy Scale (TES) and the Science Teaching Efficacy Belief Instrument (STEBI) [17,18]. The use of STEBI has been called into question by researchers, however, because 60% of the overall variance cannot be explained [13,17]. To redress these problems, Roberts and Henson developed the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers or SETAKIST [17]. The SETAKIST is designed to measure two constructs: teaching efficacy and knowledge efficacy. The teaching efficacy construct portion of the instrument is similar enough to the STEBI so it was left intact. The knowledge efficacy construct is based on the work of Lee Shulman in pedagogical content knowledge. This instrument was piloted on a sample of 274 elementary science teachers or science specialists, and results indicated that it produced a good data fit to the hypothesized model [14]. We therefore intend to utilize the SETAKIST instrument as part of the assessment of our program.

Description of Study

The goal of this study was to develop a model for in-service teacher development that encompasses the factors deemed essential for a successful program. In the VCU program, in-service elementary teachers (twenty-three teachers in 2002 and twenty-nine in 2003) participate in *PHYS 510 – Physical Science Demonstrations*, an intensive summer course taught by physics faculty. They learn physical science concepts associated with the third to fifth grade SOL, which include the metric system, matter, motion/force/energy, simple machines, electricity and magnetism, and sound and light. The course integrates inquiry-based learning through ten hands-on activities that have been developed at VCU for the elementary classroom (see Appendix A). During follow-up visits to the classrooms, VCU physics faculty and undergraduate assistants deliver lessons based on these activities to provide a continuum of learning (over 130 lessons delivered to thirty-six teachers over one and a half years). This program has also recently incorporated a service-learning course for pre-service teachers in which they learn about the hands-on activities and participate in the follow-up visits. This paper reports on the impact of this program on the in-service teachers' self-efficacy beliefs and their content knowledge for teaching elementary physical science.

Design and Method

To evaluate the effectiveness of the summer course and overall program, we utilize the following assessments: 1) pre- and post-content tests; 2) a self-assessment survey to evaluate teaching efficacy and knowledge efficacy (SETAKIST); and, 3) a feedback questionnaire with open-ended questions. Teachers' knowledge of physical science content was evaluated before and after their participation in the summer course. A ten-item test consisting of multiple choice and short answer questions was administered on the first and last days of the course. No review was done prior to administration of the post-test. To evaluate the perceived science teaching efficacy of the teachers, we chose the SETAKIST survey which consists of sixteen Likert-scale questions. This survey was administered at the beginning of the summer course, and will be given again at the end of the 2003-2004 school year. Since the SETAKIST is a self-assessment instrument, it should be noted that respondents' answers may not be completely accurate; however, this widely used instrument has proven trustworthy. Lastly, a feedback questionnaire consisting of twelve open-ended questions was administered by the instructor (A.A. Baski) on the last day of the course. In the study discussed here, the population includes the City of Richmond teachers who participated in the summer 2003 graduate course (total of twenty-nine teachers). Independent variables include gender, years of teaching, and graduate education.

Content and SETAKIST Data Analysis and Results

The teachers' gain in content knowledge significantly increased as a result of the two-week summer course. The pre-test mean was 55% ($\sigma = 2.4\%$) and the post-test mean was 86% ($\sigma = 1.4\%$), resulting in a 31% improvement in the mean test score. This substantial increase in physical science content knowledge is quantitative support for the teachers' perception that their ability to teach physical science is increased by the end of the course, as indicated by responses on the feedback questionnaire.

The SETAKIST survey questions (see Appendix B) were examined for inconsistencies between the knowledge efficacy construct questions (1,3,5,7,9,11,13,14) and the teaching efficacy construct questions (2,4,6,8,10,12,15,16). According to Corston and Colman, paired samples *t*-tests can be used to test for a significant difference between the means of two such construct clusters [19]. Our calculations on the group means of each cluster show a significant difference, i.e., $t(7) = 5.15$, where the teachers indicated a higher confidence level for the

knowledge versus teaching efficacy construct questions. Their confidence level was highest when responding to question #1 from the knowledge efficacy cluster which states, “When teaching science, I usually welcome student questions.” Their confidence level was lowest in response to the following two questions from the teaching efficacy cluster: #15 “I feel anxious when teaching science content that I have not taught before”; and #16, “I wish I had a better understanding of the science concept I teach.” The high and low confidence levels for these questions from the knowledge and teaching clusters, respectively, are a factor in the significant difference between the two construct clusters. Overall, it appears that the teachers had a level of anxiety when teaching new science content because possibly they did not have a deep understanding of the concepts.

