DOCUMENT RESUME

ED 383 563 SE 056 387

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TITLE	Complex Instruction in Complex Classrooms: A Synthesis of Res.arch on Inquiry Teaching Methods and Explicit Teaching Strategies.
PUB DATE	Apr 95
NOTE	29p., Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (San Francisco, CA, April 22-25, 1995).
PUB TYPE	Reports - Research/Technical (143) -- Information Analyses (070) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Educational Research; High Schools; *Inquiry; Instructional Effectiveness; Intermediate Grades; Junior High Schools; Literature Reviews; Middle Schools; *Science Instruction; *Teacher Behavior; *Teaching Methods
IDENTIFIERS	*Explicit Instruction

ABSTRACT

Achieving national standards for science education for all students requires that the research agenda for inquiry-oriented instruction be well informed by current knowledge of successful and unsuccessful teaching practices in typical classrooms. Given the persistent lack of data about the nature of teacher behavior in inquiry-oriented teaching and given the significant effects of explicit teaching methods for certain objectives for some students, research on inquiry-oriented teaching is reviewed against a background of explicit teaching research. The purpose is to achieve a productive synthesis. A brief review of explicit teaching research focuses on research on teacher behaviors and teaching functions to inform discussion about inquiry teaching. Studies that contribute to understanding of inquiry teaching practices in typical middle or high school classrooms are reviewed. A summary discusses techniques for synthesizing knowledge on explicit teaching with knowledge on inquiry-oriented teaching in order to make complex forms of teaching and learning accessible to a greater number of students with more diverse backgrounds. Contains recommendations for further research, 2 tables, and 61 references. (LZ)

Complex Instruction in Complex Classrooms: A Synthesis of Research in Inquiry Teaching Methods and Explicit Teaching Strategies

by
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National Association for Research in Science Teaching
San Francisco, CA April 22-25, 1995

Complex Instruction in Complex Classrooms: A Synthesis of Research on Inquiry Teaching Methods and Explicit Teaching Strategies

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Inquiry-oriented instruction continues to receive considerable attention from science education reform documents. Both the National Research Council (NRC, 1994) and the American Association for the Advancement of Science (AAAS, 1994) have devoted a significant portion of text to inquiry-oriented curriculum and instruction. Yet teachers often struggle with or reject the notion that inquiry should be a frequent part of classroom instruction (Hurd et al., 1980). Their reasons are by now quite familiar to observers in science education and include obstacles such as time, appropriate materials, student ability and interest, and teacher expertise and motivation (Costenson & Lawson, 1986). Lederman (1992) reviewed literature on teacher knowledge of the nature of science and concluded that they were generally uninformed concerning the basic tenants for why inquiry should be an important feature of instruction in science. However, even when theses obstacles are overcome, it is not obvious that inquiry teaching methods are the frequent choice for instruction. For example, at the college level, where expertise and learning environment could be adjusted to support inquiry-oriented instruction, it usually is not (Tobias, 1990; 1992). In well supported high school and middle school classrooms, it appears that the dominant instructional model is closer to the college experience than to the type of experience expressed in science education reform documents (Hurd, Bybee, Kahle, & Yager, 1980; Reid & Hodson, 1987; Tobin, Kahle, & Fraser, 1990; Tobin, Tippins, & Gallard, 1994).

Inquiry is a complex idea and popular use of the term has led to multiple meanings. To establish a starting point for discussion, inquiry has at least two meanings as it relates to classroom instruction. Inquiry is a mode of instruction for teaching science concepts and is itself a topic of instruction. Students can both learning about inquiry and the nature of science as well as practice its use in learning about science. Schwab (1962) established the ground work for this discussion and it has been liberally included in the draft National Science Education Standards (NRC, 1994). When students are practicing inquiry, there is thinking associated through overt manipulative activity as well as thinking through covert mental activity. The classroom environment is infused with a "substantial component of doubt" (Schwab, 1962, p.) concerning the ideas and problems under investigation. In short, students are expected to question all aspects of the instructional content.

When observing classrooms, even ones that are considered to be effective, the dominant mode of instruction is one that emphasizes order and control and material to be covered (Gallagher & Tobin, 1987). Observations of exemplary science teachers also suggest significant managerial skill while promoting the active participation of students. The atmosphere is conducive to inquiry as well as structured and focused feedback (Tobin & Fraser, 1990). It might be inferred from this brief sketch that highly skilled teachers manage both kinds of instruction, teacher control and active inquiry, very likely at the same time.

The rhetoric surrounding inquiry-oriented teaching has typically cast teacher-controlled, more linearly organized instruction in pejorative terms. Standard euphemisms for explicit forms of instruction include "traditional" or "textbook" approach. The issues that have been solved by exemplary science teachers are obscured by characterizations of instruction that arbitrarily place one form against another (Good & Brophy, 1994). To illustrate this point, below are two contemporary descriptions of instruction. The passages cast the teacher in two very different roles. While it was not the intent of either set of authors to exclude other forms of instruction in the full context of the source documents, these excerpted descriptions typify contrasts that are often highlighted in research on inquiry that often mask fundamental issues teachers must face when working in the complex environments of classrooms.

"Our vision of problem-centered learning begins with students who are motivated to learn and teachers who see their roles in terms of facilitating learning. It begins with teachers understanding the rationale for implementing the curriculum as they do and reflecting as they implement the curriculum. Teachers negotiate with students, asking questions to elicit thinking about the viability of knowledge representations, arranging students together so that they can argue toward consensus, and pointing the way to additional learning resources. To the students, the teacher is a mediator, guide, provocateur, friend, and colearner" (p. 47, Tobin, Tippins, & Gallard, 1994).

"(Effective) teachers accept responsibility for teaching their students. They believe that the students are capable of learning and that they (the teachers) are capable of teaching them successfully. ... These teachers actively instruct - demonstrating skills, explaining concepts and assignments, conducting participatory activities, and reviewing when necessary. They teach their students rather than expecting them to learning mostly from interacting with curriculum materials on their own. ... Following active instruction on new content, these teachers provide opportunities for students to practice and apply it. They monitor each student s progress and provide feedback and remedial instruction as needed, making sure that the student achieve mastery" (pp. 376-377, Good and Brophy, 1994).

At a theoretical level, these descriptions contrast two different perspectives of research on teaching, the former going by the name "constructivist" and the latter by the name "active" or "explicit" teaching. The constructivist perspective places the learner at the center of the educating process that focuses on an epistemology of the student as active builder of concepts from a variety of inputs. The active-teaching perspective places the teacher at the center of the educational process directing the major activities of the classroom. When considering these two perspectives, an important question for teachers is to figuratively ask, Where do they stand relative to their students?

At a practical level, the two passages present instruction aimed at two different types of goals. Tobin et al. (1994) describe students and teacher engaged in inquiry by arguing, debating, and consulting resources. Good and Brophy (1994) describe teacher behaviors specifically designed to help students achieve mastery over the use and application of particular information or skills. Practical questions for teachers are, Do I explicitly teach selected science knowledge and skills? How does inquiry fit into the process? What are appropriate models of teaching behavior that connect the two kinds of instruction?

