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ABSTRACT

This paper is a part of a research program whose purpose it is to design instruction for scaffolding classroom inquiry in middle school classrooms. Scaffolding is a dynamic process, reflecting teacher adjustments based on student responses. Even though a computer, textbook, or laboratory materials may serve as proxy for a "teacher", arguably the most important source of scaffolding in a classroom is the flesh and blood teacher. The teacher decides, consciously or unconsciously, how and when to use a computer, textbook, or laboratory materials. The actions of the teacher are also the primary mediator of the scaffolding effects of other classroom materials. The purpose of inquiry-based instruction is to prompt focused effort on a specific problem. The effort includes recall and application of relevant knowledge and implementation of procedures for generating, analyzing, and interpreting data. Mental effort for inquiry requires evaluation of the fit among a problem statement, recalled knowledge, and evidence either empirical or theoretical. This type of thinking requires self-monitoring of one's understanding of the problem and processes undertaking to solve it. Middle level students are just beginning to show the capabilities for the kinds of thought necessary for scientific inquiry. However, most of the evidence for these thinking skills is clinically based (Keating, 1990). Classroom-based reasoning situations do not afford the time, focus, and cues for employing critical thinking. Cognitive scaffolding is necessary to support student thinking necessary for benefiting from inquiry-based instruction. Cognitive scaffolding has been defined as what a teacher does when working with a student "to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts: (Wood, Bruner, & Ross, 1976, p.90). As a psychological construct, it refers to a cognitive orientation in the teacher to select and structure tasks, communicate purpose, and hold expectations with the intention of guiding student work at the limits of their independent capabilities. Scaffolding also refers to an affective orientation in the teacher that is sensitive to variations in student cognitive and affective capabilities that results in adjusting elements of the task or context that promotes continued student effort. For scaffolding to work, however, there must be a complementary cognitive and affective orientation in the student. The student must be willing to apply existing knowledge and make active use of the teacher or other resources to leverage that knowledge toward a learning goal. Student affect must be willing to accept less than immediate gratification and persevere in the task. (Contains 17 references.) (Author/YDS)

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Integrating Elements of Inquiry into the Flow of Middle Level Teaching

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Problem

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Science educators and teachers need a better picture of what inquiry instruction looks like as it is being practiced in a typical classroom. Current models describe inquiry as a matter of steps or phases conducted in succession or in cycles expressed in terms of expected student outcomes. Descriptions of teaching practices to elicit and maintain cognitive engagement have remained at a level of generality that leaves the operational meaning up to the classroom teacher (Romberg & Carpenter, 1986). Teaching practices are often stated in vague or indirect terms. For instance, Toh and Wollnough (1993) compared achievement in laboratory investigations between students receiving explicit instruction along with laboratory experiences and students receiving only laboratory experiences. The description of explicit teaching practice is captured in this passage: "The discussion involved the students in active and meaningful learning and eventually to obtain consensus of each decision they made. The decisions generated were elicited through questions to which students had to respond" (p. 448). The reader is left wondering how discussions and classroom dynamics were structured to achieve "active and meaningful learning" that converged on consensus? How many students actually generated a response to the required questions?

Observations in classrooms (Good & Brophy, 1997) reveal that teachers who work out the operational form of complex instruction, such as instruction that teaches scientific inquiry, must be skilled in a variety of strategies in order to design instruction that maintains the desired cognitive demands of inquiry while adjusting to the constraints of a typical classroom. The National Science Education Standards (NRC, 1996) describe how the teaching of inquiry is embedded in a variety of instructional forms (see Figure 1). Sometimes the teacher must settle for an approximation of inquiry instruction. As a result, instruction may look less student centered, as the accepted view of classroom inquiry implies, and more teacher centered. That is, where students are not functioning sufficiently well with the content or materials for any of a variety of reasons (see Figure 2), the teacher must carry more of the burden for recalling approriate content, helping students monitor their understanding, and indentifying procedures for generating data.

