

**Enhancing Inservice Teacher's Constructivist Epistemology
through the Development and Redesign of Inquiry-based Investigations
together with their Students**

by

Elaine AbuSharbain
Southern Illinois University, Edwardsville

Abstract: This paper summarizes a two-year professional development project with twenty-three inservice teachers. Teachers were charged with the task of developing inquiry investigations correlated with the Illinois Standards in a state funded project titled "Connecting Outdoor Instruction to the Illinois Learning Standards" (COILS). Scientific investigations on the school grounds were developed, piloted and peer tested. Students then field-tested and redesigned the activities to test student-derived hypotheses. One purpose of this project was to facilitate a shift in teachers' constructivist epistemology. Positive changes were found in teacher's endorsements of the Constructivist Learning Environment Survey – Teacher Form. Significant change was noted in students' knowledge about scientific process. The utilization of this inquiry-based investigation design/redesign model may be one step in developing an effective professional development program for teachers in the area of science education. The project can be viewed at <http://web.stclair.k12.il.us/splashd/Experiment.htm>

Introduction

Teaching of K-12 science has traditionally been in lecture format with an emphasis on lower level learning of facts and vocabulary words. The Benchmarks for Science Literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996) have pointed to the need to shift student learning to inquiry-based strategies so that students can take on a more active role in their learning. Science teachers are advised to focus on students' learning of scientific concepts, science process skills, and the nature of science rather than the traditional memorized set of facts and vocabulary words. Both the American Association for the Advancement of Science (AAAS) and National Research Council (NRC) promote student learning through a teacher role that is student-centered and inquiry-oriented.

Inquiry-based learning has been shown to be an asset with learners (Piaget 1964; Mullis & Jenkins 1988; Smilansky & Haberstadt 1986) as it relies on children's inherent curiosity and their natural energetic explorations. Students are given some directions and asked to explore new areas. In this way, children develop their intellectual disciplines and the skills necessary to raise questions and search out answers stemming from their curiosity (Joyce and Weil, 1986).

Inquiry based learning is enhanced in a constructivist classroom where students are free to form ideas and ask questions (Yager, 1991). These questions drive the curricular planning in an environment where open-ended questions, cooperative learning and ample reflection and analyses are commonplace. The social and affective aspects of the classroom environment are important considerations in creating a successful inquiry-based experience for children.

Craven and Penick (2001) underscored the need to address the science classroom as a learning community where the social environment is key to addressing the development of higher order cognitive skills. The teacher sets the classroom climate by the roles he/she plays in fostering that climate. A teacher's beliefs about learning and knowledge strongly impact the classroom climate enabling students to explore, articulate, and analyze their beliefs on topics. However, Good and Brophy (1994) documented that most teachers are largely unaware of the components of the classroom environment and consequently overuse factual questions, do little to motivate, and neglect to emphasize meaning. Despite numerous studies showing teacher-centered instruction to be nonproductive, or sometimes detrimental, lecturing continues to be the primary method of teaching in our colleges and schools (Brophy, 1989; Caprio, 1994).

In order to move away from the traditional teaching styles, teachers themselves must first believe that instruction is more than simply memorizing facts. Teachers must acknowledge and pursue new roles such as reaching all students, turning over responsibility to students, monitoring group interactions, providing alternative assessment and providing appropriate tools for study.

Shifting from teacher-centered practices to inquiry-based teaching is a major undertaking

because inquiry-based teaching roles require a strong focus on the student and group interactions.

Lappan (2000) explains the teacher's focal point in inquiry-based teaching. Students should be engaged in complex problems dealing with the content area. Teachers should push students to think at deeper levels and explore all aspects of the problem. In addition, teachers try to facilitate students' processing of information from group interactions and class syntheses/summaries. Finally, teachers must create an environment in which all members of the class grasp the content area information or improve upon their learning abilities. This difficult and complex role is a harder sell when traditional instruction allows teachers to feel a great sense of accomplishment because projects get completed in a short amount of time, and students retain rote information or students perform well on standardized tests (Lappan 2000).

A key component to success in professional development programs is to design opportunities that facilitate a shift toward the role of inquiry-based facilitators by incorporation of additional components of constructivist epistemology. Taylor, Dawson, & Fraser (1995) provide a detailed description of the constructivist learning environment. This is where students: a) communicate their understandings with their peers, b) have frequent opportunity to identify their own learning goals, c) are faced with the tentative nature of scientific inquiry including student questioning of classroom operations and d) the classroom is conducive to inquiry.

Taylor, Dawson, and Fraser (1995) have identified and made measurable the pertinent aspects of a constructivist classroom environment, but professional development cannot proceed without an account of teacher's practical knowledge and experience. Van Driel, Beijaard and Verloop (2001) describe this knowledge as an integrated set of conceptions, beliefs, and values that teachers develop in the context of the teaching situation. Van Driel, et al., point out that this has been a missing component of professional development programs. Teachers' beliefs about their own teaching practice are the basis for constructing their own ideas about inquiry-based teaching. As a result, Van Driel, et al, suggest the following methods for working with teachers including: (a) learning networks, (b) peer coaching, (c) collaborative action research, and (d) the use of cases. In this way, reform projects can benefit from the teachers' expertise, and reform will be enhanced. In addition, a professional development project must include a blend of philosophic and practical elements (Stein & Mundroy, 1999). With a philosophical component, such as a focus on reflective process, the project brings a vision for program improvement. Without a practical component, the program runs the risk of ignoring the reality of teachers work by becoming impractical to implement.

Another important element of professional development is first hand experience in inquiry-based science. A study designed to investigate the effect on teachers and their students of immersion of the teachers in scientific inquiry found that this approach had significant impact on science instruction (Radford & Ramsey, 1996). The students' attitudes and science process skills were statistically higher than comparison groups' scores over a three-year period. The teachers became actively engaged in learning along

with the students and reported greater confidence in their teaching. They concluded that teachers must first experience inquiry-based science in order to teach inquiry-based science.

Craven and Penick (2001) compiled results of numerous studies seeking to define the role of the science teacher educator for professional development. They summarized key components of a successful model where the developer's role is to create and model an inquiry-based community of learners where: a) students have opportunities to cope with the ambiguity and flexibility involved in scientific investigation, b) collaborative and cooperative classroom interactions are valued, c) student-centered learning occurs in all aspects of education such as assessment, classroom ethics and the route of inquiry-based investigations, d) collegial attitudes are encouraged by active participation with professional societies and student organizations, and e) the learning environment goes beyond the classroom walls where students investigate relevant problems and questions tied to the real world.

The above authors call attention to the importance of providing professional development that is at its core a constructivist experience. The experience must provide the tools, support, and motivation for teachers toward change on the components of constructivism identified by Taylor, Dawson, & Fraser (1995). In this project many of the previously discussed recommendations were implemented. Learning networks, peer coaching, collaborative action research, and the use of cases were utilized as recommended by VanDriel et al, (2001). Teachers worked on inquiry-based investigations along with their students as recommended by Radford and Ramsey (1996). Group meetings were structured around participant-derived discussions about inquiry and their reflections on classroom practice in a constructivist environment as recommended by Taylor, Dawson, & Fraser (1995). Lastly, these following practices were incorporated as recommended by Craven and Penick (2001). The professional developers sought to interact in a role where they created and modeled an inquiry-based community incorporating the natural ambiguity and flexibility involved in scientific investigation. Collaborative and cooperative meeting interactions were established. Participant-centered learning occurred in all aspects of the program including assessment. The directional end-routes of the inquiry-based investigations were participant-derived. Collegial attitudes were encouraged by active participation with state and national science organizations and scientists from a regional university. Finally the learning environment went beyond the classroom walls where students investigate relevant problems and questions tied to the real world in their local outdoor environments.

Of particular interest were the possible changes in the teachers' endorsements of constructivist epistemology over the two-year period. If teachers can change their opinions about: a) how students and teachers should interact, b) how to deal with age-appropriate scientific investigation that presents the ambiguity of the scientific method, c) how to incorporate student-centered assessment and classroom ethics, d) to utilize cooperative learning, and e) the importance of real-world student investigation, then they are in a better position to put these ideals into practice. Keys and Bryan (2001) summarized research on teacher beliefs about the nature of science, student learning, and

the role of the science teacher. They suggested these beliefs do affect teachers' planning, teaching and assessment.

