RESEARCH ON FOSS and OTHER HANDS-ON SCIENCE PROGRAMS

A GROWING BIBLIOGRAPHY

(Updated: July 2001)

CONTENTS

I.
PAST RESEARCH ON HANDS-ON SCIENCE

The first major effort by the National Science Foundation to improve elementary level science instruction in schools began in the 1960s. Curricula were developed around different theoretical perspectives: The Science Curriculum Improvement Study (SCIS) built its content from a Piagetian, developmental perspective. Science-A Process Approach (SAPA) was influenced by the work of Robert Gagne whose theory espoused that knowledge is cumulative; the curriculum was constructed hierarchically toward advanced principles. The Elementary Science Study (ESS) was influenced by Jerome Breuner, and the curriculum allowed for much free exploration within specific content areas. Because of their theoretical perspectives, these programs were investigated by many researchers.

However, it took nearly two decades before summary studies could be made of the effects of these programs. By then, the programs had been used long enough that students who had experienced 6 years of a Grade 1 through Grade 6 program could be studied. Hundreds of research articles were produced. The following are some summary studies of those articles.

Summary Studies of NSF Sponsored Elementary Science Projects

1982

Shymansky, J., Kyle, W., Alport, J. (1982). **How effective were the hands-on science programs of yesterday?** *Science and Children*, November/December.

1983

Shymansky, J., Kyle, W. and Alport, J. (1983). ***The Effects of New Science Curricula on Student Performance.*** *Journal of Research in Science Teaching*, 20, 387-404.

1985

Bredderman, T. (1985). **Laboratory programs for elementary school science: A meta-analysis of effects on learning.** *Science Education*, 69, (4), 577-591.

1988

Kyle, W. C., Jr., Bonnstetter, R. J., & Gadsden, T., Jr. (1988). An implementation study: An analysis of elementary students' and teachers' attitudes toward science in process-approach vs. traditional science classes. *Journal of Research in Science Teaching*, 25, 103-120.
Kyle, W. C., Jr., Bonnstetter, R. J., & Gadsden, T., Jr., & Shymansky, J. A. (1988). What research says about hands-on science. *Science and Children*, 25 (7), 39-40.

1989

Kyle, W. C., Jr., Wolf, M., Archambault, F. X., Bonnstetter, R. J., & Gadsden, T., Jr. (1989). **Process Science and Standardized Testing: Are They Compatible?** Paper presented at the meeting of the *National Association for Research in Science Teaching,* San Francisco, California.

Shymansky, J. (1989). **What Research Says About ESS, SCIS, and SAPA.** *Science and Children*, April.

1990

Shymansky, J., Hedges, L., and Woodworth, G. (1990). **A Reassessment of the Effects of Inquiry-Based Science Curricula of the 60's on Student Performance.** *Journal of Research in Science Teaching*, 27, (2), 127-144.

II.

RECENT RESEARCH ON HANDS-ON SCIENCE

A renewed interest in elementary science curricula development was stimulated by another round of funding by the National Science Foundation beginning in 1988. The funding was stimulated by: a) the book, *A Nation At Risk* which warned that improved literacy in science, mathematics, and technology of all citizens was necessary if this country was to remain as a significant voice in the 21st century; b) international studies that indicated American students did not do well compared to students in other countries; and c) the fact that the textbook industry, which provided the basic science and math curricula for American schools, continually produced products of poor quality.

Critics have dismissed the results of international studies, implying that the results are invalid because students from a general population in the US are compared to select and often elite groups in other countries. The *Third International Mathematics and Science Study* (TIMSS), however, allows for comparisons on a more equal basis. Follow-up studies (1999 and 2003) intend to be comparied to the basic study.

References

—— (1983). **A Nation at Risk: The Imperative for Educational Reform.** Washington, DC: National Commission on Excellence in Education.

Document summarizes the need to prepare students for the 21st Century, especially in the areas of mathematics, science, and technology.

—— (1995). **Third International Mathematics and Science Study (TIMSS).** Washington, DC: National Center for Education Statistics.

Sponsored by the US Department of Education and the National Science Foundation in the United States and by the International Association for the Evaluation of Educational Achievement, TIMSS assessed fourth, eighth, and twelfth graders. Analysis of classroom practices: 87% of lessons taught by US teachers were judged to be of low quality. None were judged to be of high quality. By com parison, only 13% of Japanese and 40% of German lessons were judged to be of low quality.

—— (1999). **Third International Mathematics and Science Study-R (TIMSS-R).** Washington, DC: National Center for Education Statistics.

Follow—up study to TIMSS 1995 study. General findings: no improvement in any grade level when compared to the 1995 study. Detailed analysis suggests that schools that implement hands-on science score as well as the rest of the world; schools without such science score poorly.

Reviews of Textbook Science Curricula

The textbook industry is a 4.5 billion dollar-a-year industry—greater than the sales of all paperback and hardcover books to adults. They are generally adopted by committee members who have little time or background to examine texts thoroughly, and frequently make decisions based on splashy graphics, frills, and links to "reading" materials.

Ecenbarger, W. (2000). **"Textbooks that Don't Make the Grade"**. Reader's Digest, September, pp 165-170.
This article summarizes studies of textbooks.

Feynman, R. (1964). **Judging Books by Their Covers.** Chapter in "Surely You're Joking, Mr. Feynman!". W. W. Norton and Company.
Feynman identifies the nonacademic manner by which textbooks are written and condemns them for their numerous errors and lack of concern for correcting errors.

Hubisz, J. L (2001). **Review of Middle School Physical Science Texts, Final Report.** The David and Lucille Packard Foundation, Grant #1998-4248.
In this study of twelve middle school science textbooks, researchers compiled over 500 pages of errors, ranging from maps depicting the equator passing through the southern United States to a photo of singer Linda Ronstadt labeled as a silicon crystal. The study's reviewers tried to contact textbook authors with questions, but in many cases the people listed did not write the books and some did not know their names had been listed.

McClintock, D. (2000). **The Great American Textbook Scandal.** Forbes, October 30.
Article reviews the textbook adoption procedure in California and cites the extensive errors found in the K–8 textbooks that were submitted for adoption.

Project 2061, **Middle Grades Science Textbooks Evaluation.**
http://www.project2061.org/newsinfo/research/textbook/mgsci/default.htm
This website includes links to the following information:

- Key Ideas Used for the Evaluation
- Criteria for Evaluating the Quality of Instructional Support
- Helping Students Learn the Kinetic Molecular Theory
- Ratings of Instructional Quality

Raloff, J. (2001) **Errant Texts: Why some schools may not want to go by the book.** Science News, March 17, 2001, v. 159 no. 11.

Roseman, J.; Kesidou, S.; Stern, L.; and Caldwell, A. (1999) **Heavy Books Light on Learning: AAAS Project 2061 Evaluates Middle Grades Science Textbooks**. Science Books & Films, November/December 1999, v. 35 no. 6.
Report on the Project 2061 in-depth evaluation of middle grades science textbooks. The focus of this effort was to see textbooks had potential for helping students learn key ideas. Not one of the middle grades science texts evaluated by Project 2061 received a satisfactory rating.

The Textbook Letter. Bimonthly newsletter P.O. Box 51, Sausalito, CA 94966.
Each issue contains reviews of recently published middle-school and high-school textbooks.

Reviews of Current NSF Sponsored Elementary/Middle School Science Projects

In 1988, NSF funded a fresh round of K-8 curriculum development. Called the Triad Project, newly funded programs were required to involve scientists, teachers, and publishers in the development. NSF funded: BSCS (Biological Science Curriculum Study) which produced a K-8 science program called Science for Life and Living; EDC (Educational Development Center) which produced Insights, a K-6 science curriculum; the Lawrence Hall of Science (LHS) which developed the K-8 Full Option Science System (FOSS); the University of California at Santa Cruz which created the K-6 Life-Lab Science Program; and the Smithsonian Institution which developed the K-8 Science and Technology for Children (STC) program.

These programs are still relatively young. Summary studies are not expected to be available for at least a decade. However, a few early studies have been conducted on the FOSS program. Findings from these studies parallel the findings of the summary studies done of the 1960s programs: Students learn and retain more content knowledge; Students gain confidence in their ability to do science and solve problems; Students improve in their language arts (reading, writing) skills; Students attitudes toward science remain high; Females have as much success as males. To this date, only a few studies have been done on the other elementary NSF programs. Here is an annotated listing of studies.

Allard, D. and Robardy, C. (1991). **FOSS Training for Third and Fourth Grade Arkansas and Texas Teachers: Attitude Changes and Other Results.** Study, Texarkana College, Texarkana, Texas.

Pre- and post-test results of twenty-nine third and fourth grade teachers who received 48 hours of FOSS instruction found significant gains in attitude toward science teaching, confidence toward science teaching, and content knowledge.

Choo, J.Y. (1993). **An Investigation of Girls' Attitudes Toward Science: Are Attitudes Influenced by the Type of Science Curriculum Female Students Experience in Elementary School?** Master's Project. University of California at Berkeley.

Using projective devices to measure attitudes, a small random sample of urban female students who experienced FOSS (n=6) or a traditional text (n=6) from grades 3-6, were interviewed. Quantitative data showed that girls from FOSS classrooms displayed higher positive attitudes. Qualitative data revealed that FOSS students found investigations were "something they could do" and that science was "important in their lives." Text students said "science was hard to understand" and expressed a lack of confidence because they "make mistakes in reading or copying science from science books." To them, science was "abstract and distant" and something that "only special people could do."

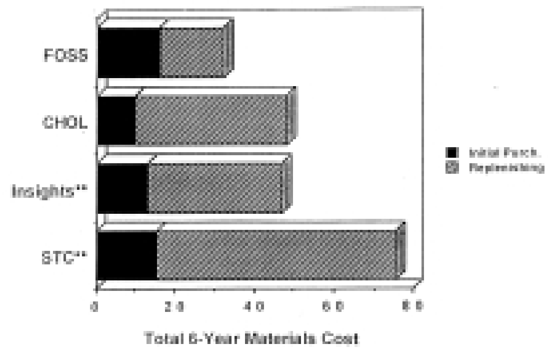
Clementson, J. (1991). **A Qualitative Study of Elementary Teachers' and Students' Interactions with the FOSS.** Ed.D. dissertation, University of Nebraska.

Study found positive results in attitudes about science and the teaching of science.

Eckelmeyer, K. H. (1998). **Study of Hands-On Science**. Sandia National Laboratories, Albuquerque, NM.

This study used a teacher questionnaire (n=200) to compare four hands-on science programs (CHOL (a teacher-made science program), FOSS, Insights, STC) on several factors-effectiveness, quality of guides, quality of kit materials, cost. Some data examples follow.

The cost of kits & replenishing is within New Mexico provision for science instructional materials*:



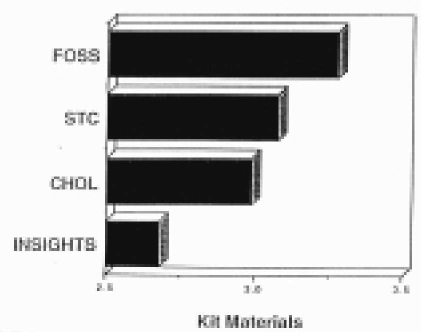
* Average of all kits available, prices quoted in current NM adoption process

* Cost per student in district: 18 classes of 30 students (3 classes per year)

** Enhanced kits from Center for Hands-On Learning

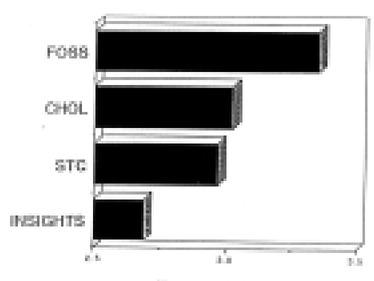
Teachers judged some kits to be more complete and teacher-friendly than others:

Paired comparisons rated kit materials in terms of completeness, durability, quality, and ease of use. The groups were too small to yield statistically significant differences, but averages suggested teacher preferences:



Teachers judged some teacher's guides to be clearer and effective than others:

Paired comparisons rated teacher's guides in terms of background information, teacher instructions, learning objectives; ideas for classroom management ideas, assessment, and curricular extensions; and overall quality. Averages suggested teacher preferences:



Estonina, A. D. (1992). **Evaluation and Observational Study of Effective Pedagogy and Curriculum for Limited English Proficient Students Implemented in a First Grade Cantonese Bilingual Classroom: FOSS Solids and Liquids Module.** Master's Project. University of California at Berkeley.

Study found students thoroughly engaged in all activities and that the program promoted second language acquisition. FOSS was found to be a useful vehicle for second language learners.

Evert, B. A. (1993). **The FOSS Scientific Thinking Processes Applied to Music. Master's Project.** Institute for Contemporary Music Education, University of Saint Thomas, Minnesota.

Study examined the transferability of the seven FOSS thinking processes to the field of music instruction. Study found parallel processes occurring in music. A new music program based on the processes (appropriate levels and pattern-seeking capacities) and FOSS-type lessons (collaborative groups) was successful: students learned more and at a quicker pace; attitudes improved.

Far West Laboratory (1995). **Report on Galaxy Science for Grades 3-5: Findings in case study schools.** Far West Laboratory, San Francisco.

Report presents effects of Galaxy program upon students and teachers. Program involves a satellite connection among schools (40 schools across the United States and in Mexico) with a 13-part motivating program delivered by satellite on a bi-weekly basis. Full Option Science System (FOSS) materials and Great Expectations in Math and Science (GEMS) materials provide accompanying classroom experiences. Findings indicate teachers' attitudes toward science improves as does their expertise in teaching hands-on science. Students' attitudes and enthusiasm improve as does the depth of their understandings of science concepts. The activities have a positive effect upon reading and language arts interest and abilities.

Foss, L. M. (1994) **Learning to Think, Together: How Cooperative Group work Affects Sixth Graders' Ability to Learn to Control for Variables.** Master's Project. University of California at Berkeley.

Study found that collaborative group work resulted in more learning of both procedures and concepts and that the FOSS Variables Module is an effective means for introducing students to the procedures of identifying and controlling for variables.

Franklin-Leach, L. S. (1992) **Hands-on Science Curriculum Helps Female Pupils.** Research study, Texas Tech, Lubbock, Texas.

73 female and 63 males in five fifth grade classes were involved in a 14-week study. Treatment classes experienced FOSS modules. Both the males and females in the treatment group scored significantly higher on a battery of assessment devices: CTBS, content achievement measures, problem solving tasks, and attitudes measures.

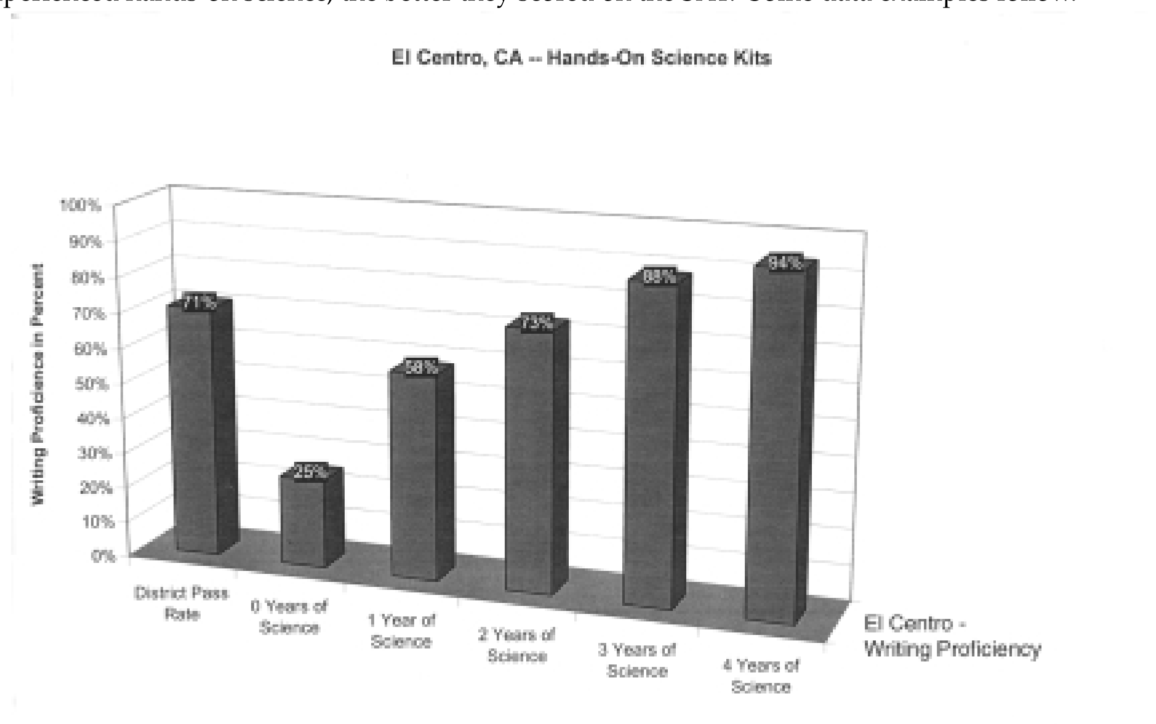
Johnson, J. (1991). **Teaching Science to Students With a Wide Range of Abilities Through the Use of Hands-On Experiences and Collaborative Groups.** Master's project. University of California at Berkeley.

Jones, B. (1990). **A Developmental Perspective of the Child's Concept of Sound: FOSS Physics of Sound Module.** Master's Project. University of California at Berkeley.

Study examined developmental changes in children's explanations for the transmission of sound from a source to a receiver. Study found that the concepts presented in the FOSS module were developmentally appropriate for youngsters in Grades 3 and 4 and that such concepts could not be attained at primary grade levels. The concepts were more easily achieved by students in Grades 5 and 6. The study provided support for developmentally appropriate placements of the FOSS Sound activities.

Klentschy, M., Garrison, L., Amaral, O.M. (2001) **Valle Imperial Project in Science: Four-Year Comparison of Student Achievement Data 1995-1999.** Research report, National Science Foundation Grant #ESI-9731274.

Findings of this study are consistent with those of Shymansky, Hedges, and Woodworth (1990) and Kyle (1988). Hands-on science has strong benefits for students from lower socioeconomic and rural backgrounds. There are also trends and indications that the program stimulates writing experiences that transfers to an overall improvement in writing. Study also found that the more years a student experienced hands-on science, the better they scored on the SAT. Some data examples follow.



Lattery, M.J.; Lemberger, J., and Herzog, B. (2001). **Evaluation of Science & Technology for Children (STC) Physical Science Units.** Fox Valley Einstein Assessment Project, University of Wisconsin, Oshkosh, WI. http:/www.phys.uwosh.edu/lattery/fveap/fveap.html

This study examines the instructional impact of NSRC's *Science & Technology for Children* curriculum in the Oshkosh Area School District. Researchers investigated the instructional effectiveness of four physical-science units for grades 1-4. Students were pre-and post-tested using a multiple-choice exam containing items adapted from the TIMMS, NAEP, TerraNova, and other widely recognized sources. Results were compared with existing instructional materials. Results suggest that the adoption of this curriculum among experi enced teachers in the district will provide little or no immediate gains on student achieve ment, and potentially a slight decrease in student attitudes toward science

Leach, S. F. (1992). **Analysis of the Full Option Science System.** PhD dissertation, Lubbock: Texas Tech University. Summary published in Educational Dealer, May 1993, pages 31-32.
Results of this control/experiment study found that the FOSS treatment group scored significantly higher in specific content science achievement and process skills. In addition, the FOSS group showed more positive attitudes toward science and greater self-confidence in science. Females liked science more and held more positive attitudes concerning their ability to have success in science than females in the control group.

Medress, T. (1993). **The Nature and Short-Term Development of Problem Solving Skills Among Fifth and Sixth Grade Students.** FOSS Models and Designs Module. Master's Project. University of California at Berkeley.
Using pre-post qualitative methods, eight sixth grade students were assessed according to their confidence in doing science, solving problems, and attitudes toward science. Specifically, pre-FOSS assessment revealed students exhibited a lack of problem-solving behaviors, lack of self-confidence, frequent off-task behaviors, and compromised academic effort. Post-FOSS assessment revealed a significant positive change in all these behaviors for all but one student.

Plank, A. et. al. (2000). **Torrance Unified School District, Science Team Report.** Torrance, CA.
This longitudinal study found that since the inception of the FOSS program (1992), the total high school enrollment increased by 13% while the enrollment in high school Science courses increased 63%. For students who were initially exposed to FOSS in kindergarten, SAT scores show that all students in grades 4-10 performed above the national average.

Robardy Sr., C. and Allard, D. (1992) **A Study of Teacher Attitudes and Confidence After Being Trained to Teach the FOSS Program.** East Texas State University-Texarkana, TX
Twenty-nine third and fourth grade teachers and twenty-five fifth and sixth grade teachers were trained in the use of appropriate grade level FOSS modules and each teacher taught at least one of the modules. Teachers were tested at the beginning and end of training in four areas: knowledge of science, attitude toward science, attitude toward teaching science, confidence in teaching science. The study found that elementary teachers improved their science knowledge and their confidence in teaching science as a result of receiving training in the FOSS program.

Robardy Sr., C. , Allard, D., and Brown, D. (1994) **An assessment of the effectiveness of the Full Option Science System training for third through sixth grade teachers.** Journal of Elementary Science Education, 6, 1.

Stein, J. (1992). **Reflection on and Modification of an Elementary Science Unit to Address the Needs of a Spanish Bilingual Class: FOSS Water Module.** Master's Project. University of California at Berkeley.
Study examined the progression of students' understanding of concepts over time at different stages of development within the context of a module of instruction. Stein found that the materials helped her to better understand bilingual students and her own development as a teacher.

Stohr, P. M. (1996). **“An Analysis of Hands-On Experience and Science Achievement”.** Journal of Research in Science Teaching, 33 (1), pp. 101-109.

In this study, student achievement was correlated with the frequency of hands-on experiences. Significant differences existed across the hands-on frequency variable with respect to science achieve ment. Specifically, students who engaged in hands-on activities every day or once a week scored significantly higher on a standardized test of science achievement than students engaged in hands-on activities once a month or never.

Tolley, B. (1991) **Survey of the Science Update Project.** Master’s Project, University of California at Berkeley.

Survey examined the impact on students who experienced FOSS, on the teaching of science and attitudes toward science by teachers, and on the successes in replicating the project through teacher-led workshops and inservices. On the basis of all variables measured by the survey, the project had a remarkable success in influencing learning, in improving the ability of teachers to teach science with hands-on materials, and upon initiating teacher-led staff workshops within schools. Greatest detri ment to exporting the model were school administrators who, in various ways, limited the frequency of workshops.

Wexler, D. (1991). **Development and Transfer of Map Making Concepts and Skills: FOSS Landforms Module.** Master’s Project. University of California at Berkeley.

Study examined student’s ability to draw overhead maps of familiar locales (classroom, schoolyard) at different grade levels. Study found that third grade youngsters consistently drew profiles of objects (from the student’s perspective) and could not convert them easily to overhead/symbolic depictions. After instruction, students reverted to profile depictions and could not transfer what was taught to a new situation. In Grade 4, students consistently drew terrain with a mixture of depictions - some overhead, some profile. In Grade 5, student’s were easily able to imagine and depict the view of terrain from an overhead perspective and could easily make up and use symbols to depict objects. Study provided support for the placement of the FOSS Landforms activities.

III.

THE EFFECT OF HANDS-ON SCIENCE UPON OTHER SUBJECT AREAS

Reading, the Other Language Arts, and Mathematics

Many educators are interested in the effect of hands-on science programs upon standardized reading scores. Most of the historical references on the preceding pages (e.g., Shymanski, Kyle, Bredderman) found that reading and other language arts skills were significantly influenced in a positive way by the hands-on science programs that were studied.

Since its inception into schools, FOSS has received much anecdotal information on the value of FOSS to reading and the other language arts. Teachers have said that their students check more books out of the library than ever before after having FOSS experiences; that the variety of titles checked out and range of interest is broader. Some teachers have said that when students write reports, the reports contain full sentences and more detail after FOSS experiences. Many teachers claim that reading proficiency is improved.

Just as the summary studies of the 1960s curricula found that hands-on science programs improve reading scores, some recent studies of FOSS and other NSF sponsored science programs reconfirm the influence of hands-on science upon standardized reading.

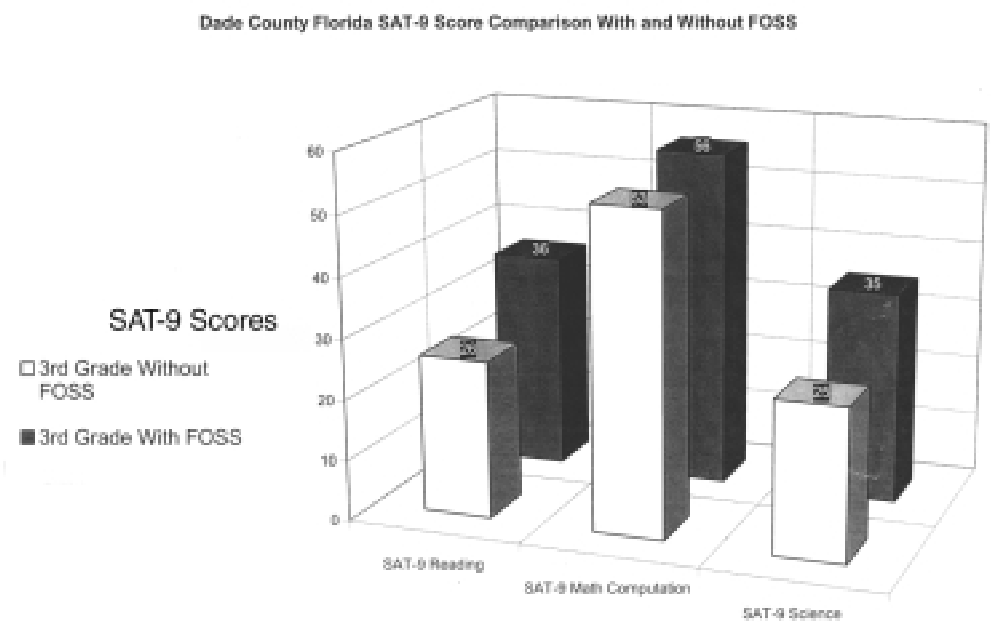
To a lesser degree, some studies indicate that hands-on science also improves the scores in mathematics.

Dade County, Florida (1996). **Report on Achievement: Effects of Hands-on Science (FOSS).** Dade County, Florida.

Staff examined the 1996 Stanford Achievement Test (SAT) science test results of third and fifth grade students in Region III schools using the FOSS Science Kits in comparison to other Region III schools that did not use the kits. Table I displays the 1996 SAT results for the two groups of students. An examination of the table reveals that third and fifth grade students in schools using FOSS Science Kits outperformed other students in science. How ever, "FOSS" students also achieved higher scores in Reading Comprehension, Mathematics Computation, and Mathematics Applications. Some data examples follow.

1996 SAT Median Percentiles for Region III Schools (Dade County) Utilizing the FOSS Science Kits Compared to School Not Using the Kits

	Schools Using FOSS Science Kits (n = 2,420)		Schools Not Using FOSS Science Kits (n = 4,145)	
	Grade 3	Grade 5	Grade 3	Grade 5
Reading Comprehension	36	38	26	28
Mathematics Computation	56	53	53	48
Mathematics Applications	48	49	37	35
Science	35	34	25	26



IV.

OTHER RESEARCH-RELATED ARTICLES ON FOSS

Lowery, L. (1990). **The Biological Basis for Thinking and Learning.** Monograph. Encyclopaedia Britannica Educational Corporation/Lawrence Hall of Science.

Lowery, L. (1990). **The Scientific Thinking Processes.** Monograph. Encyclopaedia Britannica Educational Corporation/Lawrence Hall of Science.

Lowery, L. (1991). **Preparing Future Teachers to Teach Science and Mathematics.** The Educator, 5, 14-15.

Lowery, L. (1991). **A New Curriculum Design for Elementary School Science.** The Educator, 5, 16-19.

Lowery, L. (1993, reprinted 1994). **The Importance of Understanding Child Development in Curriculum Development.** FOSS Newsletter, 1, 4-5.

Lowery, L. (1993). **Changing the Metaphor.** FOSS Newsletter, 2, 8-10.

Lowery, L. (1993). **Changing the Metaphor.** The Earth Scientist, 11, 4, 7-9.

Lowery, L. (1994). **Inquiry: The Emphasis of a Bold, New Science Curriculum.** Technological Horizons in Education Journal, 21, 50-52.

Lowery, L. (1994). **Communities of Practice.** FOSS Newsletter, 4, 6-8.

Staver, J. et. al. (1994). **Constructing Concepts of Constructivism with Elementary Teachers.** Chapter in AETS Yearbook (Ed. Larry Schafer).

Chapter uses the FOSS Models and Design module for examples of teaching constructivism.

Lowery, L. (1995). **Partners with Researchers.** FOSS Newsletter, 5, 8-11.

Lowery, L (1995). **What Does Research Say About the Learner?: The Biological Basis for Thinking and Learning.** The Catalyst, 4, Fall Winter, National Research Council, Washington D. C.

Lowery, L. (1996). **Benchmarks and Standards: an Historical Perspective.** FOSS Newsletter, 6, 8-11.

Lowery, L. (1997). **The Nature of Learning.** FOSS Newsletter, 10, 6-8.

Dembski, D. and Herdrich, P. (1997). **Getting Their Hands on Science.** Wisconsin School News, April, 5-7.

Lowery, L. (1998). **Strategies for Instruction.** FOSS Newsletter, 11, 5-8.

V.

MISCELLANEOUS RESEARCH ARTICLES

Interest in the value of hands-on science has been high in the last decade of the 20th century. Researchers continue to investigate the value of hands-on experiences. The following reference is worth reading:

Romance, N. and Vitale, M. (1993). **A Constructivist Approach to Improving Learning in Elementary School Science for Students in Grades 4 & 5.** Paper presented to the Annual Meeting of the National Science Teachers Association, Kansas City, KS.

Often, skeptics of new programs want the new programs to "prove" themselves. A fair question would ask the same of traditional textbook programs. That research and yearly scores on standardized tests continually reveal that traditional textbook programs are wanting.

It is important to note that no studies exist that show that textbook or textbook-with-kit approaches improve students in any way. To the contrary, researchers have found only negative results from these approaches: International studies comparing U.S. students with those of other countries continually reveal that U.S. students do not fare well by comparison-the U.S. students studied were predominantly taught by a textbook approach. Science textbooks are frequently filled with misinformation and outdated information (The Textbook Letter, bimonthly reviews); New vocabulary in science textbooks exceeds new vocabulary in foreign language texts, (Building a Comprehensive Model of What Teachers Do in the Classroom, Alan Schoenfeld); Textbook approaches emphasize memorization and recall of facts, more than half the activities/experiments do not work (The Knowledge Integration Environment, Marcia Linn, et. al.). In general, studies have found that at the elementary level, the content is often beyond the cognitive capacity of the students; prerequisites (prior knowledge) needed for understanding are not part of earlier experiences; the number of new vocabulary words per chapter exceed the number in a foreign language text; the presentation is didactic and the student is passive; the instruction utilizes methods for teaching reading rather than methods for teaching science.

Costenson, K. and Lawson, A. (1986). **Why Isn't Inquiry Used in More Classrooms?** The American Biology Teacher, 48, 3.

Linn, M. et.al. (1995). **The Knowledge Integration Environment: Theory and Design.** CSCL '95 Proceedings, September.

Schoenfeld, A. (1997). **Building a Comprehensive Model of What Teachers Do in the Classroom.** