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ABSTRACT

Many hands-on activities are just demonstrations in which students handle materials to illustrate concepts. These activities may initially capture students' attention, however, many of the activities are either so highly structured that they minimize exploration or are so loosely structured that they minimize conceptual understanding. To maximize learning, students need opportunities to explore in a way that enhances their understanding. A series of inquiry-based classroom activities has been designed for the elementary and middle school levels that excite students' curiosity, draw students into the experiences, use simple materials, and explain concepts at developmentally appropriate levels. The approach addresses teachers' concerns about process versus content and developmental appropriateness. The core of the approach to inquiry is the demonstration experiment, a structured exploration activity which begins with a discrepant event and then requires the use of scientific inquiry to explain the counterintuitive observations. This paper concerns the use of these activities in the classroom. (Contains 20 references.) (MVL)

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Background

The National Research Council (1990, p. 6) concluded that "... no reform of science education is likely to be successful until science is taught effectively in elementary school." At the heart of many of the more effective science teaching programs is inquiry (Anderson & Mitchener, 1994). Inquiry is an activity-based, process-oriented approach to teaching. With this approach, "... intrinsic motivation is more likely to occur" (Hameyer, Akker, Anderson, & Ekholm, 1995, p. 3). An inquiry curriculum can have significant positive effects on student performance (Shymansky, Hedges, & Woodworth, 1990; Shymansky, Kyle, & Alport, 1983; Suchman, 1960; Von Secker & Lissitz, 1999). When compared to students in control classrooms in which comparable content was presented from textbooks, students in inquiry-based classrooms outperformed the control groups in process skills, creativity, attitudes, logical reasoning, and science content knowledge. Improved performance has been found at all grade levels (Bredderman, 1983) with the greatest gains in content and process skills occurring in students who were academically or economically disadvantaged (Bredderman, 1982). The evidence for the benefits of an inquiry curriculum is so strong that the National Science Education Standards (National Research Council, 1996) include explicit recommendations for teaching science as a process and include process as a content area (Content Standard A, Science as Inquiry).

Despite the preponderance of evidence supporting the effectiveness of an activity-based, process-oriented approach to the teaching of science, teachers still rely heavily on the use of textbooks and lectures. The American Association for the Advancement of Science (1990, p.28) concluded that "... conventional science teaching suppresses students' natural curiosity and leaves them with the impression that they are incapable of understanding science," but many teachers continue to have concerns about a process-oriented approach. They believe that the focus on process in inquiry-based curricula goes too far and that too much content is sacrificed; traditional teaching methods are the only way to cover enough material. The perceived minimal content in inquiry-based curricula is not the only concern; what content is included is often not understood by students. Many times, the most interesting hands-on activities are not developmentally appropriate; thus, students are not cognitively ready to understand the concepts that explain activities they enjoy. Under these conditions, student interest cannot be sustained.

Many hands-on activities are just demonstrations in which students handle materials to illustrate concepts. These activities may initially capture students' attention. However, many of the activities are either so highly structured that they minimize exploration or are so loosely structured that they minimize conceptual understanding. To maximize learning, students need opportunities to explore in a way that enhances their understanding.

The Demonstration-Experiment

We have designed a series of inquiry-based classroom activities for the elementary and middle school levels that excite students' curiosity, draw students into the experiences, use simple materials, and explain concepts at developmentally appropriate levels. Our approach addresses teachers' concerns about process versus content and developmental appropriateness (Lynch & Zenchak, 2001; Zenchak & Lynch, 2000b).

The core of our approach to inquiry is the "demonstration-experiment," a structured exploration activity which begins with a discrepant event and then requires the use of scientific inquiry to explain the counterintuitive observations (Lynch & Zenchak, 1995; Lynch & Zenchak, 1997; Lynch & Zenchak, 1999; Lynch & Zenchak, 2001; Zenchak & Lynch, 1996; Zenchak & Lynch, 1998; Zenchak & Lynch, 2000a; Zenchak & Lynch, 2000b; Zenchak, Lynch, & Canlas, 1994). Many scientific concepts can be taught through this approach. For example, "Cannonball" gives students an opportunity to explore conservation of linear momentum at a grade-appropriate level. As illustrated in Figure 1, the teacher sets up two similar situations in which a number of differences (independent variables) have been embedded. Without any explanation, the teacher drops the two balls into the tube in Set-up 1, resulting in the balls staying in the tube. In Set-up 2, the teacher drops the two balls, resulting in the top ball shooting out of the tube. Students are asked to observe carefully what takes place, individually describe in writing what they observe, and compare their descriptions with the descriptions of other students and generate a common list of independent variables and constants. For "Cannonball" the variables are the surface at the base of the tubes (carpet versus hard), the presence of holes in the heavy ball (present versus absent), and the position of the heavy ball relative to the lighter ball (above or below the lighter ball). The constants include the size of the balls, the height from which they are dropped, and the tube into which they are dropped; in addition, the balls are in contact when they are dropped simultaneously into the tube.

