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AUTHOR	Blosser, Patricia E.
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ABSTRACT

This digest provides an overview of several meta-analysis studies which focused on various aspects of science instruction. These studies examined: productive factors in science learning for grades 6 through 12; quality and quantity of instruction; effects of various teaching strategies on science achievement; instructional systems in science education; inquiry teaching and advance organizers; and other areas. Some possible generalizations from these studies are included. For example, it is noted that instructional techniques which help students focus on learning (preinstructional strategies, increased structure in the verbal content of materials, use of concrete objects or realism) are effective in promoting student achievement in science. (DH)

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Clearinghouse for Science, Mathematics, and Environmental Education

1200 Chambers Road, Third Floor
Columbus, Ohio 43212
(614) 422-6717

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META-ANALYSIS RESEARCH ON SCIENCE INSTRUCTION

Even before the appearance of the various 1983 reports on the state of education in American schools, science education researchers were interested in learning how to improve the quality of instruction in science. Numerous instructional techniques have been investigated for their impact on student achievement, use of process skills, attitudes, or other outcomes. In 1969 Howe and Ramsey published a two-part article in *The Science Teacher* on research on instructional procedures (Part I—outcomes of instruction, 56 studies; Part II—instructional procedures, 103 studies) (1969).

Since 1969, Gene Glass has described a technique known as meta-analysis that is used to analyze the results of a number of studies on a related topic. This digest has been developed to provide ERIC users with an overview of several meta-analysis studies focused on science instruction.

Meta-Analysis Procedures

Kulik has described the four basic steps involved in meta-analysis: (1) reviewers first locate studies of an issue, using clearly specified procedures; (2) the outcomes of studies are characterized in quantitative terms; (3) as many features of the studies as possible are coded; and (4) statistical procedures are used to summarize findings and relate study features to study outcomes (1983:957).

Meta-analysis involves calculating a common measurement for each defined variable within a study in order to compare the magnitude of difference between groups. This measurement, known as *effect size*, enables researchers to measure the difference in performance of two groups on a dependent variable (Kyle in *Research Within Reach: Science Education*, 1984, p. 9).

Meta-Analysis Findings

Herbert J. Walberg and four colleagues conducted a meta-analysis of productive factors in science learning for grades 6 through 12 (1980), using those grades because science is usually either required or elective and because they considered the grade levels involved in their study to contain students at least at the onset of formal operational thinking (1980:B2). Walberg considered that learning could best be explained by a model that has eight constructs linked to learning outcomes: quality and quantity of instruction; student ability; motivation; age or developmental level; home, peer, and classroom environments (1980:B1).

David Boulanger focused on the first two constructs of Walberg's model for his part of the meta-analysis project and examined 137 published studies related to the quality of instruction construct and 3 on the quantity of instruction. For his final analysis, Boulanger examined 52 quality of instruction studies grouped into six clusters: preinstructional strategies, indirectness of instruction, inductive vs. deductive strategies, training in scientific thinking, structure in the verbal content of materials, and realism or concreteness in adjunct materials (1980:F6). Achievement outcomes for which Boulanger looked were factual learning, conceptual learning, attitudinal learning, or laboratory performance (1980:F8).

Boulanger found significant positive outcomes for four types of instructional interventions: the use of preinstructional strategies, training in scientific thinking, increased structure in verbal content of materials, and increased realism or concreteness in adjunct materials (1980:F20). Although indirectness of instruction or inductive strategies were not shown to be significantly superior to direct or deductive strategies, Boulanger noted what he termed a "trend" toward more effectiveness of indirect or inductive methods with pupils in grades 10-12 and direct or deductive approaches for students in grades 6-8 (1980:F21). He concluded that ". . . Combining the results of all clusters, systematic innovation in instruction resulted in significant positive improvements over the norm or traditional practice" (1980-F21).

Only three studies related to quantity of instruction were identified. Boulanger wrote, "Taken as a whole, the three studies indicate that simply expanding the amount of time spent on a given unit of material holds no special relationship to amount learned . . ." (1980:F20).

