A Paleontology Network Inquiry Consortium: Impact on Teacher Practice

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ABSTRACT

The Paleontology Science Network Inquiry Consortium consists of a University School of Education and Geology Department and 20 regional schools districts. The pilot group of twenty secondary science teachers represented eighteen schools from these districts. The program was designed to meet the following program objectives. (a) Increased knowledge of science discipline, (b) Knowledge of inquiry-based pedagogy, (c) Skill development in teaching in a standards-based classroom, (d) Support for implementing science inquiries in classrooms. The program goal was to help experienced science teachers do inquiry-based science in their classroom. The pilot group were experienced, successful teachers, traditional in nature, have not done inquiry prior to the program but expressed interest in learning how to do successful inquiry. Four domains composed this research agenda. (a) The teacher beliefs about inquiry and their belief about their ability to implement in classroom, (b) The teachers knowledge base for implementing inquiry, (c) The teacher inquiry/research experience, (d) The student's science learning from teacher-designed, inquiry–based instruction, including conceptual knowledge, reasoning, and the nature of science. The project objective was to investigate the teacher's attitudes about their readiness to implement an inquiry and to determine whether they actually were able to implement a meaningful student inquiry.

Keywords: Education - teacher education, geoscience- science; geology - paleontology

THE PALEONTOLOGY CONSORTIUM

The Paleontology Network Inquiry Consortium consists of a university School of Education and Geology Department and 20 regional school districts. The consortium was initiated in the fall 2000 semester. The initial pilot program began the following fall. The first group of twenty secondary science teachers represented eighteen schools from these districts. The program was designed to meet all of the following objectives.

A) Increased understanding of science discipline
B) Introduction to inquiry-based pedagogy and other advanced teaching methods
C) Skill development in teaching in a standards-based classroom
D) Introduction of paleontology research techniques that are appropriate to secondary science.
E) Support for implementation of new science inquiries into classrooms.

The program goal is to help experienced science teachers introduce inquiry-based science into their classroom - learn how to do it, have content, resources, and skills to do it effectively. The pilot group in this study is composed of seasoned, successful teachers, generally traditional in nature, who did not use an inquiry approach to teaching prior to the program but expressed an interest in learning how to create successful inquiry activities for their students.

SIGNIFICANCE OF STUDY

Today's reform rhetoric has labeled the use of inquiry as representing the essence of science education (Keys & Bryan, 2001). Documents such as the National Science Education Standards are promoting inquiry as the "central strategy for teaching science."

The challenge to incorporate meaningful inquiry into secondary science courses is especially difficult when dealing with experienced science teachers that view their present methodology of lecture and labs with pre-determined results as successful. Many teachers' belief that the nature of science is an objective body of knowledge created by a rigid scientific method (Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991) impedes inquiry-based teaching. The aim of this network is to help teachers understand that science is not just a body of immutable facts but a statement of our current knowledge of the natural world. The use of an inquiry based approach in a science classroom leads students to realize the way science is carried out and be more likely to understand and retain the principles and concepts being taught. The difficulty in changing these perceptions results from overcoming embedded prior practice (Chinn & Brewer, 1993), which has resulted from the teachers' practical knowledge (Van Driel, Beijaard, & Verloop. 2001) derived 'in action' (Schon, 1983) within environments that supported traditional teaching. This 'practical knowledge' guides teachers' actions in practice (Brickhouse, 1990; Verloop, 1992). One important feature about 'practical knowledge' is that the teachers' beliefs act as a barrier to new knowledge about teaching preventing the integration of this new information into practice (Pajares, 1992). Changing practice beliefs requires sufficient time, resources and ongoing professional support (Appleton & Asoko, 1996; Tobin, 1993). In addition, we suggest that professional development designed to support teachers in the incorporation of inquiry within their practical knowledge requires that a specific topic be included in the professional development activities. This program focused on paleontology, including pedagologic aspects such as content, methodology and field experience. Some aspect of paleontology was to become the first inquiry implemented in their classrooms. Therefore our professional development plan required that additional growth in content knowledge and research experience with the specific inquiry topic be included. Secondly, we believe that the most meaningful professional development takes place in the context of a learning community or network, not only during the content and pedagogical skill development stage, but also during the classroom inquiry implementation stage. Our plan, designed as a comprehensive program to promote this systemic change, was to provide an experience to include a stage of content and skill development, research experience and then support in classroom application, all within the context of a cohort. In addition to learning new scientific information, teachers need to learn how to use the information in inquiry-based activities that stress critical thinking by students (National Research Council, 1996) and then to experience the application while supported by teacher colleagues, science educators and content scientists.