Current models of inquiry-oriented instruction do not account for classroom variables that require teachers to adjust or redirect instruction in order to reenter inquiry at a different place. Current models suffer from at least three problems. First, they are too narrowly focused. For instance, as conceived, the learning cycle has at least three intended outcomes (a) description, (b) empirical-abductive, and (c) hypothetico-deductive. The difference across these forms is the degree to which students generate, apply, and test explicit hypotheses (Lawson, et al., 1989). As implemented, the learning cycle converges on a conceptual target that presupposes students are modifying their personal conceptions in light of tested hypotheses (Westbrook & Rogers, 1994). There are other reasonable outcomes of a learning cycle lesson that are pedagogically sound stopping points but the model as applied rarely assumes other outcomes. Second, models do not specify how to teach the cognitive skills necessary for students to carry out the complex cognitive tasks of inquiry. The instructional targets for current models expect students to analyze data and synthesize conclusions without first achieving an operational understanding of what it means to do analysis and synthesis. Third, current models of instruction are presented in isolation from each other. Models do not contain heuristic supports for helping teachers decide when a model might be useful or how it would work with other kinds of instruction such as listed in Figure 1. Skilled teachers work out methods that overcome these problems usually as they are teaching. Observing their methods for creating an inquiry-oriented environment and scaffolding student participation can offer insight into the operational details of inquiry-oriented teaching. This approach has been used in other studies in science education. The work of skilled and practiced teachers have been regularly used to establish context and to find starting points for instructional research. Tobin and Fraser (1990) observed skilled teachers to examine parameters of excellent science teaching. Effective teachers were contrasted with ineffective teachers to establish parameters of what constitutes "effective."

The purpose of this case study was to analyze the practices of two skilled and experienced middle level teachers with respect to research-based criteria for instructional scaffolding in support of inquiry-oriented teaching. The research questions were (a) What do skilled, experienced teachers do when scaffolding inquiry-oriented instruction? and (b) In what ways do they align with research-based criteria for scaffolding and inquiry-oriented instruction?

Method

Two experienced teachers were selected from a field of eight. Seven of the eight potential subjects were teachers participating in an extended inservice program supported by the National Science Foundation for improving knowledge and skills in teaching science. The eighth teacher was recommended for this study by a science educator who himself had exemplary teaching experience and was familiar with the teacher's work. Five of the eight agreed to participate in an initial observation period that lasted from six to eight weeks (Flick & Dickinson, 1997). Based on in-class observations partially supported by video tape records, two middle school teachers were selected for in-depth study. They were selected because they not only exhibited the knowledge, skill, and intent to create an inquiry-oriented instructional environment, but also presented teaching strategies that were used to provide a continuous thread of inquiry across lessons. Mr. Levine and Mr. Gunn have 10 and 13 years of experience in middle level teaching respectively. Levine currently teaches sixth grade and sees all of the sixth graders in his school. Gunn teaches seventh grade and sees all of the seventh graders in his school. Both teach physical education as part of their assignment. Both have been participants in multiple inservice programs related to improving science teaching during the last five years. Both regularly attend national and state professional science teacher meetings.

Field notes of direct observations of teaching were partially supported by video tape during. Each teacher was observed six times and video tape was used twice with each teacher as a means of triangulating interpretations with field notes and interviews. Students were aware of the video taping and they and their parents had given written consent. Students distracted by the taping were always closest to the camera but the general nature of the class was not affected. One extended interview session with each teacher was audio taped to document information gained from several informal discussions that took place before, during, and after instruction.

Analysis

Field notes and partial transcriptions of video and audio tapes were analyzed using an operational definition for scaffolding instruction derived from Palincsar and Brown (1984) and Palincsar (1986). A synthesis of the literature on the psychological construct of scaffolding resulted in the criteria listed in Figure 3. The validity of this definition for scaffolding is based on an analysis of the literature and on empirical work in examining the practices of expert teachers (Flick & Dickinson, 1997; Flick, 1996; Flick, 1995). The content validity was checked by showing Figure 3 to two science educators with 10 and 15 years of teaching experience each. They were both familiar with the literature in inquiry science teaching and the nature of science. Their assessment was that the formulation presented in Figure 3 was a more comprehensive definition of scaffolding than was typically used in the literature. They felt that all elements were appropriate to the construct and could be observed during instruction.

Construct validity is the more important form of validity in this case and more difficult to establish. The central question is, Does the stipulated criteria differentiate between teachers who do scaffold inquiry and those who do not? To accomplish such a judgment it would be necessary to validate criteria for "classroom inquiry" \ and a valid form of assessing outcomes. These are steps being taken in the next phase of this research program. It is not possible to make a judgment of construct validity at this time.

