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ABSTRACT

This study describes how the lesson plans of preservice teachers differed from the inductive learning cycle planning model, and relates these differences to persistent naive conceptions about effective science pedagogy held by preservice teachers. Strategies based on the science misconceptions literature that methods instructors can use to encourage the understanding and use of inductive learning cycle instruction by beginning teachers are suggested. The study concludes that preservice teachers majoring in secondary science education like and prefer traditional teaching methods while elementary and middle school preservice teachers find traditional methods boring and ineffective. (Contains 14 references.) (YDS)

Using the Science Misconceptions Research to Address Science Teaching Misconceptions

by

Suzanne Weber

USING THE SCIENCE MISCONCEPTIONS RESEARCH TO ADDRESS SCIENCE TEACHING MISCONCEPTIONS

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One of the most frustrating experiences for me as a science educator has been trying to persuade preservice teachers to use inductive, problem-solving science teaching strategies. I teach science methods to 90-120 elementary and middle school preservice teachers each semester, and to 15-25 secondary biology, chemistry, earth science, and physics preservice teachers each spring. The majority of the elementary and middle school preservice teachers start the semester disliking science. Only about 10% are science majors. Their first reflective writing assignment, a science autobiography (Koch, 1990), consistently reveals that most of their K-12 science instruction has been traditional direct instruction, which many characterize as boring and generally ineffective.

Unlike the elementary and middle school preservice teachers, the secondary science education majors LIKED traditional school science. Their science autobiographies reveal that they learned from lectures; they enjoyed cookbook labs; they did well on multiple choice exams on science vocabulary. Despite these difference in attitudes towards science as traditionally taught, both elementary and secondary preservice teachers are generally enthusiastic about and eager to implement the more effective "backwards" (inductive) learning cycle lessons that are modeled in class. The paradox is that too many individuals from both groups fall back on "explain-first-then-confirm-with-a-cool-demo-or-activity" (direct instruction) when planning and teaching their own science lessons during the last half of the semester.

Science educators are all familiar with the adage that "teacher teach as they were taught." After 2,340 days of traditional K-12 science instruction, it certainly is not surprising that preservice teachers are not readily able to master these new teaching strategies. However, I have begun to take this difficult challenge personally. If the goals of the National Science Education

Standards (National Research Council, 1996) are going to be widely implemented, I need to start doing a better job with these preservice teachers. And I have to be able to do it in one methods course.

The purpose of the study reported here was threefold: (1) describe how the lesson plans of preservice teachers differed from the inductive learning cycle planning model, (2) relate these differences to persistent naive conceptions about effective science pedagogy held by these preservice teachers, and (3) suggest strategies, based on the science misconceptions literature, that methods instructors can use to encourage the understanding and use of inductive learning cycle instruction by beginning teachers.

Analysis of Errors in Planning Inductive Instruction

Both the elementary/middle school methods course and the secondary methods course at SUNY Oswego are structured as a semester-long learning cycle as described by Rubba (1992), Barman and Shedd (1992), and Weber (1994). In both courses, the semester begins with opportunities for students to explore model inductive learning cycle lesson sequences focusing on the nature of science and how children learn science. In the second phase of the course, the theoretical basis for constructivist, inductive science teaching strategies is derived from the exploration activities and explained.The last half of the course is devoted to giving students opportunities to apply/elaborate learning cycle strategies as they design week-long "mini-units" on a science topic and teach one or more lessons in their practicum classrooms.

Students are expected to plan an inductive learning cycle "mini-unit" which begins with a hands-on, problem-solving activity; this is followed by a more teacher- or text-centered explanation and ends with other concrete elaboration activities connecting across the curriculum (Biological Sciences Curriculum Study, 1989). An assessment plan which evaluates content, attitudes, and skill objectives using a continuous, diverse embedded approach is also required (Hein, 1994). The rubric for the elementary and middle school units lists the specific evaluation criteria (Table 1). The secondary rubric is similar, but more extensive since it accommodates laboratory experiences and the more frequent appropriate use of direct instruction with high school students.

As units are graded each semester, extensive comments and suggestions are made throughout the materials submitted by the students. The scoring rubrics are annotated to help students understand the specific strengths and weaknesses of their plans before the lesson(s) are taught. In this study, copies of the scoring rubrics for 459 elementary and middle school mini-units over seven semesters were analyzed to determine the most frequent areas of poor fit between the requirements of the inductive learning cycle model and the actual units created by 593 students (328 individuals, 128 pairs and 3 trios). An "error" was scored in a particular category if the item was defective or missing entirely. Thus, the results emphasize the pattern of mistakes of both commission or omission, rather than the pattern of partial or complete success.