Program Overview

The program was designed to meet the following program objectives. It is sequential in nature and flows over a two-semester timeframe.

A) Increased understanding of science discipline.
In the fall 2000 semester the teachers were placed in a graduate level paleontology content course entitled Vertebrate Paleontology and Evolution. The purpose of this course was to provide in-depth knowledge of the subject.

B) Introduction to inquiry-based pedagogy and other advanced teaching methods
In the spring 2001 semester the teachers participated in six Saturday workshops entitled Introduction to Paleontology Pedagogy. The purpose of this workshop was to provide teachers with the pedagogy, content and materials needed to carry out the inquiries.

C) Skill development in teaching in a standards-based classroom
In summer 2001 the pilot teachers participated in three field days and a dinosaur dig to gain first hand experience in paleontology. The daylong trips investigated dinosaur tracks, fossil plants and insects and sedimentary sequences. The six-day dig was in Western Colorado at a university quarry.

D) Introduction of paleontologic research techniques that are appropriate to secondary science.
The program integrated research techniques throughout the coursework. All of the courses introduced paleontologic techniques such as statistical, functional, and field methods supplemented by specific pedagologic suggestions for activities to initiate classroom research.

E) Support for implementation of new science inquiries into classrooms.
Teacher implementation of inquiry based methods began in fall 2001. With questions identified, the classroom inquiries were carried out in the fall semester. The Consortium provides support for these inquiries.

DESCRIBING THE PROGRAM

A. Vertebrate Paleontology and Evolution Course - This course traced the development of various vertebrate lineages through time. The teachers selected this content course from a number of offerings because they felt that vertebrate fossils most connected with courses they taught. The participants in this study included fourteen biology/life science teachers, five earth science/geology teachers and one physic teacher. The course was designed to develop an understanding of how modern vertebrates evolved from their ancestors and how they are related to other animals, as well as the ways in which vertebrates function and how they have adapted to various environments. Along with tests and quizzes the participants were required to write a research paper on a topic of their choice. The research papers completed by the biology teachers included "The end Permian extinction and the present extinction compared", "Development and variation of proboscidae," " The evolution of mosasaurs & snakes, " " Paleoecology and diversity of the Jurassic Morrison Formation," "The demise of the mammoths and human's role in their extinction," "The evolution of the mammal ear," and " Convergent evolution of ichthyosaurs and dolphins." The choice of these topics reflects the biology teachers attempts to connect back to their own teaching, selecting topics that would enrich units in their existing biology courses. The same observation could be made with the topic chosen by the physic teacher- "Physics of flight/evolution of birds."

The choice of content classes they had, all paleontological related, are not merely a list of taxa and their relationships. While paleontology may be best described as a blend of geology and biology (Lane, 1978) research has been done on the hydrodynamics of trilobites (Fortey, 1999) and the complicated suture pattern of ammonites has been suggested to be a mechanism for resisting high water pressure at depth. Much of paleontology draws on concepts from other sciences, not just biology and ecology, but also, for instance, physics. Classic examples are the suspension bridge structure of sauropod necks and tails (Alexander, 1989) as well as the hollow braced construction of their vertebrae – lightness without sacrificing strength. The different strategies utilized by fish when swimming can be worked out in a fluid dynamic context. Vertebrate paleontology is full of such examples, but so are the other classes, which the students could have selected as part of this program.

B. Inquiry into Paleontology Pedagogy - This workshop/course took place in the spring. The program goal was to help the teachers introduce inquiry-based science on paleontology into their classrooms, learn how to do it, how to enhance the content, the types of available resources, and skills to use these resources effectively. The teachers participated in six Saturday workshops titled Introduction to Paleontology Pedagogy. The purpose of the workshop/course was to provide teachers with the pedagogy, content and the materials needed to carry out the inquiries on fossils. The six Saturday topics listed in order of presentation were:

Anatomy of Dinosaurs - This first session was generally a content delivery day. Although mostly delivered through lecture, some activities were hands-on and inquiry based. The purpose was to begin establishing a base of information. Without these understandings the teachers would be less likely to appreciate the activities we would present them over the next five sessions or in fact be able to utilize them with their students. Although transfer of knowledge is difficult to achieve through direct instruction only, there is evidence that such domain-general knowledge can be taught in such a way that it does transfer to new situations (Bassok & Holyoak, 1989). By explicitly teaching this background knowledge and then giving students many opportunities to apply it, transfer of knowledge is more likely.

Forming Fossils in Nature - The purpose of the morning activities was to generally provide knowledge on fossil formation and interpretation and to present various activities that they would be able to do with their students. Topics included 'preservation, environments and taphonomy,' 'forensic paleontology' and' how big dinosaurs were and how fast they could run?'

