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ABSTRACT

The purpose of this exploratory study was to describe the changes in middle school teachers' planning of science activities during a teacher enhancement project that involved problem-solving instruction and classroom implementation of a problem-solving curriculum model. The model reflected the cognitive science perspective and integrated the following features: students' prior knowledge, declarative knowledge, general strategy and domain-specific strategy knowledge, and instructional strategy. Twenty-eight teachers received instruction in human biology topics in five two-day workshops, in strategic pedagogy and curriculum design in two intensive three-week summer workshops, and in classroom implementation of the curriculum model in five workshops during the subsequent school year. Teachers were interviewed at three points: before and after summer workshops and after classroom implementation. Transcripts were analyzed using pre-decided categories and frequency distributions of categories calculated. Analyses indicate that increased involvement resulted in more complex patterns of planning with more emphasis on salient features of the curriculum model. Most dramatic changes occurred in teachers' attention to students' prior knowledge, which rose during the implementation phase of the project. Contains 23 references. (Author)

CHANGES IN TEACHER COGNITION WITH PROBLEM-SOLVING INSTRUCTION:

INSTRUCTIONAL PLANNING OF SCIENCE ACTIVITIES

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The purpose of this exploratory study was to describe the changes in middle school teachers' planning of science activities during a teacher enhancement project that involved problem-solving instruction and classroom implementation of a problem-solving curriculum model. The model reflected the cognitive science perspective and integrated these features: students' prior knowledge, declarative knowledge, general strategy and domain-specific strategy knowledge, and instructional strategy. Twenty-eight teachers received instruction in human biology topics in five two-day workshops; in strategic pedagogy and curriculum design in two intensive three-week summer workshops; and in classroom implementation of the curriculum model in five workshops during the subsequent school year. Teachers were interviewed at three points: before and after summer workshops and after classroom implementation. Transcripts were analyzed using pre-decided categories and frequency distributions of categories calculated. Analyses indicated that increased involvement resulted in more complex patterns of planning with more emphasis on salient features of the curriculum model. Most dramatic changes occurred in teachers' attention to students' prior knowledge, which rose during the implementation phase of the project.

Changes in Teacher Cognition with Problem-Solving Instruction:
Instructional Planning of Science Activities

What teachers think about, or "teacher cognition," has become increasingly more important in the study of effective teaching (Shavelson & Stern, 1981; Clark & Peterson, 1986; Carpenter & Fennema, 1991). Much of what teachers think about involves decision making about the structure of daily classroom learning activities (Brophy & Alleman, 1991). Tasks of this sort are continuous, complex, often ill-defined, and cognitively demanding for the teacher. Several specialists (e.g., Zais, Fraenkel, Taba, Kounin, Brophy & Good) have offered criteria for the selection of learning activities from the perspective of the curriculum generalist. Brophy and Alleman (1991) specified basic assumptions about ideal curricula, stressing that curriculum development should be driven by major long-term goals, not just short-term content coverage concerns. "Activities," defined by Brophy and Alleman to include "anything that students are expected to do, beyond getting input through reading or listening, in order to learn, practice, apply, evaluate, or in any other way respond to curricular content" (p. 9), should be organized into sets that provide opportunities for students to do something with the content--to use it in the context of problem solving, decision making, or other higher order applications that relate to contexts with application of students' lives outside of school. Declarative knowledge components would be integrated with strategic knowledge components in ways consistent with accomplishing the long-term goals.

Appropriate difficulty level for students has been studied by a number of investigators in defining the role of the teacher in selecting and designing activities (e.g., Kounin, 1970; Stake & Easley, 1978; Fisher, 1980; Brophy & Good, 1986; Doyle, 1986; Blumenfeld, Mergendoller, & Swarthout, 1987). Some researchers have suggested that optimal learning occurs when the material to be learned is moderately novel (e.g., Kahneman, 1973; Landers, 1980; Kintsch, 1980; Garner & Gillingham, 1991). Similar ideas are seen in Vygotsky's work (1934), which indicated that effective teaching and learning occur when students operate in a stimulating learning environment that is well matched to their prior knowledge and interests. Curricular decision-making is effective when teachers place students within their zone of proximal development (i.e., instructional appropriateness). As such, the learning task neither over- nor underestimates the capabilities of the students that the curriculum is intended to serve (see Glaser, 1984; Collins, Brown, & Newman, 1989).

The TARPS Teacher Enhancement Model

The goal of the Teachers As Research Partners (TARPS) project, a teacher enhancement project funded by the National Science Foundation, was to test and refine a theoretical position on the design of curricula that integrate mathematics and science knowledge and skills in problem-solving contexts. Integrated curriculum strands, designed as problems for students to solve, would include sequences of activities that complement declarative knowledge components and procedural or strategic knowledge components within a cognitively challenging yet appropriate instructional environment.