A further distinction between the two passages is that the constructivist passage is a description of how students learn and conditions for learning. The active-teaching passage describes what teachers do to achieve particular results. One result of putting these two perspectives in opposition is that authors mix discourse about learning theory with discourse about instructional design theory. Instructional design theory is concerned with what a teacher does and must include specific instructional method variables. Learning theory is concerned with mental representation, memory, reasoning, and other inferred mental processes. The distinction is important because instructional design theory directs teachers to emphasize particular variables that have been operationalized in research. Operationalizing learning theory research for the classroom is much less obvious and must be worked out by the teacher (Reigeluth, 1983).

Consequently these two descriptions also highlight the fact that research on teaching of necessity lags behind research on how children learn. While significant advances in cognitive science have improved understanding of learning (Penner et al., 1993; Gardner, 1991; Resnick, 1991), "much of the research directly addressing questions of instruction has remained untouched by the revolution in cognitive science" (Romberg & Carpenter, 1986, p. 851).

Purpose

Achieving national standards for science education for all students requires that the research agenda for inquiry-oriented instruction be well informed by current knowledge of successful and unsuccessful teaching practices in typical classrooms. Given the persistent lack of data about the nature of teacher behavior in inquiry-oriented teaching and given the significant effects of explicit teaching methods for certain objectives for some students, research on inquiry-oriented teaching is reviewed against a background of explicit teaching research. The purpose is to achieve a productive synthesis.

Explicit Teaching Research with Implications for Inquiry-Oriented Instruction

To this point both "explicit" and "active" have been used to refer to the mode of teaching that has been contrasted with inquiry forms of teaching. For the rest of the paper this mode will be called "explicit teaching." The research base derives from and extends the process-product studies of the 1960's and early 70's (Brophy & Good, 1986).

Two decades of research on explicit teaching have produced instructional principles that have been effective in teaching specific concepts or skills mainly in mathematics and reading. The components of effective teaching "include teaching in small steps with student practice after each step, guiding students during initial practice, and providing all students with a high level of successful practice" (Rosenshine, 1986, p. 62). Rosenshine (1986) points out that these principles of explicit teaching are "most important for young learners, slow learners, and for all learners when the material is new, difficult, or hierarchical" (p. 62). For older and more capable students or when the foundations for the instructional unit have been established, instructional steps become larger and students can be expected to engage in more independent work.

Rosenshine and Stevens (1986) provide and extensive discussion of the research supporting explicit teaching. They offer a list of nine principles for the effective teaching of well structured subjects that is abbreviated here:

1. Review previous and prerequisite learning.
2. Clearly state learning goals.
3. Present new material in small steps.
4. Give clear and detail instructions and explanations.
5. Provide high levels of active practice for all students.
6. Ask large numbers of questions and obtain responses from all students.
7. Guide students during initial practice.
8. Provide systematic feedback.
9. Provide explicit instruction for independent practice and continually check for understanding.

The research paradigm for this body of work has been to study teacher behaviors that correlate with student achievement. Often, student achievement was measured by standardized tests that arguably did not validly measure desired outcomes of instruction. Improvement came with the establishment of research criteria that captured more valid connections between teacher behaviors and student outcomes. These methodological guidelines are helpful in relating explicit teaching research to issues of inquiry teaching. Rosenshine and Furst (1973) outlined the important considerations as follows: (a) attend to the cognitive rather than affective aspects of teaching as they are most likely to influence learning, (b) insure tests reflect the content taught, (c) create more complex and varied coding systems, (d) attend to sequences of events rather than isolated behaviors, (e) tailor observation systems to the subject matter and context, (f) sample typical behaviors of teachers rather than those that may be induced by the study, and (g) develop a richer bank of data to facilitate interpretation of findings. While these criteria derive from a decidedly quantitative and behaviorist perspective, they foreshadow and overlap similar criteria used in more qualitative and constructivist perspectives in current studies of inquiry teaching. Contemporary qualitative studies are heavily focused on cognitive aspects of teaching and learning that seek representations of instructional outcomes that reflect the objectives of instruction. Qualitative observations attend to the specific context and attempt to capture typical activity. However, constructivist-based research has tended to place greater significance on student thinking and less on teacher activity. The result is that teachers seeking to implement constructivist-based strategies for inquiry-oriented teaching are faced with working out how that is to be done.

This brief review of explicit teaching research will draw heavily from Wittrock (1986) and focus on research on teacher behaviors and teaching functions to inform discussion about inquiry teaching.

A major question for science teachers concerns how to stimulate the growth of a knowledge base that will derive from as well as support in-depth study necessary for inquiry-oriented instruction. Explicit instruction is suitable for factual aspects in science and for teaching specific skills. It would be unwise to have students inquire into how to use a microscope and inefficient for them to "construct" all the systematic detail in the Periodic Table of Elements. Explicit instruction is less suitable for direct application to problem solving, open-inquiry, and development of creative products or responses (Rosenshine & Stevens, 1986). Research on inquiry instruction tends to emphasize problem-solving and creativity to the near exclusion of how to address the systematic and hierarchical parts of science.

Math educators have examined the balance of time devoted to development (explicit teaching and guided practice) and time devoted to independent practice. Teaching methods which utilized at least 50% of the time for development activities were more effective in generating long-term retention than those where development was less (Good, Grouws, & Ebmeier, 1983). Extended development involved high levels of interactions with students to check understanding and increased practice that produced greater fluency. With high levels of feedback, errors are less threatening and can be used to enable rather than inhibit further practice.

Good and Grouws (1987) designed an inservice program for 4th grade teachers especially designed to overcome some of the obstacles involved in changing complex teaching behavior necessary for developing concepts in mathematics. The model of instruction targeted by the inservice was intended to foster meaningful acquisition of concepts by relating the new knowledge to students' previous ideas through increased instructional time devoted to development, that is "that portion of the lesson devoted to increasing comprehension of skills, (and) concepts..." (p. 780). The inservice helped teachers design instruction that attended to: (a) prerequisite knowledge or skills, (b) the connectedness of mathematical concepts, (c) representations of concepts, (d) generality of concepts, and (e) important terminology. Teachers were presented with these criteria in parallel with an instruction/management strand that offered opportunities for designing lessons, receiving feedback based on the criteria, and ample discussion of various approaches and supporting research. The inservice training was evaluated by classroom observations which showed increased proportions of time devoted to development by nearly all of the 16 teachers. Student achievement also increased as measured by standardized tests and specially constructed tests.

This study is useful for examining the role of relatively explicit instruction in addressing instructional goals of concept development and understanding.

Demonstrations are common in science teaching. They are often used in the context of a lecture-discussion to make concrete some ideas presented abstractly in the text and in lecture. Demonstrations have come under attack for a close association with the lecture mode of instruction that does not recognize the importance of ongoing student thinking and the need for verbal interaction with ideas and physical interaction with materials to support meaningful learning. However, demonstrations can serve the important function of modeling where the more capable learner or teacher provides a cognitive or even instrumental scaffold that supports learning in other students who would not be able to accomplish the tasks on their own (Vygotsky, 1978).

Explicit demonstration of comprehension strategies has become an important part of teaching models in reading for higher level thinking (Rosenshine & Stevens, 1986). Teachers have been urged to promote higher order thinking by asking more difficult questions but students have received little guidance as to how to answer such questions. Instruction in reading comprehension has progressed as understanding of integrative mental processes and metacognitive behavior has improved (Resnick, 1987). An example of this progress is the reciprocal teaching model of Palincsar and Brown (1984). The model itself demonstrates a synthesis between explicit teaching principles and contemporary research on student thinking. The theory and practice of reciprocal teaching has implications for examining teacher behavior and teaching functions designed to develop inquiry-oriented thinking.