Several meta-analysis studies resulted from a large meta-analysis project coordinated by Ronald D. Anderson at the University of Colorado (Anderson, 1983). These included work by Wise and Okey, Willett and Yamashita, and Lott. (Information is available in the final report by Anderson and also in Volume 20 of the *Journal of Research in Science Teaching*, issue 5, 1983.)

Wise and Okey (1983) looked at the effects of various teaching strategies on science achievement. They identified 12 categories of teaching techniques: (1) audio-visual, (2) focusing (alerting students to objectives or intent of instruction), (3) grading, (4) inquiry-discovery, (5) manipulative, (6) modified (usually a revision in instructional materials), (7) presentation mode, (8) questioning, (9) teacher direction, (10) testing, (11) wait time, and (12) miscellaneous (1983:421-423). An effective science classroom as depicted by Wise and Okey's analysis of effect sizes of teaching strategies is as follows:

> . . .The effective science classroom appears to be one in which students are kept aware of instructional objectives and receive feedback on their progress toward these objectives. Students get opportunities to physically interact with instructional materials and engage in varied kinds of activities. Alteration of instructional material or classroom procedure has occurred where it is thought that the change might be related to increased impact. The teacher bases a portion of the verbal interactions that occur on some plan, such as the cognitive level or positioning of questions asked during a lesson. The effective science classroom reflects considerable teacher planning. The plans, however, are not of a 'cookbook' nature. Students have some responsibility for defining tasks (1983:434).

Willett and Yamashita (1983) looked at instructional systems in science education, defining an instructional system as a general plan for conducting a course over an extended period of time. It is general in that it often encompasses many aspects of a course (e.g. presentation of content, testing, size of study groups)" (1983:406). Like Wise and Okey they had 12 categories: (1) audio-tutorial; (2) computer linked, subdivided into computer assisted, computer managed and computer simulated experiments; (3) contracts for learning, (4) departmentalized elementary school, (5) individualized instruction; (6) mastery learning; (7) media based instruction, categorized into film instruction and television; (8) personalized system of instruction (Keller PSI), (9) programmed learning, including branched and linear; (10) self-directed study; (11) use of original resource papers in the teaching of science; and (12) team teaching. After examining effect sizes they concluded that the most innovative instructional systems for positive cognitive outcomes (as well as other variables) were mastery learning and PSI (1983:414). Media based systems in general appeared to perform at a lower level than the traditional instruction used as the control group, and most of the remaining systems operated at a level very little higher than the conventional instruction they replaced (1983:414-415).

Lott's (1983) part of the Colorado meta-analysis project involved looking at research on inquiry teaching and on advance organizers. After examining 39 studies, Lott reported that he found essentially no differences in mean effect sizes between inductive and deductive approaches. However, he did report

> ... the apparent positive effect the inductive approach has at the intermediate level. Moreover, this approach seems to be more useful in those situations where high levels of thought, learning experiences, and outcome demands are placed upon the subjects. In addition the inductive approach appears to function better when the curriculum organization is formulated across units to involve the complete program (1983:445).

When advance organizer studies were analyzed, Lott said that the use of advance organizers seemed to have been more advantageous with urban students than those in rural or suburban schools but that there was little effect depending upon grade level, style of organizer, or characteristics of materials (1983:449).

The previously-described meta-analyses were limited to K-12. Kulik (1983) analyzed 312 studies of the effects of educational technology in college teaching, involving five types of educational technology frequently used at the college level: Keller's Personalized System of Instruction, computer based teaching, programmed instruction, audio-tutorial instruction, and visual-based instruction. He concluded that instructional technology has a basically positive influence on student examination performance. Although the effects of teaching varied with educational level, the use of PSI produced stronger results than did technologies used in other studies.

Yeany and Miller (1983) used meta-analysis to examine 28 experimental studies (middle school through college) based on diagnostic-prescriptive instruction as it influenced science achievement. Studies were classified into one of three groups: I. no diagnosis, no remediation; II. diagnosis, feedback only; and III. diagnostic feedback and remediation. They found the results from groups II and III to be essentially equal in their effect on science achievement. Their conclusion was that achievement can be significantly and positively influenced through diagnostic remedial instruction, with the influence appearing to come from the diagnostic feedback to students.

Some Possible Generalizations

It seems possible to say that instructional techniques which help students focus on learning (preinstructional strategies, increased structure in the verbal content of materials, use of concrete objects or realism) are effective in promoting student achievement in science. Teachers can help students learn to think scientifically. Although the effect sizes for inductive teaching were not as large as one might hope for, the indirect approach to instruction does appear of value when a teacher's goal is to help students think at higher levels than factual recall.

Boulanger and Lott appear to be in conflict with their identification of the grade level for which the inductive approach is most effective, with Lott finding it effective for intermediate grades, while Boulanger reports it more effective for older students in elective courses. This variable should receive further study to determine whether all relevant studies were included in both reviews. If they were not, then a more complete review is needed. If all existing studies were analyzed, then procedures used in the two meta-analysis reviews should be compared to determine how the reviewer's methodology influenced his conclusions.

The findings of Willett and Yamashita, Kulik, and Yeany and Miller serve to reinforce instructional techniques focused on the progress of the individual student. Mastery learning, Keller's PSI, and diagnostic feedback all appear to involve careful planning and sequencing of instruction with the monitoring of student progress, the provision of diagnostic feedback to students, and the availability of alternatives. This, in turn, relates to the findings of Wise and Okey that considerable teacher planning is evident in effective science classrooms.

REFERENCES

Anderson, Ronald D. et al. *Science Meta-Analysis Project: of NSF Project No. SED 80-12310.* Boulder, CO: Laboratory for Research in Science and Mathematics Education, University of Colorado, December, 1982. ED 223 476

Boulanger, F. David. "Instruction and Science Learning: A Quantitative Synthesis." in *A Meta-Analysis of Productive Factors in Science Learning Grade 6 Through 12.* H. J. Walberg, et al. Chicago, IL: University of Illinois at Chicago Circle. June 1980. ED 197 939

Kulik, James A. "How Can Chemists Use Educational Technology Effectively?" *Journal of Chemical Education* 60 (11): 957-959. November 1983.

Kyle, William C. Jr. "Curriculum Development Projects of the 1960s" in *Research Within Reach: Science Education.* David Holdzkom and Pamela B. Lutz, eds. Charleston, WV: Appalachia Educational Laboratory, Inc., 1984. ED 247 148

Lott, Gerald W. "The Effect of Inquiry Teaching and Advance Organizers Upon Student Outcomes in Science Education." *Journal of Research in Science Teaching* 20(5):437-451, 1983.

Ramsey, Gregor A. and Robert W. Howe. "An Analysis of Research on Instructional Procedures in Secondary School Science. Part I—Outcomes of Instruction." *The Science Teacher* 36(3):62-70. March 1969.

Ramsey, Gregor A. and Robert W. Howe. "An Analysis of Research on Instructional Procedures in Secondary School Science. Part II—Instructional Procedures." *The Science Teacher* 36(4):72-81. April 1969.

Walberg, Herbert J. et al. *A Meta-Analysis of Productive Factors in Science Learning Grades 6 Through 12.* Chicago, IL: University of Illinois at Chicago Circle. June 1980. ED 197 939

Willett, John B. and June J. M. Yamashita. "A Meta-Analysis of Instructional Systems Applied in Science Teaching." *Journal of Research in Science Teaching* 20(5):405-417. 1983.

Wise, Kevin C. and James R. Okey. "A Meta-Analysis of the Effects of Various Science Teaching Strategies on Achievement." *Journal of Research in Science Teaching* 20(5):419-435. 1983.

Yeany, Russell H. and P. Ann Miller. "Effects of Diagnostic-Remedial Instruction on Science Learning: a Meta-Analysis." *Journal of Research in Science Teaching* 20(1):19-26. 1983.

Prepared by Patricia E. Blosser, Associate Director—User Services

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