The initial stage of the development of the TARPS curriculum model was to develop a heuristic for facilitating teachers' cognition on lesson design that focused on two aspects: (a) salient features of curriculum design from the viewpoint of the cognitive scientist; and (2) students' prior knowledge. The heuristic was developed by a team of university researchers who came from the fields of educational psychology, teacher education, science education, mathematics education, and instructional technology. Salient features were identified: Content (e.g., Glaser, 1984; Glaser, Lesgold & Lajoie, 1987; Chi, Glaser, & Farr, 1988); strategic knowledge, in particular General Strategy Knowledge and Domain-Specific Strategy Knowledge (Glaser, 1984; Alexander & Judy, 1988); and Instructional Strategy (Brophy & Good, 1986). Students' Prior Knowledge was also identified as a critical feature of planning instructionally appropriate lessons. Prior knowledge was operationalized to include two variables that interacted with each of critical variables of the model: novelty and complexity. Instructionally appropriate lessons, with an overall complexity and novelty residing within the students' zone of proximal development, would be designed by manipulating the novelty and complexity of each of the other salient features of the model. A workable framework for manipulating the variables was developed with the assistance of visualization technology programmed in Hypercard, identified hereafter as the "TARPS Tool" (Tucker, 1994; Tucker & Stuessy, 1994; Stuessy & Tucker, 1995).

TARPS Teachers and Their Instructional Context

The TARPS project engaged both university and public school professionals in a complex, open-ended task: to examine and apply aspects of an integrated problem-solving curriculum model, which was strongly based in the cognitive science perspective, in the planning, implementation, and assessment of the teaching and learning of problem solving within integrative contexts. The context of adolescent wellness, which relies heavily on science content knowledge in human biology, was chosen as the problem-solving context for designing prototype curricula in the testing of the model. Interdisciplinary teams were formed of 28 middle school teachers in mathematics, science, physical education, and/or technology education.

Delivery of Instruction

Science content in the domain of human biology was presented by researchers and practitioners to the 28 teachers in five two-day workshops in the spring of 1994. The first summer workshop focused on three weeks of instruction in strategic pedagogy integrated with thematic science content knowledge. Pedagogical content focused on instruction in the areas of general learning strategies, domain-specific (mathematics and science process) strategies, instructional strategies, and thematic science (Stuessy & Payne, 1993). A second summer workshop focused on integrating various aspects of the model to look at the whole: within the context of adolescent wellness, to structure problem-solving sequences of thematic lessons that integrated science content in human biology, general and domain-strategic knowledge, and instructional strategies. In this workshop, teachers used the TARPS model and tool to develop problem-solving sequences that they later would teach in their classrooms. The TARPS Tool, in particular, was used to support systems thinking. Its design provided both a heuristic for teacher cognition and a mechanism for revealing patterns of interactions among the salient features of the model.

Fall 1994 workshops focused on the implementation and testing phase of the TARPS curriculum model. As teachers began to test and question various aspects of the TARPS model, their practical knowledge base about the model grew. Information about what did and did not work in which classrooms, with which students, was shared among teachers and researchers in fall 1994 and early 1995 spring workshops.

Research Question

The form of the research question regarding change in teachers' planning was exploratory in nature, seeking to describe how teachers changed in their planning of science activities with instruction and experience in using the TARPS model. Initially, one general question was posed: How does teachers' instructional planning change during their participation in the project?

Data Collection

In-depth interviews were conducted at three points in the sequence of teachers' workshop experiences. The first interview occurred after spring content workshops and prior to the first day of the summer workshop on strategic pedagogy. The second interview occurred three weeks later at the end of the first summer workshop. The third interview occurred after teachers had worked with the model for six months in their classrooms. The first set included interviews at all three points for six teachers involved in the project. A second set included interviews at the second and last two points for ten teachers involved in the project. A final set included four new teachers involved in the project prior to and after participation in two spring workshops.

The first interview was conducted in conjunction with each individual teacher's planning of an activity that introduced the topic of "wellness" to a class of middle-school students. The second interview occurred in conjunction with a request that teachers make changes in their initial design of activities. Both of these interviews were audio-taped while a university researcher took field notes. The third interview was conducted via computer in the spring of 1995 after all workshops were concluded. In this interview, teachers were requested to plan an activity that would appear about mid-way within a problem-solving sequence. Follow-up questions were asked and answered by teachers in a computerized format. All interview transcripts were cross-checked with written lesson plans.