Reciprocal teaching is a process of the teacher modeling a comprehension strategy, teacher and student performing the strategy together, and finally the student performing the strategy independently. Palincsar and Brown (1984) identified comprehension skills from the literature and focused on four concrete activities that could be taught to students: summarizing, questioning, clarifying, and predicting. These activities were assumed to embody the metacognitive skills important to comprehending text. As such, reciprocal teaching constitutes a general strategy and appears context free, however, the research materials used expository passages from social studies and science.

The Palincsar and Brown (1984) study, while based on recent cognitive learning theory, utilized principles of explicit teaching in the design of the method. Reading excerpts were broken down into small parts to minimize frustration of poor readers. The strategy provided ample guided practice with immediate feedback that generated high levels of success with all students. In this way, the teachers are able to observe behaviors that had specific inferred connections to cognitive and metacognitive activity. This study represents an example of how research can operationalized teaching functions for developing higher order abilities in students.

In their review of reciprocal teaching, Rosenshine and Meister (1994) discuss three instructional approaches for teaching cognitive strategies. The original study of Palincsar and Brown (1984) defines the first approach described above. All instruction in cognitive strategies takes places during reciprocal teaching dialogues between teacher and students. In the second form, cognitive strategies are explicitly taught before the dialogues. In the third form, described as general cognitive strategy instruction, students are explicitly instructed in the strategies and the support is gradually withdrawn during practice without any reciprocal teaching framework.

All three approaches have the following set of instructional features: modeling, teacher-controlled scaffolds, guided student practice, regular student responses, teacher feedback for responses, and diminished teacher and peer support as students gain competence. All reviewed studies attained significant effects especially when measured by researcher-designed instruments (Rosenshine & Meister, 1994).

A study by Anderson and Smith (1984) concerning student comprehension of science text contrasts with Palincsar and Brown (1984) and serves as a convenient transition to considering research on inquiry-oriented science instruction. The case study approach of Anderson and Smith (1984), which examined learning of science concepts, shifts the emphasis from research on specific learning goals for students to research that describes processes of teaching (Calfee & Drum, 1986). Fifteen fifth-grade teachers presented either a physical science unit on light from a didactic text or a life science unit on photosynthesis from SCIS (Science Curriculum Improvement Studies) materials that require students to conduct investigations during inquiry-oriented instruction. Students were pre and post-tested concerning information contained in the respective unit.

After instruction, a small percentage of students understood the post-test material. For example, of the 200-plus students tested on the nature of light transmission, fewer than 25% understood a 100-word passage about the nature of light. The authors contended that the problem was not in the text but in preformed mental schema students had about the nature of light or how plants get their food. The treatment phase involved rewriting appropriate sections of the teacher materials to include information about the most common student preconceptions. The authors revised the teaching objectives to include contrasting preconceptions with the scientific perspective and presented a teaching strategy for bringing about conceptual change toward the scientific view.

Understanding of both the didactic text unit on light and the inquiry-oriented unit on photosynthesis improved as a result of the altered objectives, modified materials, and teaching strategy. The study was criticized for its assumption that the text used in the pre and post-tests were not at fault. Calfee and Drum (1986) argued that the clarity and explicitness of the text samples was in question in that they did not explicitly state information specific to the assumed preconceptions. For instance in the light unit, the authors assumed that the problem was preconceived notions about the nature of sight that do not include the idea that seeing is the detection of light waves by the eyes. The sample text dealt only with the nature of light and therefore students were not cued to think about the nature of sight. The study appeared to achieve its effects by having the teacher foster a direct confrontation of student preconceptions rather than improve the explicitness of the written communication.

This study offers one further contrast between explicit and inquiry-oriented instruction. The authors felt that the inquiry-oriented SCIS unit made conceptual change more difficult because student investigations allowed for more ambiguous interpretations that may not stimulate student questioning of their own preconceptions. Both the didactic (or explicit) method and the inquiry method were defined as such by the nature of the materials used by the teachers and not specific teacher methods. The study focused on adjusting curriculum and infusing objectives and a strategy into established teacher behavior. This raises the question as to what the teachers were actually doing.

A later analysis of these case studies (Roth, Smith, & Anderson, 1984, pp. 286-287) identified general principles upon which to base conceptual change teaching:

1. Teachers need to be sensitive to their student's misconceptions, and they need to continually consider how these misconceptions are influencing students' responses to instruction.
2. Teachers need to focus what they say and what their students are saying on the "whys" of science.
3. Teachers need to know more than just what questions to ask; they also need to now how to respond to student statements.
4. There must be a balance between open-ended verbal interactions and directed, structured discussions that lead to closure and consensus.

This outline of a conceptual-change strategy contrasts with the explicit-teaching strategies cited above. The conceptual change strategy outlines what teachers need to know and should be thinking about while explicit-teaching strategies outline what teachers are to do. The discrepancy between these two different types of "teaching model" outlines can be described in terms of differences between the underlying theories. Explicit teaching strategies are based on instructional design theory which relates teaching models to desired outcomes through a set of required conditions. Inquiry-oriented strategies are based on learning theory which describes or explains mental processes in the student (Reigeluth, 1983). The problem with implementing research-based, inquiry-oriented practice in classrooms occurs when teachers recognize that the operational features of a proposed inquiry model based primarily on learning theory have not be worked out in the research. The following questions might be raised about the Roth, et al. (1984) model:

- How does a teacher show sensitivity to student misconceptions?
- What techniques can a teacher use to reveal how student misconceptions are influencing their responses?
- What are strategies for responding to student statements that promote deliberation about their own ideas?
- How does a teacher recognize that there is a balance between open-ended verbal interactions and directed discourse that leads to consensus?
- How does a teacher relate consensus to the target science concepts so that students recognize that there still are differences?

Research on Inquiry-Oriented Instruction

This section concerns studies that have investigated instruction on inquiry teaching. The guidelines for selecting studies focused on those that were most likely to contribute to understanding of inquiry teaching practice in typical middle or high school classrooms. The guidelines included the following:

- The study has direct implications for normal school populations which would exclude most clinical studies and studies with special populations.
- The teacher normally assigned to the classroom was involved in delivering the instruction as part of a normal teaching load.
- Classroom support for instruction was commensurate with normal classroom instruction and would exclude special arrangements where the classroom teacher is freeded from many responsibilities or provided special equipment drastically changing the normal classroom environment.
- The teaching model was defined and monitored during the study to assess the validity of the treatment.
- Evaluation of teaching was based on data closely associated with the classroom context and specific content of instruction.

The selection process involved a systematic search of the ERIC system using the descriptors Teaching Methods, Inquiry, Laboratory, Higher Order Thinking, Problem-Solving, High School, Middle school. Elementary classrooms were eliminated from this review because the structure of teaching in self-contained settings is considerably different and should be reviewed from a perspective oriented toward that setting. The nature of inquiry and teaching objectives are necessarily different to account for differences in development and would require a perspective on inquiry different from the one taken in this review. The search was also limited to reports published in journals under the rationale that the peer review process is a critical step in shaping and sharpening descriptions and results in this complex area of study. Lott's (1983) meta-analysis of inquiry teaching and advance organizers pooled 39 studies from a initial population of 151. Of the 39, 36 were dissertations and six from published reports. Most of the studies had very limited description leading to the elimination of half of the student characteristics, 30% of the treatment characteristics variables, and all of the teacher characteristics.