Teaching episodes from both teachers were analyzed with the criteria shown in Figure 3. The analysis examined teaching behavior across lessons and content to reach an evaluation of the level of instructional scaffolding for fostering inquiry in a middle school science classroom. A model of classroom inquiry based on Rowe (1973) was stipulated to include the following components: (a) addressing a specific question, (b) applying specific background information, (c) performing procedures for the purpose answering the question by collecting observations, (d) making inferences from these observations with the purpose of answering the question and (e) interpreting new experiences using concepts they already have or using concepts developed through instruction. This model of inquiry was validated by the same two science educators described above and, as a result, modified to include (f) presenting results to others, sharing ideas or techniques and (g) using social skills to engage in all elements of inquiry within a small group context.

Table 1 shows a detailed analysis of elements of teaching for each teacher that fit under each category of scaffolding. Each category also includes an element of teaching where additional scaffolding was possible and, if implemented, in the judgment of this researcher, would have brought instruction into closer alignment with the criteria for scaffolding used in this study. The analysis of contrasts was modeled after Miles and Huberman's (1984) matrix-summarizing techniques used to describe relationships among variables. They recommended various coding techniques to convey information about data sources or conflicting data. In Table 1, data for the two classrooms are coded with + to indicate teaching behavior considered consistent with scaffolding criteria and a - teaching behavior that would have improved the alignment with criteria.

An extended description of each teacher's practices was written that characterized instruction based on all observations. Each characterization offers an analysis of both instructional practices and their relation to the elements of inquiry discussed earlier. It was not practical to submit the extensive data set to an independent and knowledgeable researcher to check for consistency of interpretations. However, each teacher reviewed his own description as a "member check" and each concurred with the characterization.

Characterizing Instruction: Mr. Levine

Levine opened most classes with a warm-up problem presented on an overhead transparency. Because math and science were taught in a 90-minute block, instructional patterns were somewhat conflated across the two subjects. However, there was a clear emphasis in math to teach specific problem-solving skills while in science the content was more conceptual in nature. As a discussion leader, Levine helped students engage with the warm-up problem or question through direct hints or prompts concerning the expected answer. While student responses were solicited and encouraged, Levine's instruction directed them toward a statement of the expected answer in a fast-paced and efficient manner. Efficiency was a major concern to Levine throughout his teaching.

Levine created cognitive supports in the form of words, phrases, techniques for processing information, or analogies for how to understand the problem. Following the warm-up, Levine introduced an activity (e.g. video, lab, creating a product, or worksheet) around which he eventually developed more discussion of the target concept. Most of the work in the science portion of the class was conducted either in small group structures or as whole class discussions. There was very little individual seat work. Levine employed specific procedures to structure transitions to and from small-group work. His goal was to establish and maintain an atmosphere of academic work, attention, and courteous behavior. These rules were so well known by students that a minor prompt resulted in a complete choral recitation. For example the rules for small group work were: (a) "quiet voices," (b) "invisible walls" symbolizing that small groups were not to interact, (c) "polite disagreement," (d) "stay focused," (e) "encourage participation," and (f) "value all ideas." Levine himself modeled these behaviors in whole-class work and through this structure he established a safe atmosphere conducive to the divergent thinking of inquiry. Small group work included only cursory opportunities to present results to each other or the class as a whole.

Inquiry questions were posed and specific background information was brought to bear on these questions. Students perceived the class as a safe place to offer ideas and there was a specific expectation that they speak out. Some questions tended to be broad and not directly researchable by evidence generated in the classroom. For example, students discussed causes for the extinction of dinosaurs. Other questions were more accessible to investigation. Students examined the composition and structure of rocks and devised their

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own classification schemes. Rarely did students actually perform a whole investigation where they followed procedures, collected data, and made inferences for the purpose of answering questions. The mix of these inquiry elements was informal but did lead to the application of concepts to new experiences. In the case of dinosaurs, they analyzed the research presented in a video presentation.

Levine used a video from the PBS series Scientific American Frontiers entitled "Life's Big Questions." Students were arranged in groups with a worksheet that outlined the content of the video and posed questions for recall and reflection. Levine stopped the video at appropriate points to check student understanding. He stated his expectation that they respond to each question on the worksheet and offered questions and prompts that embellished what was presented in the video. The ensuing discussion modeled his expectations of student behavior in small groups and he reminded them of these points as stated above. In the process, student ideas were elicited and he explicitly expressed that the ideas were important and valued. Students offered interpretations and original points of view. Each video segment lasted not more than 10 minutes and Levine's structured feedback required review and occasionally synthesis on the part of students. His wait-time for synthesis or summary responses was short and he often provided a model response or rephrased the question for a lower level response. He was careful to call on a wide range of students covering most of the class. During activity sessions and even during whole class discussions, he noted positive and negative behaviors relative to maintaining a productive and inquiry-oriented classroom atmosphere. He regularly provided specific feedback to the class about these behaviors in the form of complements and how to improve. These reminders about the conduct of work in the class was also connected with the nature of the work. That is, the desired atmosphere was important because students needed to be focused on solving a problem and discussing notes or ideas.