Table 1

Scoring Rubric for Elementary and Middle School Learning Cycle Units

MINI-UNIT INDIVIDUAL SCORE (80 POINTS)			
<u>Engagement/Exploration</u>			
Activity reveals children's initial ideas (link)	0	2	4
Activity is likely to be interesting to kids (hook)	0	2	4
Activity is hands-on, concrete, problem-solving	0	4	8
Main idea is clearly understandable from activity	0	2	4
Activity is developmentally appropriate	0	2	4
Activity includes emphasis on skills and/or attitudes	0	2	4
<u>Explanation</u>			
Children discuss results, focus question (activity closure)	0	2	4
Materials clearly & concisely explain the main idea	0	4	6
Materials are developmentally appropriate	0	4	6
<u>Elaboration/Reinforcement/Curriculum Connections</u>			
Includes hands-on, concrete, problem-solving activity	0	4	6
Materials are directly related to main idea	0	2	4
Materials are developmentally appropriate	0	2	4
Materials appeal to diverse learning styles	0	2	4
Includes related math activity, children's tradebook	0	2	4
<u>Evaluation</u>			
Directly related to main content/attitude/skill ideas	0	2	4
Uses diverse strategies & learning modalities	0	2	4
<u>General</u>			
Syllabus references are appropriate	0	0	2
Generalization clear, cover sheet complete	0	0	2
Variety resources used, learning cycle labels correct	0	0	2

Table 2 shows that preservice teachers had the most difficulty with those portions of the exploration portion of the mini-unit which were not typically part of a direct instruction lesson. For example, their lessons often failed to adequately elicit student ideas before the initial activity was conducted. In contrast, preservice teachers were generally attentive to the need to plan an motivating, hands-on, concrete, developmentally-appropriate activity at the beginning of the sequence and as elaboration after the explanation. However, some preservice teachers chose "cute" activities instead of activities related to the main idea of the unit, and in nearly one third of the units, these same activities did not provide a genuine problem-solving opportunity for children. In fact, about 10-15% of the students every semester simply ignored the idea of providing an initial exploratory experience of any description; these traditional direct instruction units began with a teacher-centered explanation instead.

Table 2

Inductive Planning Errors Made By Elementary and Middle School Preservice Teachers

Error	Planning Criteria	Total M	Total SD	F93	S94	F94	S96	F96	S97	F97
		Percent of Preservice Teachers Making								
		Total		By Semester						
	Planning Criteria	M	SD	F93	S94	F94	S96	F96	S97	F97
Exploration	Initial Student Concepts	36	10	31	47	19	33	44	43	36
	Motivating Activity	16	6	14	14	19	12	21	26	8
	Problem-Solving Activity	29	8	20	39	18	38	28	30	33
	Hands On Activity	15	5	13	10	12	10	18	24	18
	Concrete Activity	12	4	11	10	8	12	15	17	8
	Concept Clarity	26	7	21	33	14	24	29	28	32
	Developmental Level	10	7	2	11	5	10	16	22	7
Explanation	Activity Discussion	38	10	42	54	28	47	37	35	25
	Concept Clarity	24	12	23	49	15	12	26	28	17
	Development Level	26	6	26	36	18	28	23	26	24
Elaboration	Problem-Solving Activity	23	9	10	20	14	29	25	35	31
	Hands On Activity	6	3	7	3	5	9	9	9	3
	Concrete Activity	5	3	6	2	7	9	9	0	3
	Concept Clarity	8	5	14	13	5	2	9	4	11
	Developmental Level	9	4	7	12	5	12	14	7	5
Overall	Traditional Direct Instruction	12	3	13	11	7	12	13	17	8
	Proficient Inductive Instruction	31	9	39	20	45	29	26	37	25
	n	593		107	92	85	58	117	46	88

In the explanation phase of the learning cycle, student often ignored the importance of beginning with children's own explanations of the science concept underlying the activity. Other kinds of difficulties preservice teachers had in providing teacher or text-centered explanation to enhance student explanations seem to result from ignorance or overzealousness, rather than a misunderstanding of the teaching model. Preservice teachers routinely overestimated the cognitive development and reading abilities of children at particular grade levels. The most common mistakes were the use of above-grade-level text selections, often with the developmentally unrealistic notation that the "teacher will read and explain the text to the students."

Common Misconceptions Inherent in Inductive Planning Errors

I have begun to think about the problem of preservice teacher preference for direct instruction as a "pedagogical misconception." Like science content misconceptions, my students' pedagogical preference for direct instruction is implicit, based on everyday experience, robust, and resistant to change. Based on this analysis of my student's culminating units and the work of others (Appleton & Asoko, 1996; Gee, Boberg, & Gabel, 1996; Gee & Gabel, 1996; Hampton, Odom &Settlage, 1995), Table 3 juxtaposes the apparent underlying naive conceptions – myths about science teaching – with the related inductive learning cycle planning "errors" from Table 2.

Strategies Which Support Conceptual Change About Pedagogy

It seems likely that conceptual change about pedagogy needs the same conditions as conceptual change about science concepts: (1) students must be dissatisfied with their existing ideas and (2) the new idea must be plausible, attractive, and more useful than the old concept (Posner, Strike, Hewson & Gertzog, 1982).

