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Rose M. Pringle

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The upcoming implementation of science in the Florida Comprehensive Assessment Test (FCAT) indicates that science will be considered a staple subject along with mathematics and language arts because what is tested becomes what is taught in the schools. This teaching to the tests raises concerns for science teacher educators who are involved in the preparation of teachers for elementary classrooms. Competing with mathematics and language arts, how can we best ensure adequate and appropriate science instruction at the elementary level? In this paper I describe teaching and learning activities in a science education course to promote the integration of reading and science among a group of preservice elementary teachers. The extensive assignments improved their science content knowledge and led to the awareness that the reading process utilizing higher order thinking can be an interesting, and a promising, way to incorporate science learning in elementary classrooms.

The preservice teachers had just returned from their three-week field experiences. One of the objectives for today's science education class was a discussion of their observations of teaching and learning science in the local elementary classrooms. As the lesson began, Renee declared, "We are doing all these science activities in our education course, yet in the schools, science is not being taught. The teachers are literally told not to teach science." "Oh yes," Jenny chirped, "Three weeks in schools, and all the kids did was just language arts and scripted math." "Science, anyone?" I asked. Heads shook in disgust. Then, "No," Kim said emphatically, "It is all reading and math, all for the state tests." "Are the teachers aware that high-stakes testing in science is about to be implemented in the state of Florida?" I ask. "Yes, they are aware," Kim responded, "but they say the test is not until another year." "Will you be prepared to teach science to your children?"

The preservice teachers, during their field experiences, observed the dilemma of the place of science in the elementary school curriculum. Elementary science has not been regarded as a staple compared to mathematics, reading, and writing because of the strong emphasis on teaching students to read, write, and do arithmetic (Tobin, 1997). This is further compounded by the recent emphasis on mathematics and language arts as the primary subjects in the state testing programs and whose results are used as measures of educational success and accountability. However, with the upcoming implementation of science in the Florida Comprehensive Assessment Test (FCAT), indications are that science will be considered a staple subject along with mathematics and language arts. Reports state that standardized tests have resulted in a curricula shift toward test preparation, as what is tested becomes what is taught in the schools (Amrein & Berliner, 2002; Jones, Jones, Hardin, Chapman, Yarbrough, & Davis, 1999; Mitchell, 1997; Pringle, 2001). This teaching to the tests raises concerns for science teacher educators who are involved in the preparation of teachers for elementary classrooms. Competing with mathematics and language arts, how can we best ensure adequate and appropriate science instruction at the elementary level?

Since reading takes up much of a normal day in the elementary classroom, and has received serious attention, the integration of reading and science will be absolutely necessary (Howe & Jones, 1998). Making a case for such integration, Bloome (1991) describes the reading process as a social event that involves internal regulation, is influenced by context, and utilizes higher order thinking—all processes involved in learning science. Baker and Saul (1994) note that both reading science and doing science include inquiry, focus on children's learning processes, foster the development of comprehension strategies, increase conceptual knowledge, and allow for critical thinking. This article describes teaching and learning activities in a science education course to promote the integration of science reading and the learning of science in elementary classrooms among a group of preservice elementary teachers. Capitalizing on the already favorable position that reading has in the elementary school curriculum, the goal of these assignments was to allow the preservice teachers to learn science as well as how to teach science to children in elementary classrooms.

Concerns about Reading and Science

The National Science Education Standards (NSES) (NRC, 1996), in their mandate to develop a scientifically literate populace, strongly support students learning science by being actively engaged in inquiry. Identifying science as inquiry, the standards state that science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers and establish connections between their current knowledge of science and the scientific knowledge found in many sources (NRC, 1996). Inquiry implies a codevelopment of skills such as high-level reasoning, application of existing scientific ideas, and communication of scientific information. Ideally, these would be accomplished through involvement in a variety of activities that are experientially based, allowing students to work as scientists as they make observations and develop their science knowledge and understanding about the natural world.

If the goals of producing a scientifically literate society (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996) are to be achieved, the process should begin in the earliest grades and proceed in a coordinated manner throughout the school years. The limited science exposure being observed in elementary grades will result in low levels of science achievement, inhibit further science pursuits (Gess-Newsome, 1999), and retard the achievement of a scientifically literate population. However, advancements in reading can now overcome some of the dismay caused by disregarding science teaching in elementary classrooms.