Characterizing Instruction: Mr. Gary

Gary opened nearly every class with a routine he called "Reflections." In a Reflection, Gary posed a question or problem for the purpose of applying a concept or developing a skill. Reflections were structured as an open-ended question about half the time, but during every discussion Gary solicited and valued divergent points of view. This procedure established an atmosphere of inquiry that emphasized drawing inferences and making interpretations. In this sense, students were regularly asked to address specific questions and apply appropriate background information. Written responses to Reflections were recorded in a special student notebook and collected periodically for evaluation. A Reflection exercise could take anywhere from 10 to 35 minutes depending upon how productive the discussion and how many supports were needed for students to produce a response. Gary provided cognitive supports in the form of prompting questions and summary statements. These were generated often enough to keep active discussion going. This could mean a new statement or question as often as once a minute or as little as one in 10 minutes as explanations and ideas were exchanged. The prompt always connected work done during the most recent lessons with a planned activity or lab. Cognitive support also came through student questions and statements that attempted to address the prompt. From the prompt, "How can you increase the density of water?," students offered the following ideas: freeze it, compress it, or turn it to a gas and compress it. Each of these ideas stimulated additional comments from the class mediated by Gary's summaries and restatements.

The pace was kept brisk with short wait-time in the course of whole class discussion. He structured wait-time in the form of brief discussions with pre-assigned partners. Typically he allowed 30-60 seconds for students to generate a question or a response to a problem currently under discussion. During that time he was circulating among the groups asking questions to focus or redirect attention. He also gathered examples of ideas that he could use to prompt participation from less vocal students. The transition from whole-class to partners and back to whole-class wasted no time and student attention was not allowed to wander very far.

The goal of Gary's instruction was to direct attention to the focus problem stated in the Reflection written on the board. At some point where Gary felt the discussion had ceased being productive, he introduced or reiterated a specific answer. It was presented in the context of all the ideas offered during the class and students were expected to write their own synthesis of this discussion. Many students wrote reflections during the class discussion but Gary provided a specific time to write at the end of the discussion.

The Reflection helped to introduce or follow-up a lab activity, such as measuring the density of various materials, building a small electric motor, or designing a car with little friction. Gary closely monitored the activities by offering observations and suggestions concerning procedures and results. Questioning in this context was different from the Reflections portion of the lesson. Teacher-student interaction was far more directed, convergent, and explicit. Students had a product to produce and Gary helped them do it. It was likely that some aspect of the lab work would become the focus of the next Reflection. Formal investigations, such as testing a consumer product, combined with Reflections provided opportunities for students to perform procedures, collect data, and make inferences to answer specific questions. Reflections offered regular opportunities to interpret new experiences using the results of investigations. The presentation of results to other was usually done in the context of small group discussions during the Reflection portion of the lesson.

Results

Both Gary and Levine were active in creating scaffolds for instruction that supported learning in science in general and learning about inquiry in particular. They created learning environments and procedures that allowed students to do what they would otherwise be unable to do if unaided. They did not structure these learning environments in the same way nor did they create all the elements of scaffolding as outlined in Figure 3. While there were several differences in methods of scaffolding, there were interesting similarities in those elements of scaffolding that were <u>not</u> in evidence. Each teacher is discussed in turn followed by a summary.

Gary taught science to all seventh graders in his middle school. His scaffolding focused heavily on creating opportunities for student participation in reflective thinking about the concepts or tasks upon which the class was working. At the beginning of each period, students were presented with a problem to which they would respond in writing in a special notebook. Through whole-class discussion, discussion with partners, and individual written responses, Gary scaffolded instruction that guided students through analysis of the problem and application of concepts. A reflection problem might involve application of ideas to a novel setting such as examining a U.S. map showing the location of atomic power plants and answering the question, "Why are there more atomic power plants in the east than in the west?" Other problems focused on ongoing investigative activity such as, "Identify three possible sources of error in your data."