In the afternoon the group visited the Dinosaur Track Museum, which is located on the University campus. Selecting such a site opens up the participants to a large and more complete set of collected fossils than may be studied in the classroom. This activity was necessary to begin moving participants to a more predictive and productive understanding of fossil formation. By itself we could not expect a complete understanding of fossil preservation, but our hope was to move them in that direction. Coupling that experience with the later summer field studies, where we involved the participants in collection of data and samples, participation in discussions at the collecting sites and validation of their conclusions, we felt that in the end we promoted a more complex understanding of the processes involved in fossilization.

Molding and Casting Fossils and Constructing an In-Classroom Dig - These two sessions provided a range of activities to assist the teachers in bringing the content alive in their classroom through active student involvement and inquiry. The teachers were taught techniques in making fossil molds from silicone rubber and casting fossils in plastic and plaster, how to design in-classroom digs, and how to construct sedimentary models with the correct sediment size and composition. The majority of the products were teaching models needed to prepare their students to do actual field inquiries.

Language Arts/Paleontology - The activities for this day centered on language arts connections. Topics and examples were specific to paleontology. Making science concepts, definitions, and data meaningful requires a range of expressive activities. Memorization only has value if followed by some form of manipulative application. In addition to hands-on investigation and observation, the various language arts skills are necessary tools in understanding science. The ability to critically interpret readings and assess their validity opens for the student an unlimited resource of human thinking about a topic. Recognition of valid information supported by scientific investigation vs. unsupportable myth and creative misinformation is a necessary skill in doing and understanding science. The ability to express understanding through thoughtful, reference supported writing not only helps clarify the learner's thinking during the writing process, but stimulates high level thinking on the topic. Self-questioning during the writing may lead the writer back to further observation and assessment about what he or she truly understands. Oral communication may take this process of understanding even further. Verbal interaction may stimulate further questions or help clarify understandings. The openness of the discussion and the preparation of the participants determine the amount of potential gain in understanding. Although artistic expression is not usually included under language arts, it incorporates other ways of making meaning or expressing understanding. Thus it is another tool in the search to understand and apply the content.

With the above in mind, we provided the students with a large amount of valid and invalid information from scholarly publications, newspapers, web pages, video clips, and science fiction publications. Utilizing these materials we had the teachers participate in a range of language art activities. These included writing and verbal discussions on "whether dinosaurs and humans existed together in the past," and "whether myths about dragons were based on fossil remains." We also provided each teacher a number of books and a range of written materials (funded by a grant) to support student science writing in their classrooms.

Local Field Study Sites - The final workshop meeting was held as an extended classroom experience. The first half of the day was outside at Dinosaur Ridge, which is a local National Monument and the afternoon was inside at the Morrison Museum, which centers its collection on dinosaur fossils collected at the Ridge. The discussion focused on managing student fieldwork while doing meaningful inquiry. Methodology on field mapping, fossil extraction, and field preparation were discussed at each of the sites.

C. Summer Field Studies - The general purpose of the summer activities was to provide the teachers with field experience to help them further develop an understanding of paleontology. How students engage in a science activity influence how and what they learn. Unfortunately many teachers have not had the opportunity for field experience. Most of their knowledge comes from listening to experts or reading text. As Don Schon (1987, p.36) wrote, "when someone learns in practice, he is initiated into the traditions of a community of practitioners and the practice world they inhabit. He learns their conversations, constraints, language and appreciative system, their repertoires of exemplars, systematic knowledge in action." Rather than take them only to the quarry for the six day-long experience, we felt it first necessary to introduce some field techniques through three one-day experiences.

Field Day Trips - We developed three one-day field trips mainly intended to provide context and introduce skills, especially for non-geologists that would be useful in the dinosaur dig. Topics included map reading, sedimentary rock environmental interpretation, observing and collecting data and samples, and geological mapping.

The first day trip was to the Florissant Fossil Beds National Monument, where we investigated plant, insect fossils and petrified trees. We began with this site because it contained a number of active dig sites where proper extraction techniques could be observed and discussed. It also allowed for the group to try out the techniques at a private site outside the park. At this site they were able to collect samples for later classroom preparation and use with their students. The second location was to the Purgatoire Dinosaur Tracksite in the Comanche National Grasslands. Here the participants were introduced to site mapping and interpretation, as well as the proper techniques of casting and mold making in the field. They had learned some of these techniques in the spring workshop and were able to see them in practice. The third location was near Canon City, Colorado. First we took a traverse from the Ordovician to the Carboniferous looking at the changes in rock types and fossils, reflecting extinctions and changing environments through time, stopping at a number of sites. We then spent the afternoon at one site to examine Cretaceous rocks and fossils and to apply mapping and collecting techniques. This allowed the teachers to see for themselves that environments and faunas can change even when the rock sequence looks superficially homogenous.