The single most important advancement in science reading has been the parallel but independent reconceptualizations of reading as an interactive-constructive process and science learning as more than conditioned responses and rote memorization (Holiday, Yore & Alverman, 1994). Holiday et al. contend that both science reading and science learning can be described as an interaction between prior knowledge, appropriate experiences, and information accessed from print and other sources in a specific social context that is focused on constructing meaning. According to Yore (2000), embracing science reading is not simply a bottom-up process of taking meaning from printed materials. Rather, he suggests that the learner is involved in inquiry. The reader makes meaning by negotiating understanding among the text, the reader's concurrent experiences, and memories of the topic within a sociocultural context. That is, the readers are not only introduced to the body of ideas called scientific knowledge, but are allowed to think about the unknown.

Through elaboration, refinement, and modification of the abilities they bring to the reading process, the readers make sense of the experiences (Layman, 1996).

Science Reading and the Science Education Course

The preservice teachers were enrolled in the course Science Education for the Inclusive Classroom in the semester before the pre-internship in their teacher education program. The course was designed to help them develop the competence and confidence needed to teach science in elementary classrooms. This competence involves a level of understanding of the subject matter, making sense of their surroundings based on observations and reflections, and flexibility in planning towards continuous improvement of science teaching and learning. The course was divided into four primary areas: nature of science, integration, the role of the science teacher, and issues in teaching and learning elementary science. A number of assignments were specifically developed to coincide with each of the primary areas. In the following sections of the paper, I discuss the assignments that promote the teaching of science through reading, the impact of the activities on the preservice teachers' learning of the science content, and their responses to the activities.

The Assignments

In this section, I describe the assignments that were implemented to incorporate science learning through high involvement with reading. The goal was that involving the preservice teachers in such activities, inclusive of reading comprehension, would facilitate their science learning and stimulate the inclusion of science in their classrooms. This kind of reading instruction implied reading comprehension that required the application of high level thinking skills. These assignments were (1) science into the classroom via informational books, (2) current science article presentation, and (3) science and the standards.

Science Into the Classroom via Informational Books

For this assignment, the preservice teachers were organized into grade level teams and assigned science topics that were correlated to the state's standards. Some of the topics were weather, habitats, mammals, machines, space, and the solar system. In groups, they explored libraries and bookstores and selected science informational books that were relevant to their topics and appropriate to their grade level. Some groups chose a variety of texts on the topic, but each member read the same texts related to their topic. Other groups chose and read different books on similar or related topics.

Students read the texts individually, then to one of their peers. As a group, they discussed the content of the text, developed classroom goals for integrating reading and science, and identified lesson objectives applicable to the topic. A group journal of their activities, inclusive of reflections from group discussions, was maintained throughout the process. They were required to document the science concepts and to reflect collectively on their experiences while noting any questions about the science content and about the strategy of learning the science through reading. This resulted in some groups developing running conversations in their journals.

Current Science Article Presentation

Another assignment that integrated reading into the science education course required the students to read a current science related article from a daily paper or weekly published magazine. At the start of each class session, two students reported on the content of their article. Each presentation lasted for five minutes

and included a summary of the main points and an indication of how the content of the article could be related to, or integrated into, the curriculum in elementary classrooms. A question and answer session following each presentation facilitated further discussions on content or pedagogical issues that emerged. A copy of each of the articles was then displayed on a Current Science bulletin board in the classroom.

Science and the Standards

This assignment involved a number of sections that were accomplished over the semester. At first, each student selected a science topic from the state standards. Students chose a topic about which they had some anxiety and a desire to learn more in order to be able to provide meaningful learning experiences. Using a variety of resources, they learned the topic on their own, constructed a concept map, and wrote a conceptual paper indicating knowledge of the topic above the high school level. A science lesson plan for a named grade was then developed around a concept chosen from their concept map. Along with the plan, they created their own reading resource—expository, narrative, or poetry—to accompany the science lesson.

Data Collection and Analysis

Data were collected using a variety of qualitative methods, including students' journals, audiotaped excerpts from class discussions, and the students' responses on an exit questionnaire administered at the end of the science education course. Sections of the students' journals directly related to each of the assignments were photocopied, read, and coded. The audiotapes were transcribed, coded, and used to compare themes emerging from the students' journals. The exit questionnaire contained specific questions that required the students to rank the three assignments integrating reading and science and also explored the students' reactions to each assignment.

Data analysis followed the procedure suggested by Miles and Huberman (1994) whereby the data sources were meaningfully read toward identifying patterns while keeping intact the relation between the various assignments. The analysis addressed the identification of themes and their essential features. Systematic descriptions of the students' responses were paraphrased during the search for common patterns and themes. The preservice teachers' reactions and the noted impacts were the key findings that emerged from the reflective analysis and interpretation of the data sources.