Gary's daily routine provided opportunities for accentuating critical features of important tasks in an investigation such as how to identify trends in data or how to write an hypothesis statement that met specific criteria. Multi-step investigative tasks or complex applications of concepts were beyond the independent capabilities of most of Gary's students. Through classroom routines for examining selected problems or examining the characteristics of important procedures, Gary helped students identify approaches to performing these tasks, guided practice to approximate appropriate cognitive behaviors, and provided corrective feedback for target responses.

However, even with these routines in place and almost daily practice, some students participated marginally or not at all. During small group work or structured conferences with partners, Gary circulated around the room often answering the basic question "I don't understand what to do?" Gary observed that even several weeks into the term, some students would enter class, forgetting their notebook unaware that other class members were already reading and discussing the reflection problem written on the board. Many of these behaviors fit the description of underachievers shown in Figure 2. According to Gary's description, his students were representative of average, middle class children in terms of standardized test scores and socio-economic status. Yet despite the supports and advantages associated with middle class living, there was a significant portion of the class that did not respond to Gary's scaffolded instruction. We will see that this was also true for Levine's middle class students.

Levine taught science to all the 6th graders in his middle school. His scaffolding focused heavily on creating opportunities for student participation in discussion and activities. He designed specific routines and rules of behavior that promoted student input and specifically required that students listen to one another. This was particularly effective in soliciting points of view when attempting to identify a problem or understand a problem for investigation. His code of conduct and expectation of mutual respect was also invoked when soliciting background information to apply to a problem. Early in the year, he structured a lesson where students inductively answered the questions, What is science? The lesson involved several steps with students generating personal examples of "science", writing them on paper, taping them on the board, and participating in a categorization process. Instruction was based on Taba's

(1965) model for teaching inductive thinking. Scaffolding in this case involved (a) specifically requesting and publicly acknowledging all student input, (b) making and managing the large visual display on the board, (c) questioning to prompt summary and synthesis of emerging categories, and (d) reminding students of rules for whole class and small group interactions. These points are aligned with scaffolding elements A, C, D, E, F, H, I, and K. The result was that nearly all students were involved and most received feedback directly or indirectly by hearing other student-teacher interactions. This lesson was typical in that it reached the intended closure.

Levine was very active throughout his lessons and his own energy often seemed like the main force that drove the discussion. Levine reflected on this general state of affairs:

"My plan is supposed to build a concept but I feel I am doing most of the thinking. Some students are actively thinking and some of these are trying to make comments. However, there are individuals you hardly have a clue what is going on."

Levine's comment captured problems with the scaffolding process with both teachers. Neither teacher was generally satisfied with the participation of the class as a whole. Students in both classes were well coached in how to behave, provided with carefully selected tasks that had been rendered accessible through various kinds of support, and given feedback on their prompted input. Most students were successful in learning content objectives. However, both teachers sensed that too many students did not have an understanding of the direction of instruction or in some cases even the purpose of instruction. Instructional routines were designed to scaffold student participation in inquiry-oriented activities but not to understand the inquiry nature of those activity. Effects of instructional routines observed in this study provided considerable support for students while they were being asked to respond to complex questions. Figure 4 is a synthesis of the type of effects generated by the routines observed. Clearly, not all students benefited equally. The analysis in Table 1 revealed that both teachers had problems delivering their intended instruction. The benefits of focused and consistent routines provide strucutures prerequisite to complex instruction but do not guarantee involvement by all students.

There were elements of scaffolding as shown in Figure 3 by capital letter that neither teacher employed in their instruction. Neither systematically evaluated tasks for difficulties (B); nor calibrated difficulty of assessments (J); nor gradually reduced levels of support to promote independent learning (L). Tasks were selected to be challenging and meaningful within the context of instruction. Instruction scaffolded student engagement with the specific problem and students were reminded of the general purpose. However, there was little attention given to the relative difficulty of the task and how or if students would eventually accomplish the task or one like it on their own. Adjustments were made at the level of procedures within a lesson but not at the level of the overall task or its purpose. In neither class were students verbally informed of the intention that they were expected to became capable of handling selected inquiry-oriented tasks on their own. For instance, Gary allowed students to take varying degrees of control in solving the daily inquiry problems (see Table 1: B, C, D, & K), but there was no specific statement to students that they were learning "how" to respond to these problems. Levine communicated to students that they were expected to follow specific procedures for working together that included scaffolding for sharing ideas and roles within small groups (see Table 1: D, F, I, & K), but scaffolding was not handled with the intention that students would eventually handle the tasks independently.