The Six-day Dig at Cactus Park Dinosaur Quarry - The University runs a dinosaur quarry in western Colorado near the Utah border. The students worked in the Upper Morrison Formation. This quarry contains mainly *Camarasaurus*, although there is also some *Allosaurus* material. The one week field course formed an introduction to field techniques and allowed the students to develop some of the techniques they had observed on the day trips, as well as a chance to immerse themselves in the geology of the area for a week. One of the advantages of having a quarry worked solely by the University is that the students can participate in all aspects of paleontological documentation and excavation, including recording stratigraphic sections, making quarry maps, as well as excavating and jacketing the specimens. They learned how to make a plaster and foam jacket and learn when reinforcement of jackets was necessary.

Dental instruments are used to excavate the bones. 150 million year old dinosaur bones are very fragile and so the process of excavation is slow, delicate and painstaking work; larger tools have a much greater likelihood of damaging the bones. Glues are used to stabilize the bones and once the bone has been revealed it is covered with aluminum foil as a separator and then protected with a plaster of paris jacket for transportation back to the laboratory. This week in the field allowed the students to become familiar with the rock formations of the area just from sheer proximity. As they worked slowly through the matrix they made many observations on the texture and color of the sediment, all of which are relevant to the depositional environments and to the chemical composition of the sediment. They could see the different characteristics of each layer which are related to the slight changes in the paleoenvironment at the time of deposition. A day trip would not have allowed these observations to be made by the teachers but a week of close-up work in the quarry really brings home to them the idea that rocks reveal a great deal of information when examined closely.

D. Museum Studies in Paleontology - This following fall (2001) course covered several aspects of museum studies; covering the whole museum provcess from reception of material, cataloguing and curating to preparation and display. Students learned how to stabilize and prepare fossil bones removed from the field. The bones that the participants collected on the summer dinosaur dig were extracted from the plaster jackets, stabilized, and prepared, so that they were ready for molding and casting. They also learned several different methods of molding fossil bones and footprints and making casts from the bones. They learned to read tha shapes and preservation of the bones and decide which moulding and casting methods would be best for the intended purpose – display or study. Finally, as group projects they put together displays of their own for the museum and contributed to the museum as a whole by researching one area of museum studies and assessing how the museum could be improved by the application of their research.

E. Implementation of Paleontology Inquiry in Classrooms - Also in the fall 2001 semester the teachers began implementing student inquiries in their classrooms. Student inquiries were generally completed by groups of two or three students but in a few cases by individuals. A wide range of topics was selected based on the science discipline and grade level. Both Internet and direct support were provided on request by the project support team of science educators and paleontology content specialists. The teachers varied in the amount of support they needed and requested. A few needed validation that they were providing their students with correct information and direction throughout, keeping the support team comprised of each step of the implementation. Others reported results but required minimum input from the support team. The teachers as a whole maintained close contact among themselves, frequently sharing ideas and results. We determined through interviews and classroom observations that they had reached a comfort level with the materials and their ability to manage a classroom inquiry on this content, and had become much less dependent on the project support team for the implementation.

ASSESSING THE IMPACTS

Four domains composed this evaluation aspect. (a) the teachers understanding of student inquiry and their belief about their ability to implement in classroom; (b), the teachers knowledge base for implementing inquiry; (c), the teacher inquiry/research experience,; and (d), the student's science learning from teacher-designed, inquiry–based instruction, including conceptual knowledge, reasoning, and the nature of science understanding.

The study was divided into two parts, the initial involving the first three domains was completed in the summer of 2001. The second part was completed in fall 2001. The two stages of data assessment were determined necessary to first investigate the teacher's attitudes about their readiness to implement student inquiry and then to determine whether they actually were able to implement a student inquiry that resulted in meaningful student learning.

The assessment of the first stage utilized a multi-method design which focused on specific, well-defined aspects of teacher's knowledge and skills—Likert-type questionnaires, in combination with interviews and experimental tasks (Peterson, Fennema, Carpenter & Loef 1989). The feeling was that this comprehensive approach to assessment would be more likely to capture the complex aspects of the teachers' attitudes about their ability to learn the necessary content and utilize an inquiry approach to teaching and whether this had been accomplished by the project activities. Kagen (1990) supports this position. The second stage of assessment collected observational data in the participants' classroom on the implementation of the inquiry. This data included student products, and pre and post assessments of the topic content.