Preservice Teachers' Actions and Reactions

Much has been written about the problematic status of elementary science education (Baker & Saul, 1994). When faced with the dilemma of limited science teaching in the elementary classrooms and the increased focus on math and language arts, attempts were made in the science education course to explore ways of integrating science and language arts. Students appreciated the number of available science informational books, the impact of reading on their own science learning, and the level of interactions that emerged from the reading as they synthesized the information and made connections between ideas, their own experiences, and other contexts.

Students were amazed at the number of science informational books available at the public library and in the bookshops. One students' journal entry contained the following, "There were so many books on the solar system at the library and the two bookshops we visited ... they ranged from picture books with very low reading levels to ones that were appropriate for upper elementary." They also noted the ease of accessibility and the range of texts related

to the various ages and topics. A number of students indicated that regardless of the topic chosen, more than an adequate number of books could be easily obtained. In the class discussion, one student said, "If I had chosen any other topic, it would still be easy for my group to have more than enough books, both from the library and the bookshop." Another student added, "For my group's topic, Metamorphosis, we found books suitable for all grade levels." A number of groups also noted that informational books were available for different reading levels; some had limited texts and more pictures for lower grades while others had more texts supported by drawings or photographs.

In choosing the books, however, some students were not sure if they should use only reading levels or attempt to match the science content to the guidelines as recommended in the standards. Discussions and journal entries depicted their concerns such as the following:

> In choosing the books, we were not sure how to be consistent with the content requirement and the reading level of the grade. We did not want to choose a text that did not adequately cover the content as outlined in the standards, but we did not want to make the reading level above our grade two students. (Reflective Journal, Grade 2 group)

> Our group tried to select books based on readability, but we were not sure exactly what would be right for a regular group of grade two students. We all had different ideas as to what would be right for them and how to make such a decision when you have your own classroom. (In-Class Discussion)

> Our most difficult section of the assignment was matching the reading level to the content standards. We were not sure how to decide if the content was right for our grade ... (Reflective Journal, Grade 5)

Most grade level groups echoed the same concern and this led to discussions about choosing content-specific reading materials.

> If we plan to teach the lesson, we develop the activities to match our students, but the books do not really know our students, neither do the standards, and sometimes they contain too much information or too little for the grade level." (In-Class Discussion).

As a class, however, we decided that because of the difficulty in finding the text that perfectly matches the content specific requirements of the grade level, it would be better to choose a range of texts that targets various reading levels while not limiting the scope of the content.

The in-class discussions and the students' journal entries indicated that guidance was needed in determining the criteria for making appropriate choices given the abundance of science informational books. Tomlinson and Lynch-Brown (1996) identified the importance of readability and conceptual difficulty as two of the features to be considered when choosing books for children. They describe readability as an estimate of the text's difficulty based upon its vocabulary and sentence structure, while conceptual difficulty pertains to the complexity of ideas and how they are presented. From our class deliberations, considerations were given to readability and conceptual difficulty and the notion that the books selected should challenge the children and guide them toward an appreciation for both reading and science. The understanding was to provide appropriate experiences for the range of academic abilities that exist in the elementary classroom and to facilitate meaningful learning through the integration of reading and science.

The preservice teachers noted that each of the assignments facilitated the achievement of state standards for both science and language arts. They explained that reading the informational texts and creating their own reading resources allowed them to process information while switching between the text-based information and their experiences. Then, as they interacted with their peers, they were able to compare the information and experiences with their personal knowledge and also with those of their peers. Further responses on the questionnaires noted that the assignments, when translated into elementary classroom experiences, would foster the achievement of language arts and reading standards as well as skills ranging from comprehension and critical thinking to familiarity with science vocabulary. Almost unanimously, they stated that one of their classroom goals for integrating science and reading would be to teach science to their children consistent with the mandate of the National Science Education Standards and satisfying the standards for language arts. The NSES (NRC, 1996) states:

> The goals for school science that underlie the National Science Education Standards are to educate students who are able to experience the richness and excitement of knowing about and understanding the natural world; use appropriate scientific processes and principles in making personal decisions and engage intelligently in public discourse and debate about matters of scientific and technological concerns. (p. 13)

That is, they wanted their elementary students to have the experiences that will foster the development of scientific skills, attitudes, and content knowledge toward becoming scientifically literate citizens while effectively using the reading process and being able to construct meaning from a wide range of texts.