An analogy to coaching a soccer team makes a useful contrast between learning content and achieving skills for independent learning. Let's say these two teachers were soccer coaches as part of their physical education assignment and coached their teams in ways similar to the scaffolded instruction used in their classrooms. They would present problems in defense that required certain physical skills. Students would practice these skills in the selected problems, perhaps rotating through different positions such as wing and defender. However, they would not be coached in how to size up different defensive problems as they occur in a game. Further the problems they were presented would not have been selected nor adjusted for improving skills. Rather, they would be selected for their relevance to specific problems deemed important for learning about soccer not learning how to play the game of soccer. Students would learn how to set up plays but only under the guidance of the coach and not with the goal that they were responsible for learning how to "solve soccer problems" on their own while actually playing the game.

Instructional scaffolding focused on using inquiry skills and not on learning the skills themselves nor how and when to employ those skills in scientific problems. Put another way, the teachers paid more attention to using inquiry as a method for teaching science than teaching how to do inquiry. The teachers attended to the difficulty of the science content and typically "scaled" it to a developmentally appropriate level, but rarely attended to the cognitive challenges inherent in inquiry. Elements of inquiry were used as a means for teaching science principles or facts but neither the elements of inquiry themselves nor the thinking necessary to engage in inquiry were explicitly the subject of instruction.

Implications for Teaching and Further Research

Both teachers were successful in eliciting and maintaining a high degree of student attention, participation, and cognitive involvement. A feature of instruction that was effective in both classrooms was specific teaching routines that fostered student behavior that supported student participation in inquiry-oriented procedures (see Figure 4). However, both teachers observed that the students did not understand the inquiry purpose of instruction. Instructional routines were effective in fostering behaviors that supported participation. Could instructional routines be designed to support thinking skills important for understanding inquiry?

Palincsar and Brown (1984) showed that making "reciprocal teaching," an instructional routine was effective in fostering comprehension and comprehension-monitoring in seventh-grade students reading science texts. They focused on development of a set of skills found to be in common across

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many reading comprehension studies. These skills were summarizing, clarifying, stating questions answerable from the text, and predicting the content of the next portion of text. A direct analogy may be useful in applying this line of research to cognitive skills for teaching students scientific inquiry. Reading comprehension can be though of as a form of inquiry into the meaning of data in the form of printed text. Students investigate the text for information that is interpreted and finally synthesized into meaningful ideas, or comprehended. Are these skills useful in promoting cognitive skills for investigating empirically-based problems? It is possible to imagine, for example, that teaching students how to ask a "clarifying question" when faced with inquiry task in science would lead to better performance on that task. If students were taught how and when to form questions that are answerable by a set of data, might they become better at interpreting those data in terms of the original inquiry question?

What other cognitive skills are important for engaging middle school students in the meaning and purpose of inquiry? Are these skills developmentally appropriate for early adolescent children? The National Science Education Standards (NRC, 1996, p. 20-21) offer some suggestions: (a) engaging in interactions with teachers and peers, (b) making connections between current understandings and new ideas, (c) planning, (d) decision-making, (e) group discussions, (f) using rules of evidence, (g) formulating questions, and (h) proposing explanations. Given appropriate objectives, what instructional practices are effective in fostering these cognitive and metacognitive behaviors? What are appropriate tasks of graduated difficulty that can be used to assess these skills? And finally, is it possible to gradually reduce instructional support to promote independent inquiry at the middle school level?

References

Flick, L. B. (1996). Understanding Generative Learning Models of Instruction by Elementary Teachers Trained in a Linear Instructional Process. Journal of Science Teacher Education, 7, 95-122.

Flick, L. B. (1995). Navigating a Sea Of Ideas: Teacher and Students Negotiate a Course Toward Mutual Relevance. Journal of Research in Science Teaching, 32, 1065-1082.

Flick, L. B. & Dickinson, V. L. (1997). Teacher intentions, teaching practice, and student perceptions of inquiry-oriented teaching. Manuscript submitted for publication.

Good, T. L. & Brophy, J. E. (1997). Looking in classroom, seventh edition. New York: Longman.

Keating, Daniel P. (1990). Adolescent thinking. In S. S. Feldman & G. R. Elliott (Eds.). At the threshold: The developing adolescent. Cambridge, MA: Harvard University Press.