Data Analysis

Transcripts of interviews were used for the analysis. Categories were pre-decided according to analyst-constructed typologies that reflected the salient features of the Teachers As Research Partners model (e.g., Content, Instructional Strategies, Domain Strategies, General Strategies, and Student Prior Knowledge). At the initial reading of the transcripts, the pre-decided categories were checked for appropriateness and inclusiveness. Other non-TARPS categories (e.g., Affective Concerns, Management/Time, Application to Real Life, Interest of Instructor, Focus on Learning Goal) that emerged from the reading were added to the list. All categories were color coded in the transcripts, and their frequency distributions were calculated.

Patterns between categories became apparent in the data and resulted in developing hypotheses about changes in TARPS teachers' instructional planning. These hypotheses were tested against the data and were useful in illuminating other questions. Hypotheses regarding changes from Interview I to II were tested with the data from the first set of teachers. The hypotheses regarding change from the end of the first summer workshop through the classroom implementation phase were tested with data from teachers who participated in both interviews II and III. Very tentative hypotheses were generated regarding the changes in new teachers who were interviewed before and after limited instruction in the model. Alternative answers to the research question were explored, and the most plausible answer was generated.

Results and Discussion

The process for data collection was chosen because it was a natural way for teachers to think about their instructional planning: by planning an activity. The open-ended interview process revealed useful information about changes in teachers' planning of activities over the course of the project. Data analysis revealed a number of patterns. With involvement in the project, TARPS participants' planning became more complex, with 83 per cent of the teachers mentioning more planning categories in Interview II than in Interview I and only slight reductions in numbers from Interview II to III. Attention to TARPS features increased over the course of the project, with roughly two-thirds of the participants showing more attention in Interview III than in Interview I. New teachers followed a similar trend, even with a very limited exposure to the model. Regarding attention to content, teachers focused their attention away from content in Interview I to either instructional strategies or what students would be doing with the content in subsequent interviews. Teachers' attention to a particular feature of the TARPS model, students' prior knowledge, surprisingly did not change directly after strategy instruction in the first summer workshop. Attention to prior knowledge increased with time and use of the model in the classroom. Changes occurred as teachers used the TARPS model in their classrooms and shared information in follow-up workshops that focused directly on teachers' implementation efforts.

The TARPS project was designed to enhance the practical and research experiences of classroom teachers and university researchers as they tested a model for the development and teaching of problem-solving to middle schoool learners. Workshops were designed to facilitate the professional exchange of expertise, perspectives, ideas, and information regarding the facility of the model. Unlike teacher enhancement projects that are traditionally structured, the TARPS project was designed so that teachers and researchers shared a genuine sense of responsibility for the project. In terms of designing activities, the analysis indicated that the teachers continually expanded their capacity to design lessons that reflected the salient features the problem-solving curriculum model. New and expansive patterns of thinking, most noticeable in attention to students' prior knowledge, emerged over the course of the project, perhaps as a result of the growth in collective knowledge and aspiration in an environment that encouraged teachers to continually learn how to learn together.

Changes in Teachers' Planning Emphases with Early Instruction (from Interview 1 to 2)

Planning Emphasis	Decreased Emphasis f	Decreased Emphasis %	Increased Emphasis f	Increased Emphasis %	No Change f	No Change %
Content	5	50	5	50	0	0
Instructional Strategies	5	50	5	50	0	0
Domain Strategies	2	20	5	50	3	30
General Strategies	2	20	5	50	3	30
Students' Prior Knowledge	5	50	5	50	0	0
Affective Concerns*	6	60	2	20	2	20
Time/Classroom Management	4	40	3	30	3	30
Applications to Real Life*	2	20	6	60	2	20
Interest of Instructor*	3	30	1	10	6	60
Focus on Learning Goal*	0	0	5	50	5	50

* Changes were interpreted as significant (corrected chi-square = 3.84; $p \leq 0.05$) using nonparametric statistical techniques; the McNemar test was used when expected frequencies were 5 or greater, and the binomial test used in instances where expected frequencies were very small (< 5).

Changes in Teachers' Planning Emphases (from Interview 2 to 3) with Classroom Implementation of the TARPS Model

Planning Emphasis	Decreased Emphasis		Increased Emphasis		No Change	
	f	%	f	%	f	%
Content	7	70	3	30	0	0
Instructional Strategies	8	80	2	20	0	0
Domain Strategies*	2	20	6	60	2	20
General Strategies	7	70	3	30	0	0
Students' Prior Knowledge*	2	20	7	70	1	10
Affective Concerns	3	30	4	40	3	30
Time/Classroom Management*	6	60	2	20	2	20
Applications to Real Life	6	60	2	20	3	30
Interest of Instructor*	0	0	4	40	6	60
Focus on Learning Goal*	8	80	0	0	2	20

* Changes were interpreted as significant (corrected chi-square = 3.84; $p \leq 0.05$) using nonparametric statistical techniques; the McNemar test was used when expected frequencies were 5 or greater, and the binomial test used in instances where expected frequencies were very small (< 5).

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