One of the high points of the experience for the preservice teachers was the level of content knowledge that emerged from their interactions with the texts and was further refined by the group discussions that followed. Reading the texts highlighted much of their deficiencies with the science knowledge and a lack of understanding of some basic concepts applicable to the elementary science curriculum. Overall, they indicated that as they read the texts they vaguely remembered bits of science information indicating some previous formal experiences. For example in a text dealing with water, the students said they remembered terms such as solution and suspension but were not able to recall what these words meant nor how they related to water.

> I remember the words from my science class but honestly, I do not even know which class that was. Reading the text and discussing with my friends, who also remember some things, help me to make sense of mixtures and the role of water as a solvent. ... For re-enforcement (sic) I would allow my students to mix substances at home and for homework describe their observations and include how what they did was related to the text they read. (Reflective Journal, Grade 4)

> Reading the texts helped me to recall some of the science that I should know and also helped me to realize that there was much that I needed to relearn. (In-Class Discussion)

This triggered a whole domain of science learning for the preservice teachers and the need to become comfortable with teaching and learning science. Agreement was expressed that to adequately integrate language arts and science, they would need to first understand the science content knowledge and, through questioning and other teaching strategies, provide

opportunities for the elementary students to think critically about important ideas, make connections to their experiences and, in the process, re-present the knowledge learned.

The students' conceptual paper (Science and Standards Assignment), allowed them to document and re-present the science content learned. Completion of this assignment required the skills of comprehension and synthesis while thinking about key ideas and valid science knowledge. It provided me, as the instructor, with the opportunities to identify and challenge some of the subtle science misconceptions. Lessons involving specific activities to confront their misconceptions were taught and clarifications were made. Some misconceptions were also evident in the reading resource they developed as part of their assignment. For example, students wrote that animals inhaled only oxygen and exhaled only carbon dioxide. Another common misconception was that during the day, plants take in carbon dioxide and pass out oxygen while the reverse occurs at night. During our lessons, the students explored the composition of air and the differences between the physical process of breathing and respiration as a life process in all living things, and between respiration and the food-making process of photosynthesis. A benefit of this experience was that they recognized the importance of allowing their students to represent the knowledge learned via multiple means such as writing, drawing, and drama. The teacher as facilitator then uses appropriate teaching and learning strategies to clarify the inconsistencies and guide the development of valid science knowledge.

Discussion

The theoretical perspective guiding the assignments was consistent with a social constructivist epistemology. Social constructivism, an offshoot from mainstream constructivism, has gained much attention as a referent for teaching and learning over the past years (Tobin & Tippens, 1993; Fosnot, 1996). Drawing upon Vygotsky's (1978) attention to the social context of learning, it recognizes the dynamic interplay between social interaction and cognitive activities. However, the consensus is that while the construction is personal, each of us makes sense of our world by synthesizing new experiences from the physical and sociocultural world into what we have previously understood as we engage in joint activity. According to Keys (1994), such peer interactions facilitate the learners' ability to acquire concepts, solve problems, and as members of a collaborative group, attempt to come to a consensus through a process of meaningful negotiation. A collaborative reading task can, therefore, structure student discussions and create contexts in which students generate meanings from texts by sharing and evaluating ideas, raising questions, and constructing viable mental models toward an understanding of their environment.

In this paper, I shared the efforts employed in the science education course to incorporate science learning through high involvement with reading. The goal was that involving the preservice teachers in such activities would foster their own science learning through reading comprehension, enrich their curriculum, and stimulate the inclusion of adequate and appropriate science instruction at the elementary level. In accordance with supporters of integrating science and reading (Bloome, 1991; Yore, 2000), the preservice teachers learned that reading can make science experiences more meaningful and can provide vicarious experiences. The assignments required them to read for understanding, evaluate the credibility of information sources, and produce a variety of written sources. The preservice teachers indicated that each experience was positive and facilitated the learning of science content knowledge while achieving language arts standards

such as using the reading process effectively and constructing meaning from texts. They recognized that in order to construct meaning from the texts, they had to employ high level thinking skills to make inferences, consider implications, and decide on applications (Flick & Lederman, 2002).