FINDINGS

At the beginning of the project the participants were surveyed to determine their attitudes on teaching science and how students acquire knowledge in the classroom. After the field experience they were again questioned. Initial results of the teacher's view of how students acquire knowledge indicated a change of perception following the summer. Prior to the field experiences, 16 of the 20 teachers expressed a view that the teacher determines all content to be learned, how it should be delivered and is responsible for student learning. They felt that the textbook, worksheets and activities with pre-determined results led to success on traditional assessments. The remaining teachers felt that students needs some hands-on involvement to aid students in understanding science concepts, but that generally this should be controlled by the teachers and only occasionally should students be allowed to have open-ended experiences. An apparent change in perception showed strongly in the post questionnaires with most of the teachers recognizing the importance of open-ended inquiry in the acquisition and understanding of science knowledge. A number of the teachers based this changing view on their own feelings while participating in the extended classroom experiences in comparison to their earlier traditional classroom science experiences. They stated that they "finally understood a concept" or had "never made that connection before."

Results also indicate that the teachers feel adequately prepared to support their student's inquiries. Assessment of the content knowledge showed extensive gain of new knowledge and correction of most false perceptions about the content. Participants expressed a great satisfaction in their new knowledge and enjoyment in the rigor of the class. A number of the participating teachers highlighted that they had been 'allowed to take a pure content class separate from educational pedagogy' at this point in their career. As one stated, 'it had been quite a while since [he] had been in a real science class.' When asked about what parts of the preparation program were more or less important they were unable to identify any part that they felt was less important. No participant felt than any part of the program could or should have been omitted. On-going assessment during the student inquiry phase helped us better understand what additional content and experiences teachers would need to successfully support their students.

REFERENCES

Alexander, R. McN., 1989, The dynamics of dinosaurs and other extinct giants, Columbia University Press, 167p.

Appleton, K., and Asoko, H., 1996, A case study of a teacher's progress toward using a constructivist view of learning to inform teaching in elementary science, Science Education, v. 80, p. 165-180.

Bassok, M., and Holyoak, K.J., 1989, Interdomain transfer between isomorphic topics in algebra and physics, Journal of Experimental Psychology: Learning. Memory, and Cognition, v. 15, p. 153-166.

Brickhouse, N. W., 1990, Teachers' beliefs about the nature of science and their relationships to classroom practice, Journal of Teacher Education, v. 41, p. 53-62.

Chinn, C.A., and Brewer, W.F., 1993, The role of anomalous data knowledge acquisition: A theoretical framework and implications for science instruction, Review of Educational Research, v. 63, p. 1-49.

Duschl, R. A., Wright, E., 1989, A case study of high school teachers' decision making models for planning and teaching science, Journal of Research in Science Teaching, v. 26, p. 467-501.

Fortey, R.A., Owens, R.M., 1999, Feeding habits in trilobites, Palaeontology v. 42, p. 429-465

Gallagher, J.J., 1991, Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science, Science Education, v. 75, p. 121-133.

Kagen, D.M., 1990, Ways of evaluating teacher cognition: Inferences concerning the Goldilocks principle, Review of Educational Research, v. 60, p. 419-469.

Keys, C.W., Bryan, L.A., 2001, Co-constructing inquiry-based science with teachers: essential research for lasting reform, Journal of Research in Science Teaching, v. 38, p. 631-645.

Lane,G., 1978, Life of the past, Columbus, Ohio, Merrill Publishing Co.

National Research Council, 1996, The National Science Education Standards. Washington, DC: National Academy Press.

Pajares, M.F., 1992, Teachers' beliefs and educational research: Cleaning up a messy construct, Review of Educational Research, v. 62, p. 307-332.

Peterson, P.L., Fennema, E., Carpenter, T.P.., and Loef, M., 1989, Teachers' pedagogical content beliefs in mathematics, Cognition and Instruction, v. 6, p. 1-40.

Schon, D., 1983, The reflective practitioner. How professionals think in action, New York: Basic Books.

Schon, D., 1987, Educating the reflective practitioner, San Francisco, Jossey-Bass

Tobin, K., 1993, Referents for making sense of science teaching, International Journal of Science Education, v. 15, p. 241-254.

Van Driel, J.H., Beijaard, D., and Verloop, N., 2001, Professional development and reform in science education: the role of teachers' practical knowledge, Journal of Research in Science Teaching, v. 38, p. 137-158.

Verloop, N., 1992, Craft knowledge of teachers: A blind spot in educational research, Pedagogical Studies, v. 69, p. 410-423.