Research on teacher professional development, however, is incomplete. While the main focus of professional development is at the level of the teacher, the true measure of success should be a corresponding enrichment in student learning. Frechtling's analysis of evaluation research has shown student learning to be a vital, but overlooked component of most studies (2001). Programs touted to be successful in changing teachers' practices or philosophy must show significant gains in student learning as well.

Method

This state-funded project sought to facilitate 23 teachers in their ability to execute inquiry-based investigations in the local outdoor environment and assist them in developing their own inquiry-based experiments with their students over a two-year period. The activities were based on Illinois Science Standards, which originated from the National Science Education Standards (NRC, 1996). This project used a model of professional development for the project whereby teachers and students developed inquiry-based investigations to be done in the local outdoor environments and subsequently redesigned them to test another student-derived hypothesis. One goal of the project was to evaluate the effectiveness of this model in changing teacher's constructivist epistemology as well as their students' knowledge about scientific process.

Participating 4th – 11th grade teachers were from a suburban Illinois county. The teachers were preassessed by administration of the Constructivist Learning Environment Survey – Teacher Form (CLES) (Taylor, Dawson, and Fraser, 1991; Taylor et al, 1995; Taylor et al, 1997). This instrument was used to assess the teacher's self-reported level of constructivist epistemology. The CLES – Teacher Form was developed to enable teacher researchers to assess their teachers' progression toward constructivist approaches in teaching science (Taylor, Dawson, and Fraser, 1995). A comparison group of teachers for this analysis were identified by matching criteria on variables such as proportion of minority students, number of students in free lunch program, school size, and urban, rural or suburban school characteristics. The comparison group teachers were administered the CLES at the same time. The comparison group received no professional development during the two-year period. Comparison and participant groups were analyzed for initial differences by an independent samples t-test and found to be the same on these variables.

Following completion of the pretest assessments, the teachers participated in a 4-day workshop early in the fall where they began investigating how they could incorporate student inquiry into their curriculum by utilizing six preexisting, field-tested, online investigations namely: a) Soil Dwellers Experiment, b) Pitfall Trap Experiment, c) Schoolyard Flower Experiment, d) Sweep Net Experiment, e) Animal Sign Experiment and f) Capture/Recapture Experiment. In working on these investigations, teachers developed skills in scientific methodology such as: designing testable hypotheses, isolating an independent variable, limiting sources of error and many other aspects of scientific procedures and research design.

During the fall of the first school year, the teachers completed one of the original 6 experiments with their students ranging from 4th to 11th grade. The students followed the procedures and entered the data to the public online database housed on the Internet website. Students could compare their data to data from other students at other schools in the world. Teachers then asked their students to redesign the investigation to test a new student-derived hypothesis. Teachers worked on facilitating this process with students. For example, in the pitfall trap experiment, students devised new questions, using the same pitfall trap device when presented this challenging problem by their teacher, "Using a 180 ml. (6 oz.) glass baby food jar as a pitfall trap, design and conduct an investigation to measure the number and types of macro-invertebrates living at ground level and at different locations in the schoolyard." One student team's question was "Is there a difference between the diversity and quantity of macroinvertebrates in tallgrass versus shortgrass regions in the schoolyard?"

During the second year, the teachers created a new online investigation with the help of their students, which included a new data collection protocol. It was field-tested and peer reviewed by other participant teachers during monthly meetings. Teachers then challenged their students to redesign it to test another new student-derived hypothesis keeping the same data collection procedures in place. They field-tested and peer-tested the experiments. Their final products and students' results were posted online at: <http://web.stclair.k12.il.us/splashd/Experimt.htm>

At the end of the second year, all teachers completed a final assessment posttest corresponding to the original pretest. Teachers gave out a cognitive posttest to assess students' knowledge about scientific process. The student comparison group consisted of students at the same school site and the posttest was given on the same day.