The preservice teachers, from their own experiences with the assignments, recognized that the vast array of available texts and the inclusion of reading strategies could facilitate science learning. Reading multiple texts about the same topic has been lauded as one way to enrich and build knowledge (Schoenbach, Greenleaf, Cziko, & Hurwitz, 1999; Walker, 2000). They contend that learning is enhanced when students read multiple texts and encounter similar ideas and vocabulary through different examples. For the preservice teachers, the multiplicity of available texts allowed for cross checking of information. This sometimes initiated further research in other texts to check accuracy. Along with the variety of texts, reading strategies such as imagery instruction, analytic phonics, chunking, cloze instruction, and collaborative were all identified by the preservice teachers. The preservice teachers discussed with ease the implementation of these strategies. Earlier in their teacher education program they had completed courses that taught them how to identify and teach these specific sets of reading skills and strategies. While the reading strategies were discussed as integral to learning science from texts, the students were aware that they were by no means sufficient to ensure complete understanding of all science.

The preservice teachers raised the concerns that with a focus on reading, one could lose sight of the need for hands-on experiences necessary to achieve learning by doing and the development of some physical skills as advocated by the NSES (NRC, 1996). Class discussions on the individual assignments, science and reading, using science as the basis for reading, and reading about science concluded that while science must be primarily taught by means of an active, hands-on, experiential approach, teaching reading comprehension strategies within the context of science will support high level learning goals. Then, as the preservice teachers began to identify the physical and mental skills in science, it became clear that inquiry in science embodies some of the same high-level skills developed and sustained during reading comprehension. This is consistent with the agreement among educators that a focus on the literary aspect of science can lead to proficiency in reading and communication skills (Casteel & Isom, 1994; Rice, 2002).

The preservice teachers expressed concerns about the accuracy of science information in informational texts and their abilities to make such judgments based on their own limitations. The variety of reading assignments allowed them to refamiliarize themselves with some science concepts and, through class discussions, recognize the need for their own continued learning. As a class, we concluded that reading a variety of informational texts on the same topic allowed for recall of previously learned information or served as the impetus to learn new ones. Motivated classroom teachers, by reading critically, could, therefore, improve their science knowledge by exploring an array of texts.

In addition to focusing on accuracy of science information, strategies for self-learning, and pedagogical issues such as integration, post-assignment discussions aimed to make the preservice teachers aware of their own misconceptions and preconceptions garnered from both formal and non-formal science experiences. It was clear that one semester of the method's course could not adequately address all the science content applicable to the Sunshine State Standards. Further discussions contemplated ways to improve their own conceptions and students noted

that the range of assignments pointed to possible resources that can be accessed toward their own learning. They were cautioned, however, that information from these resources should be validated and crosschecked against other sources and media such as traditional textbooks. Involvement in science teacher organization and continued professional development were also encouraged as possible means of maintaining and developing collaborative relationships that can foster further science learning.

Conclusion

One of the goals of the science education course stated in the course syllabus was the provision of opportunities for the preservice teachers to construct a vision of science teaching and learning and assist them in projecting themselves into that vision. As a result, using hands-on minds-on science as the context, the preservice teachers were involved in activities to develop strategies and techniques applicable to teaching and learning science in the elementary classroom. The extensive assignments involving the reading of science improved their content knowledge and provided strategies to incorporate science teaching and learning in the elementary classrooms. Students also became aware of the need for continued learning of science and that this should continue into their professional life.

I am not advocating reading science from science informational books as the universal method for science teaching in elementary classrooms. This should not replace inquiry as indicated by the NSES (NRC, 1996). However, the reading process as a social event involving internal regulation, influenced by context, and utilizing higher order thinking (Bloome, 1991) is an interesting and promising way to incorporate science learning in classrooms while accomplishing standards related to reading as indicated in state mandates. The effectiveness of the reading and science-integrated assignments depends on the quality of the instructional context in which it is used, the reader's past experience, and the science reading procedures within the sociocultural milieu. From the experiences in our science education course, I am convinced that integrating science and reading is one viable means of supporting science learning while developing language arts skills, specifically ones related to reading. Teaching effective reading comprehension skills within the context of a subject area such as science will support high level learning goals. All participants asked questions, expanded their vocabulary, thought critically about important ideas, synthesized information from texts, increased independent reading skills, and re-presented their knowledge through various forms of writing. This integration also facilitated a number of valid classroom interactions that are important in learning. As the preservice teachers worked in cooperative groups, were involved in discourse, and negotiated meaning among their peers, it was clear that they benefited from the teaching and learning activities that integrated science and reading. They not only learned how to learn science but also how to teach it within the context of reading.

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Rose M. Pringle is an Assistant Professor in the College of Education at the University of Florida. Currently she teaches Science Education to undergraduates and graduates. She can be contacted at (352) 392-9191 ext. 229 or e-mail: rpringle@coe.ufl.edu