Feedback Questionnaire

All twenty-nine teachers completed the feedback questionnaire (see Appendix C), with a few teachers leaving one or two answers blank. A summary of the teachers’ responses is given in Table 1. Responses to questions 1, 2, 4, 7, and 9 were analyzed to evaluate the impact of the experience on the teachers’ opinions about the course.

Question 1 — Respondents were asked to rank their knowledge on the course topics listed in Table 1 on a scale from 1 (no knowledge) to 5 (proficient knowledge). Each topic had a higher mean value in the “After” category, indicating that the course improved the teachers’ perceived knowledge. A statistical analysis indicates that the Cohen’s d values are greater than 0.8 for all of the topic areas, which is considered a significant effect. This result is consistent with results of the pre- and post-content tests.

Table 1
Responses to Question #1

Topic	Mean Before	Mean After	Cohen’s d
Metric System & Matter	3.12	4.58	1.61
Mechanics	2.74	4.52	2.08
Electricity & Magnetism	2.85	4.41	1.78
Sound & Optics	2.37	4.15	1.86

Question #2 — The respondents were asked which topics in Question 1 they found most and least interesting. Electricity and Magnetism was the most interesting topic to the teachers by a wide margin. A summary of the responses is: Electricity and Magnetism (eighteen most interesting, one least), Sound (eight most, six least), Metric/Matter (seven most, five least), Mechanics (eight most, seven least).

Question #4 — With regard to the hands-on activities, most respondents enjoyed them and twenty-three respondents stated that they were good. One teacher stated that, “The activities really helped to connect the dots.” It was mentioned that the activity sheets should continue to be improved using feedback from the teachers.

Question #7 — When asked whether they had learned new instructional strategies during the course, most of the respondents indicated that they had not, but that they did learn more physical science content. The teachers already knew that hands-on activities were important for teaching science; however, many of them did not utilize them much in their classrooms. As a result of the course, however, fourteen teachers mentioned that they would now use more hands-on activities in their classrooms.

Question #9 — Nearly half of the respondents (fourteen of twenty-nine) stated that their attitude concerning teaching science had changed for the better as a result of the course. As one teacher stated, “I feel so much better about teaching science. I feel qualified. It is difficult to teach a subject that you don’t clearly/fully understand.” The remainder said that they already enjoyed teaching science and that their attitude remained the same.

Two themes emerged from the feedback questionnaire. First, the teachers expressed the importance of hands-on instruction in science, indicating that they would be taking the activities that they learned directly into their classrooms. Second, the participants indicated that they started to feel much more comfortable teaching science because of the knowledge they gained during the class. One person wrote, “I can say I feel more confident in teaching many of these activities, since I have received lots of knowledge about what was taught during these two weeks.”

Discussion

At the inception of this study, the teachers’ responses to the SETAKIST survey appeared to indicate that they had higher confidence in their science knowledge than their teaching self-

efficacy. In particular, they reported low confidence when teaching new science content, and wished to have a better understanding of underlying concepts. The low teaching self-efficacy may actually reflect their true level of science content knowledge. Teachers are less comfortable teaching content when they do not possess a deep understanding of it. Given the dichotomy in the responses between the knowledge and teaching constructs, the conclusion can be drawn that the teachers in the sample overstated their science content knowledge and their ability to teach science. These results are in line with previous research about teachers' self-report of science teaching practices [20].

The feedback questionnaire administered at the end of the course indicated that the teachers' confidence in teaching science was more comparable with their teaching of other subjects. Their anxiety about teaching science decreased because they had a better understanding of the concepts and now knew the necessary steps to teach science. Their newfound confidence to teach science was supported by their significant increase in content knowledge. Research has shown that students' achievement test scores increase as a result of their teachers' increase in content knowledge. Inclusion of the hands-on activities in the summer course played a significant part in moving the teachers toward a deeper understanding of the content. Using the activities to support content learning allows the teachers to personally construct their concept understandings. This approach to in-service professional development is recommended by science education researchers [5].