Results

The Constructivist Learning Environment Survey assessed teachers' endorsement of statements descriptive of learning climate as characterized by constructivist epistemology (Taylor, Dawson, and Fraser, 1991; Taylor et al, 1995; Taylor et al, 1997). A matched t-test analysis revealed that the teachers' self-reported overall more neutral position of 3.58 (SD .5) shifted to agreement 4.13 (SD .7) with constructivist epistemology where a Likert rating of 5 indicates strong agreement. This change was highly significant ($p < .001$). The comparison group pretest mean of 3.53 (SD .7) was not significantly different at the end of the study with a mean of 3.66 (SD .9).

Table 1. Constructivist Learning Environment Survey Pre and Posttest Means of Teachers in Professional Development Training Versus a Matched Comparison Group.

	Mean	SD	t	p
Pretest, Comparison Teachers(n=12)	3.53	.7		
Posttest, Comparison Teachers	3.66	.9	.35	.156
Pretest, COIILS Teachers (n=23)	3.58	.5		
Posttest, COIILS Teachers	4.13	.7	1.94	<.001

The students' responses on the scientific process test were analyzed with a t-test for samples with equal variances and revealed a significant difference ($p < .0001$) in knowledge about scientific process between the COIILS group with a mean of .65 (SD .2) and the comparison group mean of .52 (SD .2), see Table 2.

Table 2. Student Knowledge About Scientific Process Differences Between Participant Students (COIILS) and a Comparison Group.

	Mean	SD	t	p
Post test only				
Comparison Students n=81	.52	.20		
COIILS Students n=426	.65	.21	4.839	<.0001

Discussion

This research investigated the effectiveness of a teacher-training model over a two-year period. Significant changes in teachers' beliefs regarding constructivist teaching methodology were found on the Constructivist Learning Environment Survey. These findings indicate that this model of teacher professional development was successful in changing teachers' self-reported endorsement of constructivist epistemology. The teachers' students showed gains in knowledge about the process of scientific inquiry.

Guskey and Sparks (2002) specified that while research in professional development include variables relating to the content of the development, they mention that process and context variables are other unmeasured and important aspect. Context variables include aspects of participants, the school environment, the student population, the school's organization. Process variables relate to the way the professional development is carried out. The process of this project can be described as constructivist and participant-centered. In this professional development project, the teachers took on an active role in interpreting standards and in planning of science investigations that were developed. Project investigators sought to facilitate a constructivist environment rather than dictate procedures for teachers' learning (Lewis,2000). The professional development team interacted with the teachers modeling constructivist epistemology throughout the two years in all of their interactions with the teachers. This included cultivating a positive

learning climate by encouraging good working relationships amongst the teachers, safeguarding the freedom to explore new ideas and prizing creativity. In the beginning of the two-year project, some time was spent in formal teacher workshops, but teachers soon took the charge of developing these activities and worked with each other and with the project directors/resource experts to accomplish their objectives in a problem-based manner.

The Illinois Science Standards were the foundation for the work to be done as suggested by Audet and Jordan (2000). They were revisited and discussed throughout the project, but one Illinois Science Standard was a focal point for all investigations. This standard calls for learning of scientific inquiry. Monthly meetings with the science educators and teachers included discussions about scientific inquiry and the meaning of inquiry-based teaching and how to implement this into their classroom practice. Discussions were important in helping teachers construct their own meaning about inquiry and to reach a consensus about how their investigations would evolve. While a science educator, resource personnel and scientists were involved in question and discussion sessions, it was the teachers and their students who were responsible for and in charge of activity development. These project directors agree with Keys and Bryan (2001) that teachers can and do create their own perspectives on and definitions of inquiry.

While investigators did visit and observe teachers completing several inquiry-based investigations successfully with their students throughout the two-year period, long-term behavioral change in teaching methods can only occur when teachers work in a supportive environment and have access to a long-term collegial professional community (Fullan, 2002), concerned with long-term coherent plans as is recommended by the National Science Education Standards (NRC,1996). Also, this project's inquiry-based activities focused on activities in local outdoor environments. This shift of environment to the out-of-doors may have been an influence to the model because a change in teaching environment may help to avert or overcome a teachers' customary style of teaching in and of itself. This aspect should be investigated.