Lawson, A. E., Abraham, M. R., & Renner, J. N. (1989). A theory of instruction. National Association for Research in Science Teaching Monograph, No. 1, pp. 45-57.

Miles, M. B. & Huberman, A. M. (1984). Qualitative data Analysis, 2nd ed. Thousand Oaks, CA: Sage Publications, Inc.

National Research Council. (1996). National science education standards. Washington, D.C.: The Author.

Palincsar, A. S. & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. Cognition and Instruction, 1, 117-175.

Palincsar, A. S. (1986). The role of dialogue in providing scaffolding instruction. Educational Psychologist, 21, 73-98.

Reid, D. J. & Hodson, D. (1987). Science for all: Teaching science in the secondary school. London: Cassell Educational Limited.

Romberg, T. A. & Carpenter, T. P. (1986). Research on teaching and learning mathematics: Two disciplines of scientific inquiry. In M. C. Wittrock (Ed.). Handbook of research on teaching, third edition. New York: Macmillan Publishing Company.

Rowe, M. B. (1973). Teaching science as continuous Inquiry. New York: McGraw-Hill.

Taba, H. (1965). Teacher handbook for Contra Costa social studies grades 1-6. San Francisco, CA: Contra Costa Schools.

Tobin, K. & Fraser, B. J. (1990). What does it mean to be an exemplary science teacher? JRST, 27, 3-25.

Westbrook, S. L. & Rogers, L. N. (1994). Examining the development of scientific reasoning in ninth-grade physical science students. JRST, 31(1), 65-76.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry, 17, 98-100.

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Figures and Tables

- Execute methods for presenting content in the form of problems that stimulate selected aspects of inquiry (p. 20).
- Model or demonstrate inquiry so that students can copy the traits of an expert (p. 36).
- Execute skills needed for designing, implementing, or evaluating hands-on investigations (p.33).
- Teach skills and procedures for interacting in small groups (p. 50; 136).
- Execute procedures for promoting interaction between existing student knowledge and new knowledge (p. 33; 121).
- Execute explicit instructional methods for teaching specific knowledge, process skills, or scientific attitudes (p. 31; 220).

Figure 1: Teaching skills implied or stated in the National Science Education Standards that support classroom instruction in science. Page numbers refer to the Standards (NRC, 1996).

Say they are bored
Indulge in idle chatter
Fail to do homework
Fail to take care over work
Rarely have pen, pencils, books, etc.
Lose things
Respond better to individual attention
Disrupt other pupils' work
Are distrustful of teachers and of authority
Form unstable or weak friendship bonds
Are often late for lessons
Are absent more frequently than other pupils
Claim that what they learn is of no use
Feel that school is an imposition
Wish to leave school to earn money
Express non-involvement in their form of dress
Are disrespectful of property
Are attention seeking
Dress untidily

Figure 2: Traits of classroom behaviors shown by underachievers. Source: Reid, D. J. & Hodson, D. (1987).

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A. Selection of task that teaches a skill emerging in the learner
B. Evaluation of task for difficulties it will present to learner
C. Structuring opportunities for student participation
D. Render the task accessible to learner
E. Accentuate critical features of task
F. Organize task for presentation
G. Identify and represent appropriate approaches to the task
H. Identify and represent approximations of successful completion
I. Elicit and sustain interest
J. Designing assessments to calibrate the level of difficulty
K. Providing learner with feedback on her production and on correct production
L. Adjust levels of instructional support toward gradual withdrawal

Figure 3: Elements of scaffolding, based on: Palincsar, A. S. & Brown, A. L. (1984) and Palincsar, A. S. (1986).

- Communicates expectations common to entire class.
- Provides guidance for specific behavior at various stages of instructional activity.
- Provides a starting point for action.
- Structures a way to coordinate the efforts of an individual student with those of the entire class.
- Reduces emotional stress caused by uncertainty about procedures and releases more working memory for thinking about content.
- Provides check points for progress or metacognitive prompts.
- Becomes a model that can be used independently reducing the need for repeated instruction and supervision.
- Becomes a general tool for use in other academic work.
- Deviations from routines can be used to make a point or focus attention on new or alternative elements.
- Repetition inherent in the use of a routine aids in memorization of steps and the development of automaticity and the development of effective variations and adaptations.

Figure 4: Effects of instructional routines based on classroom observations of teachers in the current study.

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