Since ordinary instructional approaches are not effective in altering science content misconceptions, researchers have investigated a variety of alternative strategies (Pfundt & Duit, 1987, 1991). A meta-analysis of the reading education and science education research (Guzzetti, Snyder, Glass, & Gamas, 1993) identified four effective interventions for science content misconceptions: (1) discrepant events, (2) bridging analogies, (3) refutational text, and (4) Learning Cycle instructional sequencing. It is these four strategies that I have consciously begun to use to persuade preservice teachers to substitute an inductive, constructivist pedagogy for the less effective direct instructional strategies with which they are most comfortable.

Discrepant (Pedagogical) Events

I have both my elementary and secondary students write a "Science Autobiography" (Koch, 1990) which helps them identify the experiences that influence their initial negative or positive attitudes toward science and science teaching. The discrepancy for the elementary students involves recognizing that while they might have hated traditional high school science, they are actually enjoying doing the model learning cycle lessons in their methods class. With the secondary science majors (who liked traditional high school science), I do a class activity which involves comparing their own biographies with a representative selection from my elementary methods students. This discrepancy begins a serious discussion on effective and ineffective science pedagogy which we revisit all semester.

Refutational Text (About Pedagogy)

Guzzetti and her colleagues (1993) point out that simply having students read a scientific explanation does not modify students' misconceptions about a science topic. Only refutational text – which presents the scientific explanation and explicitly refutes the common misconceptions – was effective in altering student science content misconceptions. It seems likely that the same principle applies to preservice teachers as they read descriptions of pedagogical models of teaching in a typical science methods textbook. Students do not really attend to the distinctive differences between direct instruction and inductive learning cycle planning frameworks because the text does not directly address their tendency to confuse the two strategies. I have not rewritten the textbook, but I do provide a written advanced organizer which points out the problem before they read. After the reading assignment, we explicitly discuss the possible confusion as we review the material in preparation for using both models in the next activity.

Bridging Analogies (for Pedagogy)

The use of bridging analogies – linking a situation in which a scientific concept is correctly understood to a new situation likely to be misconstrued – was another strategy identified as effective in changing science content misconceptions (Guzzetti, Snyder, Glass, & Gamas, 1993). After modeling an inductive science lesson, I have students in small groups outline the instructional sequence. A consistent minority will reconstruct the lesson as direct instruction, even though they experienced it as an inductive "backwards" learning cycle sequence. We explore this discrepancy as we achieve consensus on what really happened. Then I have them deliberately rewrite the lesson as a direct instruction sequence, a pattern which they understand very well, using only the activities in the original lesson. In a side-by-side comparison, I try to help these students build a mental bridge between the direct instruction they understand, back to the inductive, problem-solving approach that I want them to adopt. Being clear about how the two strategies are related is critical before students attempt to create their own instructional units later in the semester.

Learning Cycle Strategies (for Teaching Pedagogy)

Finally, Guzzetti and her colleagues (1993) concluded that learning cycle and related conceptual change instructional sequences were effective in altering student science content misconceptions. I think the reason is that these instructional models tend to incorporate discrepant events, refutational explanation, and bridging analogies in a sequence that (1) causes students to question their old ideas and (2) presents new ideas as plausible, attractive, and useful (Posner et al., 1982). The instructional sequence I described above for changing student pedagogical notions – science autobiography comparison and model inductive lessons as discrepant events, refutational text/discussion, and the inductive/direct lesson writing bridging analogy activity – also fall into the inductive learning cycle pattern of engagement/exploration, explanation/invention, and elaboration/application.

A Metaphor for Preservice Teachers Naive Conceptions about Effective Science Pedagogy

Learning to teach is sometimes compared to learning to ride a bike. However, this simple comparison fails to describe the complexity of what our preservice students need to do in order to learn to teach science from a constructivist perspective.

Preservice teachers have spent many years watching their own science teachers ride a direct teaching tricycle (Figure 1). In fact, many have already mentally purchased their own tricycles before they even enter a science methods class, and they are expecting to be taught how to ride it. However, the direct teaching tricycle depends mainly on abstract teacher-directed explanation, supported by an anticipatory set to motivate students and guided practice to reinforce student understanding of the new ideas presented by the teacher.

When we ask preservice teachers to implement inductive teaching strategies, we require them to deconstruct their mental direct teaching tricycles and rearrange the parts into an inductive learning bicycle – expand the tiny anticipatory set wheel into a full-size problem-solving exploration wheel, retool the explanation wheel into a drive shaft linking exploration to application, and transform the guided practice wheel into the much larger application/elaboration wheel. Even more difficult, we ask preservice teachers to relinquish control of the vehicle, putting students rather that the teacher in control of the bicycle. There is no doubt that it would be far easier for everyone involved just to stick to tricycles!

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