While many aspects of the teacher-training model may have had differential impacts, it appears that the utilization of this inquiry-based investigation design/redesign model is one step in developing an effective professional development program for teachers in the area of science education. In light of this study, it is therefore suggested that teacher professional development programs can be effective in assisting teachers to make a transition toward further endorsement of components of constructivist epistemology when teachers work as a team and with their students in designing and redesigning their own inquiry-based investigations in their schoolyards. The activities are published online, <http://web.stclair.k12.il.us/splashd/Experimt.htm>, and may serve as a good resource for other teachers wishing to reproduce inquiry or for science education researchers to peruse inquiry-based investigations developed by teachers along with their students.

References

- American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.
- Audet, R.H. & Jordan, L.K. (2000). A professional development model for exploring the National Science Education Standards, Science Educator; the National Science Education Leadership Association Journal, 9, (1), 27-33.
- Brophy, J. (1989). Advances in research on teaching (Vol. 1). Greenwich, CT: Adler.
- Caprio, M. (1994). SCST position paper. Journal of College Science Teaching, 23, 143
- Craven, J. & Penick, J. (2001). Preparing new teachers to teach science: the role of the Science teacher educator. Electronic Journal of Science Education, 6,(1), 1-17. Available: <http://unr.edu/homepage/jcannon/ejse/ejse.html>
- Frechtling, J. (2001). What evaluation tells us about professional development programs in mathematics and science. In C. Nesbit, J. Wallace, D. Pugalee, A. Miller, and W. Dibase (Eds.), Developing Teacher Leaders: Professional Development in Science and Mathematics. (Ch. 2, pp 17-42). Washington, D.C.: Office of Educational Research and Improvement. U.S. Department of Education.
- Fullan, M.G. (1999). Change Forces: The Sequel. Bristol, PA: Falmer Press.
- Good, T. & Brophy, J. (1994). Looking in classrooms (6th ed.). New York: Harper Collins College Publishers.
- Guskey, T.R., & Sparks, D. (2002, April). Linking professional development to improvements in student learning. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.
- Joyce, B., & Weil, M. (1996). Models of Teaching. Englewoods Cliffs, NJ: Prentice Hall.
- Keys, C., & Bryan, L. (2001). Co-constructing inquiry-based science with teachers: essential research for lasting reform. Journal of Research in Science Teaching. 38 (6), 631-45.
- Lappan, G. (2000). A vision of learning to teach for the 21st century. School Science and Mathematics, 100 (6), 319-326.
- Lewis, A. (2000). Revisioning Professional Development: What learner-centered professional development looks like. Oxford, OH: National Staff Development Council.
- Mullis, I., & Jenkins, L. (Eds.) (1988). The Science Report Card: Elements of Risk and
AbuSharbain Electronic Journal of Science Education, Vol. 7, No. 1, September 2002

Recovery. Princeton, NJ: Educational Testing Service.

National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press, 262 pgs.

Piaget, J. (1964). Development and learning, part 1 of cognitive development in children. Journal of Research in Science Teaching, 2, 74-85.

Radford, D., & Ramsey, L. (1996.) Experiencing scientific inquiry and pedagogy: A model for inservice training for science education reform. Paper presented at the Annual Meeting of the National Association of Research in Science Teaching (69th, St. Louis, MO, March 31, 1996). U.S. Louisiana, 1996-03-31.

Smilansky, J., & Haberstadt, N. (1986). Inventors versus problem solvers: an empirical investigation. Journal of Creative Behavior, 20 (3), 183-201.

Stein, M. & Mundroy, S. (1999, Oct.). Professional development for science and math teachers: dilemmas of design. High School Magazine, 7 (2), 14-18.

Taylor, P., Dawson, V. & Fraser, B. (1991). CLES: an instrument for assessing constructivist learning environments. Paper presented at the annual meeting of the National Association of Research in Science Teaching, Fontane, WI.

Taylor, P., Dawson, V., & Fraser, B. (1995, April). Classroom learning environments under transformation: a constructivist perspective. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Taylor, P., Fraser, B., & Fisher, D. (1997). Monitoring constructivist classroom learning environments. International Journal of Educational Research, 27, 293-302.

van Driel, J., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. Journal of Research in Science Teaching, 38 (2), 137-158.

Yager, R. (1991). The constructivist learning model: Toward real reform in science education. The Science Teacher, 9, 53-57.