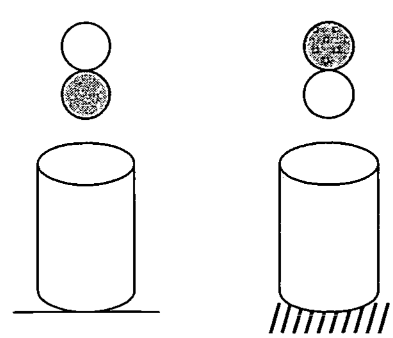

Figure 1. Original set-up for "Cannonball." Variables: Surface at base of tubes, presence of holes in heavy ball, and position of the heavy ball.

Based on the independent variables, the teacher guides the students as they generate a list of hypotheses about what occurred. One hypothesis is generated for each independent variable and takes the form of an "If ... then" statement that links the independent variable with the outcome (dependent variable). The teacher repeatedly reminds the students that, in order to identify the reason why the outcome was different between the two situations, they must focus on a single variable while making sure that nothing else changes. In other words, all other variables, except the one in the hypothesis, must be held constant. A hypothesis testing the independent variable surface might be "Holding all other variables constant, if the surface on which the balls are dropped is important, then changing the surface will determine whether one ball shoots out of the tube."

After the hypotheses are formulated, students construct a separate experiment to test each hypothesis. They need to keep the original constants and change the other independent variables into additional constants. Thus, to test the hypothesis that surface is important, students must use one carpeted surface and one hard surface; they might choose to use balls without holes and place the heavy ball on the bottom (see Figure 2). As long as one surface is carpeted and the other is hard, there are three alternative tests of this hypothesis that are equally valid (see Figure 3).

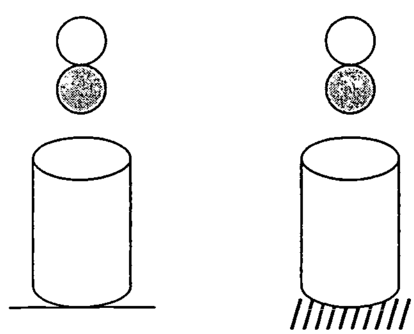

Figure 2. Test of hypothesis that surface is important. Variable: Surface at base of tubes (hard versus carpet). New constants: No holes in heavy ball, heavy ball on bottom.

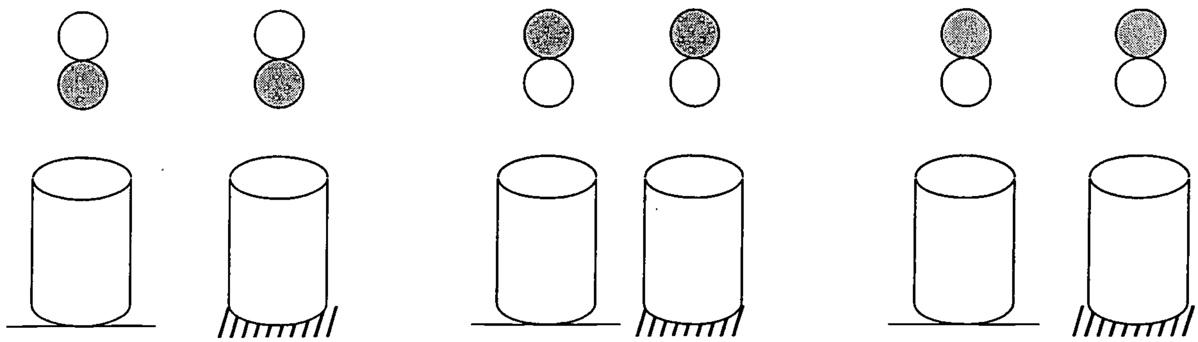

Figure 3. Alternative tests of hypothesis that surface is important. Variable: Surface at base of tubes (hard versus carpet). (a) New constants: Holes in heavy ball, heavy ball on bottom. (b) New constants: Holes in heavy ball, heavy ball on top. (c) New constants: No holes in heavy ball, heavy ball on top.

Next, based on their observations of the initial demonstration, students predict what will happen in each experiment. In the test of the surface variable, students should predict that a ball will shoot out of the tube when the balls are dropped onto the hard surface but not when they are dropped onto a carpeted surface because that is what happened in the initial demonstration. Finally, students conduct all of the experiments they design. They then compare their predictions to the outcomes of the experiments. When their prediction matches the actual outcomes of the experiment, the students know that they have identified the important variable. When their prediction does not match the actual outcomes of the experiment, the students know they can rule out that variable. For "Cannonball" students find that their predictions match the outcomes for the test of the hypothesis about the position of the heavy ball relative to the lighter ball; thus, the position of the heavy ball is the causal variable. After students have identified through their experiments which variable is responsible for the different outcomes, the teacher develops the concepts that explain the results at an age-appropriate level and emphasizes everyday applications.

The demonstration-experiment is unique in a number of ways beyond its combining of discrepant events, inquiry, and structured exploration. First, the situations are deceptively simple. The "equipment" in most demonstration-experiments consists of a few inexpensive common materials that do not necessarily seem "scientific." Because the materials are nonthreatening and do not require training to use, they do not cause teachers and students to doubt their ability to handle them. In fact, the equipment is so simple that nobody expects anything out of the ordinary to take place. However, the demonstration-experiment immediately captures students' attention when small, seemingly inconsequential differences in the two set-ups cause very obvious, yet unexpectedly different results. Second, because the results are unanticipated, the initial differences must be considered in identifying potential causes. Third, students are engaged in the activity because it challenges them to "write the recipe," instead of merely following a cookbook-like approach to finding a solution to the problem presented in the demonstration. They become aware that there are several possible appropriate experiments to test the effect of an independent variable. In turn, teachers are freed to facilitate student inquiry rather than supply them with specific directions and the final answers.

Students are drawn into the experience for two reasons – the two similar situations produce different results, and initially it is not obvious which of the differences embedded in the demonstration-experiment caused the results. Much curiosity is generated and observers immediately start questioning. Through this approach students learn a format for conducting experiments which is structured enough to focus them on the underlying concept, yet loose enough for them to be creative in designing and doing controlled experiments in which only one variable is changed and the others are held constant. Teachers discuss the findings as they relate to the lives of their students. Terminology is minimized to such an extent that it is not seen as the focus and therefore the learner can focus on the underlying concepts.

The demonstration-experiment focuses students on factors which are essential in promoting their understanding of science process and content: the demonstration clearly captures the attention of the students by playing with their minds, not just their senses; it focuses them on variables which may potentially explain what they have just seen; and it prepares them to begin to explore those potential explanations in a format which is structured to encourage both exploration and conceptual understanding.

References

American Association for the Advancement of Science. (1990). *The Liberal Art of Science:Agenda for Action*. Washington, D.C.: American Association for the Advancement of Science.

Anderson, R. D., & Mitchener, C. P. (1994). Research on science teacher education. In D. L. Gabel (Ed.), *Handbook of Research on Science Teaching and Learning* (pp. 3-44). New York: Macmillan Publishing Company.

Bredderman, T. (1982). What research says: Activity science -- The evidence shows it matters. *Science and Children, 20,* 39-41.

Bredderman, T. (1983). Effects of activity-based elementary science on student outcomes: A quantitative synthesis. *Review of Educational Research, 53*(4), 499-518.

Hameyer, U., Akker, J., Anderson, R.D., & Ekholm, M. (1995). *Portraits of Productive Schools: An International Study of Institutionalizing Activity-based Practices in Elementary Science*. Albany, New York: State University of New York Press.

Lynch, M. J., & Zenchak, J. (1995, October). *Engaging elementary teachers and students in science.* Paper presented at the National Science Teachers Association Western Area Convention, Salt Lake City, UT.

Lynch, M. J., & Zenchak, J. (1997, December). *Activities that excite students' curiosity and engage them in science.* Workshop presented at the National Science Teachers Association Southern Area Convention, Nashville, TN.

Lynch, M. J., & Zenchak, J. J. (1999, October). *Hands-on activities that engage students' minds as well as their hands.* Workshop presented at the National Science Teachers Association Midwestern Area Convention, Detroit, MI and Windsor, Ontario.

Lynch, M. J., & Zenchak, J. J. (2001, March). *Adapting scientific inquiry activities for different grade levels to enhance conceptual understanding.* Workshop presented at the National Science Teachers Association National Convention, St. Louis, MO.

National Research Council. (1990). *Fulfilling the Promise: Biology Education in the Nation's Schools*. Washington, D.C.: National Academy Press.

National Research Council. (1996). *National Science Education Standards*. Washington, D.C.: National Academy Press.

Shymansky, J.A., Hedges, L.V., & Woodworth, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance. *Journal of Research in Science Teaching, 27,* 127-144.

Shymansky, J. S., Kyle, W. C., & Alport, J. M.. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching, 20,* 387-404.

Suchman, J. R. (1960). Inquiry training in the elementary school. *Science Teacher, 27,* 42-47.

Von Secker, C.E., & Lissitz, R.W. (1999). Estimating the impact of instructional practices on student achievement in science. *Journal of Research in Science Teaching, 36,* 1110-1126.

Zenchak, J., & Lynch, M. J. (1996, November). *Drawing elementary students and teachers into science.* Paper presented at the Joint National Science Teachers Association-Science Teachers' Association of Ontario and Eastern Area Convention, Toronto, Ontario, Canada.

Zenchak, J.J., & Lynch, M. J. (1998, December). *The next step in hands-on activities: Engaging students' minds.* Workshop presented at the National Science Teachers Association Southwestern Area Convention, Albuquerque, NM.

Zenchak, J. J., & Lynch, M. J. (2000a, April). *Structuring hands-on activities to enhance process skills and content acquisition.* Workshop presented at the National Science Teachers Association National Convention, Orlando, FL.

Zenchak, J. J., & Lynch, M. J. (2000b, October). *Developmentally appropriate scientific inquiry activity.* Workshop presented at the National Science Teachers Association Northwestern Area Convention, Boise, ID.

Zenchak, J., Lynch, M. J., & Canlas, A. (1994, October). *Reviving science curiosity in teachers and students.* Paper presented at the Sixteenth Annual Rural & Small Schools Conference, Kansas State University, Manhattan, KS.

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