Conclusion

This program has successfully assisted teachers in augmenting their science content knowledge. During the school year, all of the participating teachers will receive follow-up visits where physics faculty provide model lessons based on the hands-on activities. At the end of that period, the teachers will again complete the SETAKIST survey to determine if these multiple experiences influence their teacher self-efficacy score. A comparison of results before and after participation in the program will be the subject of a future study. In conclusion, the study indicated that the teachers enjoyed the class, learned a great deal of information, and plan to use this information on the job.

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Appendix A

Summary of Hands-on Activities

Third grade SOL:	Matter, Energy, and Simple Machines
Measurement and Volume	Measure objects and explore volume with water and blocks.
Density	Do sink/float experiments and measure densities of materials.
Hot Wheels™	Learn about energy using HotWheels™ cars on a track.
Simple Machines	Use pulleys to lift buckets, construct levers with legos.
Fourth grade SOL	Electricity and Magnetism
Salt Battery	Make a battery from nails and copper wire to make a buzzer work.
Electrical Circuits	Build series and parallel circuits using batteries and lights.
Magnets	Predict and measure whether materials are magnetic.
Fifth grade SOL	Sound and Light
Loudspeaker	Use a nail and wire to build a “cup” speaker that works with a radio.
Mirrors and Scopes	Use mirrors to make a periscope and kaleidoscope.
Light Rays	Watch how mirrors and lenses bend light.

All activity sheets with photos of hands-on equipment are available at:

<http://www.courses.vcu.edu/PHYS510/>.

Appendix B

SETAKIST Survey

Likert Scale with 1 = strongly disagree, 5 = strongly agree

1. When teaching science, I usually welcome student questions.
2. I do not feel I have the necessary skills to teach science.
3. I am typically able to answer students' science questions.
4. Given a choice, I would not invite the principal to evaluate my science teaching.
5. I feel comfortable improvising during science lab experiments.
6. Even when I try very hard, I do not teach science as well as I teach most other subjects.

7. After I have taught a science concept once, I feel confident teaching it again.
8. I find science a difficult topic to teach.
9. I know the steps necessary to teach science concepts effectively.
10. I find it difficult to explain to students why science experiments work.
11. I am continually finding better ways to teach science.
12. I generally teach science ineffectively.
13. I understand science concepts well enough to teach science effectively.
14. I know how to make students interested in science.
15. I feel anxious when teaching science content that I have not taught before.
16. I wish I had a better understanding of the science concepts I teach.

Appendix C

Feedback Questionnaire for *PHYS 510* Course

1. On a scale of 1 to 5, rank your perceived understanding of the material presented in this course before and after taking the class.
2. Of the four topic areas listed above, which topics were the most and least interesting to you? Do you have suggestions for topic areas that should be added?
3. Please make comments about the lecture format for this course. Were the *Powerpoint* notes sufficiently clear when accompanied by the lectures? Given the time limitations for this course, was the amount of lecture time appropriate?
4. Please make comments about the activities performed during this course. Were the activity sheets clear to follow and the equipment for the lessons straightforward? Did you enjoy doing the activities and find them informative? Should we continue to include the “guest” activities from Laura Domalik (Learning Cycle) and Cindy Wright (Rocketry/Newton Carts, Sound Tubes, Light Demos) next summer?
5. What were your two most favorite activities and why? (block volumes, density of cylinders, HotWheels™, simple machines, salt battery, series/parallel circuits, magnets, electromagnetic speaker, scopes, light box)
6. For your classroom visits this coming school year, which three or four activities do you plan to schedule? Do you have any estimated timeframe (fall, winter, spring) for any of the lessons yet?

7. What new instructional strategies did you learn for teaching physical science? Did the course cause you to think differently about the way you approach teaching physical science in the elementary classroom? If so, how?
8. Describe any specific plans you have for implementing what you learned in *PHYS 510* (either the science activities or your own final project lesson plan) into your own classroom this year. Also, what plans do you have for using the provided equipment?
9. If applicable, describe how your attitude changed about teaching science.
10. Rank the importance of the incentives provided for enrolling in the *PHYS 510* course: graduate credit for recertification, stipend, equipment, follow-up visits.
11. Would you recommend this course to your colleagues?
12. If you have any other comments for us, please include them here!