The review data set involved 18 empirical studies and nine reviews of the literature. No one study uniformly met all the guidelines. This was in part due to the extremely complex nature of "inquiry-oriented instruction" as an instructional design construct. The language describing inquiry teaching used in the literature is closely associated with language related to problem-solving and conceptual change. This was incorporated into the ERIC search strategy. In addition, inquiry teaching is closely associated with a variety of other teaching strategies being studied in their own right including laboratories and small group instruction, such as cooperative learning groups. The difficulty of achieving a clear focus in the literature for what constitutes inquiry-oriented instruction highlights the major concern of the current review: the contradiction between the repeated recommendation of inquiry teaching and its rare occurrence in classrooms. It also reinforces the need for researchers to more clearly define instructional modes and stop relying on an artificial and poorly understood dichotomy between "inquiry" and "traditional" instruction.

As a map to the territory of this review, Table 1 and Table 2 outline the design of the studies reviewed and their educational context respectively. Qualitative studies dominate the landscape of research on classrooms reflecting the difficulty of quantifying meaningful variables for complex teaching. Brophy and Good (1986), reviewing research in the 1970's, demonstrated the difficulty of capturing "direct" and "indirect" teacher behavior with Flanders Interaction Analysis Categories and the problem remains today. The correlational study of teacher behavior and student tasks by Blumenfeld (1992) represents a significant advance in studying complex teaching behavior. In maintaining a focus on intact classrooms, Table 1 lists studies of one classroom, taught and studied by the teacher-researcher (Roth, 1994), to an analysis of over 3000 students representing as many as 100 classrooms (Gallagher, 1994). This range highlights the tradeoff between studying a teaching method in detail but with limited external validity and documenting more generally valid effects of a vaguely specified methods across a broad range of classrooms. Teaching methods were both defined in advance and observed across well defined variables (Blumenfeld, 1992; Toh & Woolnough, 1993) and described as a result of the study (Tamir, 1977; Gallagher & Tobin, 1987; Tobin & Fraser, 1990). Verification of teaching method ranged from none in the structural modeling studies (Gallagher, 1994; Germann, 1994) to direct observations of classrooms (Keys, 1994; Westbrook & Rogers, 1994).

Table 2 categorizes the context of instruction in order to evaluate the potential for knowledge about ordinary classrooms. In addressing science education standards that state all students will both learn *about* scientific inquiry and learn science *through* inquiry (NRC, 1994), science educators need to understand the nature of desired teaching across a variety of classrooms. The sample of studies represents classrooms from late elementary to early college with most of the classrooms studied between the 8th and 11th grades. Gender distribution was not always described (noted by a ? in the table) but an estimate of "equal" is noted where it seem justified by other description. Student ability and socio-economic status (SES) of students in England has been shown to be significant in studying the effects of teaching methods and curriculum on student achievement in science (Reid and Derek, 1987). In this country Brophy and Good (1986) review studies showing that positive teacher affect, teacher controlling behaviors, and drill/recitation are more functional for low SES students than for high SES students. Description of student SES and ability was not always sufficient to categorize, but judging from those studies where a determination was possible, disadvantaged students are rarely studied. Likewise, low ability students receive less attention than high ability students. Notable exceptions are Brown and Campione (1994) and to a lesser extent Jones and Carter (1994) and Cater and Jones (1994). Also of concern to anyone wishing to study broad application of complex teaching strategies is the matter of teacher ability and teacher support. In examining the use of inquiry methods in a broad group of studies, Welch et al. (1981) noted that inquiry forms of teaching were especially sensitive to teacher skill and the level of classroom support. Consequently, Welch et al. (1981) concluded that inquiry teaching may not be suitable for all classrooms. Table 2 shows that authors do not often describe the level of support available to teachers. Where it is mentioned, teachers are well supported with equipment, curriculum materials and even teacher aids and research assistants (Roth & Roychoudhury, 1993). Generally researchers have chosen teachers with strong backgrounds and successful experience. This survey of the literature supports the Welch et al. (1981) conclusion but does not discount other possibilities given a better understanding of the nature of inquiry-oriented teaching. Good examples of work that explored important dimensions of classroom dynamics that support instruction for higher cognitive involvement are Blumenfeld (1992) and Brown and Campione (1994). Their work with the late elementary and early middle school student needs to be continued with older students.

Inquiry Teaching in Typical Classrooms

Schwab (1962) wanted the school laboratory to be a place where students would experience a variety of problem-posing situations. He wanted labs to offer opportunities for miniature scientific investigations. To that end, he proposed that lab manuals present problems at three levels for the purpose of developing an orientation to inquiry. These levels were later codified by Herron (1971) for use in evaluating inquiry instruction. At the first level, the manual presents problems, not already discussed in the text, with descriptions of different ways to approach the solution. At the second level, problems are posed without methodological suggestions. The third level presents phenomena designed to stimulate problem identification. Each level assumes greater background knowledge and skill in students and, assuming that the students don't already have this background, greater effort and skill in the teaching of these students. Schwab translated scientific inquiry into educational terms but the role of the teacher had to wait for a further analysis of the classroom.

Rowe (1973) described the means by which teachers prepare students for learning science <u>through</u> inquiry and science <u>as</u> inquiry. Rowe outlined specific components of inquiry which should guide teachers in their stimulation of student thinking and sequencing of instruction. The model began with problem identification and ended with applying newly learned concepts to novel situations. Like Schwab (1962), Rowe (1973) placed the examination of problems at the beginning of instruction for inquiry. However, unlike the highly capable high school students in Schwab's context, Rowe recognized that with younger and more inexperienced students, the teacher would need to stimulate awareness of problem settings. Scientific inquiry applied to more typical students would require attention to the importance of gathering information and being critical of methods. In addition, teachers should prompt students to critically examine information for relationships and in the skills of making inferences and forming interpretations. With this general structure for inquiry in the classroom in mind, we now turn to what two to three decades of thought and practice has taught us about inquiry in classrooms.

Welch et al. (1981) examined four national programs in inquiry teaching and described the desired state of inquiry in school science in terms of three themes: (a) process skills, such as observing and interpreting data, (b) scientific inquiry, for example, conclusions being tentative and verifying observations, and (c) general inquiry, such as logical and analogical reasoning and reasoning from evidence. Contemporary research in social cognition (Resnick, 1991) would add to this list of ideal characteristics processes for promoting social interaction. Finally, research on learning has shown that existing conceptions about the world are a powerful influence on student thinking within the context of science instruction (Penner et al., 1994). Inquiry-oriented instruction would ideally include processes for interacting with a wide variety of ideas generated by students.

In summary, the application of scientific inquiry translated into the classroom involves the following components from the perspective of what the teacher must be able to do: (a) methods for presenting content in the form of problems that will stimulate selected aspects of inquiry, (b) modeling or demonstrating inquiry, such as the one proposed by Rowe (1973), that includes problem identification, the collection and interpretation of information, and possibly application of the results to new situations, (c) determining skills needed for designing, implementing, or evaluating hands-on investigations, (d) establishing skills and procedures for students to interact in small groups for the purpose of generating, sharing, or interpreting information, or for practicing skills or knowledge, (e) procedures for facilitating the interaction of existing student knowledge or misunderstandings with the new content or problem, and (f) methods for teaching specific knowledge, process skills, or group skills.

In terms of classroom practice, the literature offers the most information concerning the handling of classroom tasks, interacting in small work groups, and procedures for facilitating the interaction of existing student knowledge.

Classroom Tasks

Classroom tasks refer to non-lecture activities that range from individual seat work to hands-on laboratory activity. Hands-on laboratory work has been described as the most "distinctive feature of science instruction" (Shulman & Tamir, 1973, p. 1118), but there are many activities clustered around the actions of manipulating materials during labs. These include making charts, graphs, answering questions, writing reports or descriptions, and general discourse. Inquiry teaching challenges teachers to manage these tasks in optimal ways.

Hofstein and Lunetta (1983) reviewed research on laboratory work and found it lacking in information that would guide teacher practice in the classroom-lab. Researchers often worked with comparatively small groups of students of limited diversity that ignored significant subsets of students such as low SES students, those who are less able or those with traditionally low motivation. They often used standardized tests that were not designed to measure effects produced by labs. Most did not examine teacher behavior, classroom learning environment, and teacher-student interactions. In short, the reader did not get a clear picture of what was actually going on in the classroom. The materials themselves were often not clearly described so that the reader was not informed about the instructions and information presented to students.

More recent work has tended to focus on the upper range of student ability (Roth, 1994; Cavallo & Schafer, 1994; Sanford, 1987) and average to small classrooms (< 26) (Roth & Roychoudhury, 1993; Keys, 1994). Under ideal conditions small, well supported classrooms with motivated students, teachers with sufficient science and teaching backgrounds can achieve significant results by being a guide or advisor and keeping a low profile (Roth & Bowen, 1994; Roth and Roychoudhury, 1993). However, these studies apply to a relatively small percentage of U.S. classrooms and do not offer clear guidance for teachers with less than ideal teaching conditions

Conditions important to inquiry may be lost where teachers provide a variety of safety nets that lower cognitive demands in an attempt to engage more students and maintain interest and motivation. Sanford (1987) observed four high school teachers, two in general science and two in honors biology, and made a qualitative analysis of their management of classroom tasks. Teachers often felt compelled to reduce the grade value of a task when students are having difficulty or offer a series of hints that lead students to the desired answers. This had the effect of leading students to expect more instruction at the beginning of the project rather than later when they would have had to think over the problem on their own.

Gallagher and Tobin (1987) observed 15 teachers from elementary to high school over a 14 week period to assess teacher and student engagement. The students were considered to be at least average and there was adequate support for teaching science. Labs tended to be handled more informally than lecture-discussion sessions with more student socializing allowed. The teacher seemed to maintain a relaxed atmosphere by focusing on procedural matters and lower the inquiry-orientation of the tasks. There was a general sense by both teachers and students that the job was to get things done. These attitudes and behaviors contrasted with teachers identified as exemplary. Tobin and Fraser (1990) made eight observations each of 20 exemplary teachers. Their practice with respect to student tasks also involved a relaxed atmosphere but this was achieved by making instructional goals clear and structuring activities for overt student engagement. The teachers actively monitored students but reinforced the goal of learning for understanding. This required providing time and opportunity for students to elaborate, clarify, summarize, and to react to other students. The teachers gave clear feedback on incorrect answers, but made the atmosphere safe for making mistakes and stating a point of view.

Blumenfeld (1992) conducted an in-depth study of instructional tasks and how teachers maintained an attitude of thoughtfulness in science. Sixty tasks were observed in 10 classes taught by five teachers at the 5th and 6th grade levels. Tasks were rated across two dimensions: product (cognitive level, form of product, length) and social organization (small or large group). Teachers were selected from those who did hands-on activities and who had superior math and science backgrounds by elementary and middle school standards. Researchers administered measures of motivation and active learning after each of the 60 tasks. The active learning measures were higher for two of the five teachers. Comparison of teacher behavior between these two groups revealed several marked differences. Teachers who fostered more active learning minimized the number of terms and facts to be remembered and modified published worksheets to include higher level cognitive items. These teachers also consistently and repeatedly maintained a focus on the main point and related facts to concepts and pointed out relationships. The whole class was engaged in responses through frequent questioning that produced high levels of success. They modeled thinking procedures and provided explicit directions for group work. Risk-taking and mistakes were valued and used in creating new learning episodes.

Teachers who engendered less active learning from their students did many of the same things as the more successful teachers but often clouded the main points. For instance, they would ask synthesis questions that were too hard for students and spent insufficient time relating new information to student knowledge. They allowed the text to carry too much of the discussion and told students what they were to learn from assigned tasks. Like the Sanford (1987) and Gallagher and Tobin (1987) teachers, these teachers repeatedly reduced cognitive demand by changing deadlines and de-emphasizing grades. Assessment was public and competitive and emphasized correctness. Student responses were often perfunctory.

The design and use of instructional tasks, especially with manipulative, laboratory-like materials are both a defining feature of science instruction and produces the greatest challenge. As with the Good and Grouws (1987) inservice study, teacher skills for maintaining appropriate levels of cognitive demand must parallel skills for managing diverse learners with varying levels of interest and background knowledge and skills.

Small Group Work

Another feature of active teaching in inquiry settings is the use of small groups of students. Teachers use small groups to stimulate discussion, increase interaction with materials, distribute responsibility for functions of activities, and to distribute expertise around the class. These teacher actions are particularly common in l oratory settings or during hands-on activities in science. It is important to understand particular teacher functions in these situations.

Teachers must regularly give instructions, explain routine procedures, list factual material, or review assigned reading that must be recalled later. Understanding has been shown to be improved when small groups are structured with assigned roles and scripts for the purpose of reviewing, rehearsing, and discussing the information (Cohen, 1994). These effects are derived most likely from increased engagement and level of discourse of all students and focused engagement through assigned roles of particular students.

Many inquiry-oriented activities are designed to engage students in higher order thinking to address more open-ended problems. In order to foster this type of interaction, instruction needs to be informed by knowledge of higher order thinking which have implications for structuring small group interactions. Features of higher order thinking were outlined by Resnick (1987) and include: (a) Nonalgorithmic - the path of action is not fully specified in advance, (b) Complexity - the total path is not (mentally) visible from an single vantage point, (c) Multiple Solutions - each with costs and benefits, (d) Application of Multiple Criteria - which sometimes conflict with one another, (e) Uncertainty - everything that bears on the task at hand is not known, (f) Self-regulation of Thinking Processes - we do not recognize higher-order thinking in an individual when someone else is directing most of the steps in the process, (g) Imposing Meaning - finding structure in apparent disorder, and (h) Effortful - considerable mental work is involved in elaboration and judgment. The teacher who provides too much structure when the task is by design ill-structured and requiring innovation, may defeat the inquiry value of the activity. Cohen (1994) states a subtle but important dilemma for teachers that has implications for conducting small group instruction in science. If teachers do nothing but supply the task, the students may stick with mundane or concrete aspects of the problem without exploring the more abstract and presumably more meaningful aspects. If teachers do too much by assigning roles and responsibilities, they may prevent opportunities for students to express novel approaches or ideas.

Work in well-supported science classrooms with highly capable students and highly trained teachers suggest that students need very little structure for carrying out productive small group tasks. Roth (1994) studied his own physics class in an all male, private school. This study is highly similar to other studies by the same author and associates, presumably in the same school, of physical science classes which in some cases involved other teachers (Roth & Roychoudhury, 1993; Roth & Bowen, 1994) Students were provided some orienting discussion about a general topic in physics and the time and materials to conduct investigations. Utilizing qualitative observations based on video tapes, student products, and field notes from his time in the classroom, he developed a detailed description of student investigative process. These students identified problems, participated in narrative descriptions to identify variables and strategies, learned about physics topics in context by asking for help and receiving it, and cooperatively carrying out the work. Roth claimed that the fact that these students actively raised inquiry-oriented questions and planned and implemented investigations presents a "marked contrast" with other studies that suggest students have trouble engaging in this type of instruction. The contrasts between Roth's classroom and typical classrooms are many. What is not clear from this work is the kind of teacher activity that is part of this classroom. As was stated by Schulman and Tamir (1973) concerning early claims for the value of inquiry in science classroom "we have little idea" (p. 1118) what the teacher is doing to bring about these effects. Reluctant, disorganized, or distracted students are challenges for all teachers. But, classroom problems can be magnified by active, small group instruction with complex tasks deemed important for instruction in science. For example, Blumenfeld (1992) noted that otherwise capable teachers often confused the main point of classroom tasks which resulted in less active learning opportunities.

Jones and Carter (1994) examined the verbal behavior of student dyads working with materials for developing understanding of balance beam concepts. The dyads were structured by ability as high-high, low-low and high-low and observed during classroom instruction. The authors stipulate that they are using ability and achievement synonymously in this situation and designated high achievers as those scoring in the top 25% of a the California Achievement Reading Test (CAT) and low achievers as those scoring in the bottom 25%. Average students were not used in this study. The focus of the classroom observations was on student behavior rather than teacher interactions with students. However, we can derive implications for teacher behavior and teaching functions be considering the results of this structured intervention. Three, experienced, fifth grade teachers from large, urban elementary schools volunteered for this study. The intervention involved three classes from each teacher. From aptitude test scores, students were placed in dyads through stratified random sampling. Each student was pre- and post-tested individually with an instrument for assessing lever concepts developed by one of the authors and observations were made over two, 55-minute periods.

Observations were made on a stratified sample from each type of dyad, totaling 30 students, to describe the small group work environment. Low-low dyads were usually dysfunctional because they were not able to approach the tasks with the overall problem clearly in mind. This led to competition for equipment and considerable off-task behavior as members focused on different aspects of the problem. The high-high dyads focused directly on the goals of the task and proceeded in an efficient and organized manner. Competition for materials and time for discussion was managed by mutual assertiveness that created a successful checks and balance system for expressing and working on ideas. In high-low dyads, the high-achieving student provided support and modeling for the low-achieving student. On-task behavior for the low student was considerably higher than in the low-low dyad. It is not clear from the report how much specific guidance or practice for working in dyads was provided. Students were instructed to read instructions out loud together and to discuss their interpretations. They were also instructed to make specific predictions concerning the behavior of the balance beam.

Results of the concept post-test showed insignificant gains by students in low-low dyads but significant gains in the other two types of dyads. The gains of high students were the same regardless of their partners. These results argue for instruction that maintains a heterogeneous mix during instruction. The authors also note that from an outsiders point of view all students during this intervention would appear to have been on task. This assessment was contradicted by field notes and close observation showing that low-low dyads were regularly distracted and unproductive, seeming to be just going through the motions. A teacher structuring small groups for hands-on instruction would need to use active means of checking for understanding so that unproductive groups derive the desired benefits. However, the teacher risks diminishing the value of an inquiry-oriented task through too much supervision. Cohen (1994) concluded that teachers should restrain from direct supervision when conducting non-routine, problem-solving or inquiry-oriented tasks in small groups. One response to teachers who were afraid to delegate control, was to devise a program where teachers learned to systematically train students in cooperative group behaviors and to institute a system that coordinated small group work to reduce the volume of activity in the classroom (Cohen, 1994).

Summary

Research on explicit teaching has shown enormous gains in student achievement for selected kinds of instructional objectives and for certain kinds of students (Waxman, 1991). The high levels of teacher supervision implied by explicit teaching models may not foster the kinds of thinking required for instruction with complex and more ill-structured tasks. Research on inquiry-oriented instruction has produced mixed results with the clearest effects occurring with more capable students, who have well trained teachers, and a supportive classroom environment. Teaching in more typical classrooms made more complex because of diverse student backgrounds requires knowledge of teaching models whose components have been operationalized through research in typical classrooms. Much of the current work on inquiry teaching has focused more on student learning and less on how teachers structure the environment and interact with students to bring about maximum opportunities for that learning.

Research on learning is always going to lead research on teaching. With the growth in knowledge about learning and higher order thinking in the last two decades, the challenge is to design research on teaching that reflects current knowledge about student learning (Romberg & Carpenter 1986). However, research that uses the language of learning theory to make prescriptions for teaching skips the critical step of operationalizing the methodological variables that purport to affect learning. Studies that leave out this step require that teachers work out details of the model in the classroom. Consider the analogy of an accountant who reads a study that works out principles for implementing links between tax forms for the purpose of calculating personal income tax on a computer. However, the article provides no spreadsheet program for doing so. The accountant returns to the office with 50 returns to complete in two weeks and tries to implement these principles using a general spreadsheet and word processor. After making a couple of unsuccessful attempts and faced with impending deadlines, the accountant remarks, “It may work in theory, but not in the real world” and proceeds as he or she has always done.

Current teaching models for inquiry-oriented instruction provide a rough outline for blocking out instruction moves. For example, Rowe (1973) suggests that teachers raise questions that help students identify the problem to be investigated. Her model proceeds with the teacher erecting scaffolds for each step in the inquiry. The explicit form (Rosenshine & Meister, 1994) of Palincsar and Brown's (1984) reciprocal teaching model offers one possible approach for supporting a more general use of Rowe's model. This approach suggests explicit teaching of an investigation strategy (e.g. for identifying problems making observations, or drawing inferences) in the context of an investigation. The teacher engages students in dialogue that provides appropriate supports so that students can use the strategy. Students are gradually taught the strategy so that they can eventually be left on their own in small groups to carry out portions of an inquiry-oriented task. This example, is only one possibility for synthesizing knowledge on explicit teaching with knowledge on inquiry-oriented teaching in order to make complex forms of teaching and learning accessible to more students with more diverse backgrounds.

Westbrook and Rogers (1994) offer a recent example of classroom research where an inquiry-oriented model of instruction was closely examined because research had shown it to be unevenly effective. They describe the learning cycle model of instruction as first using activities for engaging students in the problem then followed by hands-on investigations that help students confront their existing understandings in the context of empirical evidence and introduction of science terms and concepts. The authors determined that most learning cycle studies over-emphasized processes for describing patterns in the evidence and under-emphasized the formation of explicit hypotheses about the phenomena under investigation. The research was focused on the design of a set of materials and did not directly address teaching. However, an implication of designing materials specifically for emphasizing hypothesis testing is that teachers may need to explicitly teach aspects of this model that they deem most important.

To make inquiry work for all, or at least a much broader range of students, it is necessary to identify particular problems for future research that will more clearly define the role of teacher in an inquiry classroom. An initial set of propositions supported by this synthesis of research to be tested in research on classrooms are:

- Inquiry-oriented instruction can be defined as teacher practices that foster student use of personal experience and schooled knowledge for generating new information, new problem-solving approaches, or new solutions that were not heretofore a part of the learning environment (Rowe, 1973; Schwab, 1962).
- Productive inquiry will depend upon student perception of whether the goal is about a particular correct answer or a more ill-structured and open-ended problem (Cohen, 1994; Lederman, 1992; Reid & Derek, 1987).
- Intrinsically interesting problems and appropriate materials are by themselves insufficient for promoting classroom inquiry for most students. Necessary teaching functions include specifically relating facts to concepts, highlighting the relationship of key ideas, and modeling thinking (Blumenfeld, 1992; Palincsar & Brown, 1984).
- The effectiveness of student control over their own inquiry is mitigated by lack of appropriate knowledge and/or skills, low status within their group, inadequate materials to support inquiry, and teacher reluctance to delegate authority to students (Cohen, 1994; Welch et al., 1981).
- Structured or explicitly supported inquiry can raise the level of discourse where students are young, slow learners, or the material is new, difficult, or hierarchical (Cohen, 1994; Blumenfeld, 1992; Rosenshine, 1986).

- Critical thinking about a topic of inquiry requires facility with facts, basic principles, and key procedures. Developing this facility requires explicit teaching methods for all but the most able students (Good & Brophy, 1994; Rosenshine, 1986).
- Where students have been trained to interact effectively as a group, critical thinking is improved by group interaction (Cohen, 1994).

References

Anderson, C. W. & Smith, E. L. (1984). Children's preconceptions and content-area textbooks. In G. G. Duffy, L. R. Roehler, & J. Mason (Eds.), Comprehension instruction: Perspectives and suggestions. New York: Longman.

Anderson, C. W. & Roth, K. J. (1989). Teaching for meaningful and self-regulated learning of science. In Brophy, J. (Ed.) (1989). Advances in research on teaching Vol. 1. Greenwhich, CN: JAI Press, Inc.

American Association for the Advancement of Science. (1993) Benchmarks for science literacy. New York: Oxford University Press.

Blumenfeld, P. C. (1992). The task and the teacher: Enhancing student thoughtfulness in science. In J. Brophy, (Ed.) (1989). Advances in research on teaching Vol. 3: Planning and managing learning tasks and activities. Greenwich, CN: JAI Press, Inc.

Brophy, J. & Good, T. L. (1986). Teacher behavior and student achievement. (pp. 328-375). In M. C. Wittrock, (Ed.) Handbook of research on teaching, 3rd edition. New York: Macmillan Publishing Company.

Brown, A. L. & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly, K. Classroom lessons: Integrating cognitive theory and classroom practice, pp. 229-270. Cambridge, MA: The MIT Press.

Calfee, R. & Drum, P. (1986). Research on teaching reading, (pp. 804-849). In M. C. Wittrock, (Ed.) Handbook of research on teaching, 3rd edition. New York: Macmillan Publishing Company.

Carter, G. & Jones, M. G. (1994). Relationship between ability-paired interactions and the development of fifth graders' concepts of balance. Journal for Research in Science Teaching, 31, 847-856.

Cavallo, A. M. L. & Schafer, L. E. (1994). Relationships between students' meaningful learning orientation and their understanding of genetics topics. Journal of Research in Science Teaching, 31, 393-418.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. Review of Educational Research, 64(1), 1-35.

Costenson, L. J. & Lawson, A. E. (1986). Why isn't inquiry used in more classrooms. The American Biology Teacher, 48, (3), 150-158.

Gallagher, S. A. (1994). Middle school classroom predictors of science persistence. Journal of Research in Science Teaching, 31, 721-734.

Gallagher, J. J. & Tobin, K. (1987). Teacher management and student engagement in high school science. Science Education, 71, 535-555.

Gardner, H. (1991). The unschooled mind: How children think and how schools should teach. New York: Basic Books.

Germann, P. J. (1994). Testing a model of science process skills acquisition: An interaction with parent's education, preferred language, gender, science attitude, cognitive development, academic ability, and biology knowledge. Journal of Research in Science Teaching, 31, 749-783.

Good, T. L. & Brophy, J. E. (1994). Looking in classroom, sixth edition. New York: Harper Collins Publishers.

Good, T. & Grouws, D. (June, 1987). Increasing teachers' understanding of mathematical ideas through inservice training. Phi Delta Kappan, 778-783.

Good, T., Grouws, D., & Ebmeier, H. (1983). Active mathematics teaching New York: Longman.

Herron, M. D. (1971). The nature of scientific inquiry. School Review, 79, 171-212.

Hofstein, A. & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. Review of Educational Research, 52, 210-217

Hurd, P. B., Bybee, R. W., Kahle, J. B., & Yager, R. E. (1980). Biology education in secondary schools of the United States. American Biology Teacher, 42(7), 388-410.

Jones, M. G. & Carter, G. (1994). Verbal and nonverbal behavior of ability-grouped dyads. Journal of Research in Science Teaching, 31, 603-619.

Keys, C. W. (1994). The development of scientific reasoning skills in conjunction with collaborative writing assignments: An interpretive study of six ninth-grade students . Journal of Research in Science Teaching, 31, 1003-1022.

Lederman, N. L. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. Journal of Research in Science Teaching, 29, 331-360.

Lott, G. W. (1983). The effect of inquiry teaching and advance organizers upon student outcomes in science education. Journal of Research in Science Teaching, 20, 437-451.

Mulopo, M. M. & Fowler, H. S. (1987). Effects of traditional and discovery instructional approaches on learning outcomes for learners of different intellectual development: A study of chemistry students in Zambia. Journal of Research in Science Teaching, 24, 217-227.

National Research Council (1994). National science education standards, draft. Washington, D.C.: National Academy Press.

Palincsar, A. S. & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. Cognition and Instruction, 2, 117-175.

Penner, L. A., Batsche, G. M., Knoff, H. M, & Nelson, D. L. (Eds.). (1993). The challenge in mathematics and science education: Psychology's response. Washington, D.C.: American Psychological Association.

Reigeluth, C. M. (1 83). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), Instructional-design theories and models: An overview of their current status. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Reid, D. J. & Hodson, D. (1987). Special needs in ordinary schools: Science for all. London: Cassell Educational Limited.

Resnick, L. B. (1991). Shared cognition: Thinking as a social practice. In L. B. Resnick, J. M. Levine, & S. D. Teasly (Eds.), Perspectives on socially shared cognition. Washington, DC: American Psychological Association.

Resnick, L. B. (1987). Education and Learning to Think. Washington, D. C.: National Academy Press.

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.

Rosenshine, B. V. (April, 1986). Synthesis of research on explicit teaching. Educational Leadership, 60-69.

Rosenshine, B. & Furst (1973). The use of direct observation to study teaching. In R. M. W. Travers (Ed.), Second handbook of research on teaching. Chicago: Rand McNally.

Rosenshine, B. & Meister, C. (1994). Reciprocal teaching: A review of the research. Review of Educational Research, 64, 479-530.

Rosenshine, B. & Stevens, R. (1986). Teacher behavior and student achievement (pp. 376-391). In M. C. Wittrock, (Ed.) Handbook of research on teaching, 3rd edition. New York: Macmillan Publishing Company.

Roth, W-M. (1994). Experimenting in a constructivist high school physics laboratory. Journal of Research in Science Teaching, 31, 197-223.

Roth, W-M. & Bowen, G. M. (1994). Mathematization of experience in a grade 8 open-inquiry environment: An introduction to the representational practices of science. Journal of Research in Science Teaching, 31, 293-318.

Roth, W-M. & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. Journal of Research in Science Teaching, 30, 127-152.

Roth, K. J., Smith, E. L., & Anderson, C. W. (1984). Verbal patterns of teachers: Comprehension instruction in the content areas. In G. G. Duffy, L. R. Roehler, & J. Mason (Eds.), Comprehension instruction: Perspectives and suggestions. New York: Longman.

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

Sanford, J. P. (1984). Management and organization in science classrooms. Journal of Research in Science Teaching, 21, 575-587.

Sanford, J. P. (1987). Management of science classroom tasks and effects on students' learning opportunities. Journal of Research in Science Teaching, 24, 249-265.

Schwab, J. J. (1962). The teaching of science as enquiry. In J. J. Schwab & P. F. Brandwein, The teaching of science, Cambridge, MA: Harvard University Press.

Shulman, L. S. & Tamir, P. (1973). Research on teaching in the natural sciences (pp. 1098-1148). In R. M. W. Travers (Ed.), Second handbook of research on teaching. Chicago: Rand McNally.

Tamir, P. (1977). How are the laboratories used? Journal of Research in Science Teaching, 14, 311-316.

Tobias, S. (1992). Revitalizing undergraduate science. Tucson, AZ: Research Corporation.

Tobias, S. (1990). They're not dumb, they're different: Stalking the second tier. Tucson, AZ: Research Corporation.

Tobin, K. & Fraser, B. J. (1990). What does it mean to be an exemplary science teacher? Journal of Research in Science Teaching, 27, 3-25

Tobin, K. G., Kahle, J. B., & Fraser, B. J. (1990). Learning science with understanding: In search of the Holy Grail. In K. H. Tobin, J. B. Kahle, & B.

J. Fraser (Eds.), Windows into science classrooms: Problems associated with higher level cognitive learning. London: Falmer Press.

Tobin, K., Tippins, D. J., & Gallard, A. J., (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.). Handbook of research on science teaching and learning. New York: Macmillan Publishing Company.

Toh, K. A. & Woolnough, B. E. (1993). Middle school students' achievement in laboratory investigations: Explicit versus tacit knowledge. Journal of Research in Science Teaching, 30(5), 445-457.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes (M. Cole, V. John-Steiner, S. Schribner & E. Souberman, Eds. and Trans.). Cambridge. MA: Harvard University Press.

Waxman, H. C (1991). Productive teaching and instruction: Assessing the knowledge based (pp. 33-61). In H. C. Waxman & H. J. Walberg . Effective teaching: Current research. Berkeley, CA: McCutchan Publishing Corporation.

Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T. (1981) The role of inquiry in science education: Analysis and recommendations. Science Education, 65(1), 33-50.

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

Wittrock, M. C. (Ed.) (1986). Handbook of research on teaching, 3rd edition. New York: Macmillan Publishing Company.

Table 1 Context Characteristics of Studies on Inquiry-Oriented Teaching

	Grade Levels	Gender m - f	Student Ability	Socio-Economic Status	Class Size	Support for Instruction	Teacher Ability
Blumenfeld (1992)	5 & 6	equal	?	?	≈28	?	experienced with superior background
Cavallo & Schafer (1994)	10	equal	college prep	?	22	?	?
Gallagher & Tobin (1987)	8-12	equal	average to high	middle	≈25	average to high	?
Gallagher, S. A. (1994)	7-12	equal	?	?	?	?	?
Germann (1994)	9 & 10	39 - 28	average to high	average to low	≈17	?	average 19 yrs. experience
Jones & Carter (1994); Carter & Jones (1994)	5	?	low & high	urban school	?	?	experienced
Keys (1994)	9	?	average or above	suburban working class	26	?	?
Brown & Campione (1994)	5 & 6	equal	aveage and below	low	?	average	researcher
Mulopo & Fowler (1987)	11	all male	.5 concrete .5 formal	?	30	?	?
Roth (1994)	10 & 11	all male	high	average to high	15	high	high
Roth & Bowen (1994)	8	17 - 5	high	middle to high	22	high	high
Roth & Roychoudhury (1993)	8, 11, 12	all male	very high	?	15	very high	very high
Sanford (1987)	8th & HS	?	Gen. Science Hon. Biology	?	20-25	labs and projects	one worked on honors curriculum
Tamir (1977)	high school college	?	?	?	coll. 20-25 HS ?	?	?
Tobin & Fraser (1990)	HS, 6&7, 3&5	equal	?	?	?	?	exemplary
Toh & Woolnough (1993)	8th	170 107	?	typical urban Singapore school	70	?	same teacher for all classes
Westbrock & Rogers (1994)	9th	equal	?	midwestern city	15-20	?	teacher - researcher

Table 2 Design Characteristics of Studies on Inquiry-Oriented Teaching

	Design	Intact Classroom	Student Pullout	Teaching Method Defined	Teaching Method Verified	Length of Study
Blumenfeld (1992)	correlational	10 classes taught by 5 teachers	no	task dimensions	direct observations	?
Cavallo & Schafer (1994)	experimental	7 classes	no	minimal teacher interaction	pre-written instsructional packets	1 week
Gallagher & Tobin (1987)	qualitative	13 classrooms	selected interviews	no - various teacher methods	outcome of research	14 weeks
Gallagher, S. A (1994)	structural modeling	3116 students national sample 50 high schools		no - various teacher methods	no	6 years of data
Germann (1994)	structural modeling	4 classrooms		no - varous teacher methods	no	1 year
Jones & Carter (1994); Carter & Jones (1994)	quantitative and qualitative	9 classrooms		dyad working groups	structured in study	3 weeks
Keys (1994)	qualitative	3 classrooms	6 students studied intensively	collaborative writing	direct observation and products	4.5 months
Brown & Campione (1994)	experimental some qualitative data		selected interviews	reciprocal teaching; jigsaw; cross-talk	classroom observation & teacher report	1 year
Mulopo & Fowler (1987)	experimental	random dist. to teachers	no	Selim Obs. Instrument	classroom observation	10 weeks
Roth (1994)	qualitative	1 classroom	in classroom setting	open inquiry	classroom observation	1 year
Roth & Bowen (1994)	qualitative	1 classroom	in classroom setting	open inquiry	direct observation	60 days
Roth & Roychoudhury (1993)	qualitative	8 classes	no	open inquiry	classroom observation	7 weeks
Sanford (1987)	qualitative	2 gen. sci. 2 hon. bio.	no	no - various teacher methods	classroom observation	6-7 weeks
Tamir (1977)	qualitative	35 classes	no	no - various teacher methods	research outcome	2 class periods
Tobin & Fraser (1990)	qualitative	20 teachers observed	no	no - various teacher methods	research outcome	8+ observations
Toh & Woolnough (1993)	experiment	4 classes	no	research treatments	?	7 weeks
Westbrook & Rogers (1994)	experiment	4 classes	no	Learning Cycle	observations by authors	6 weeks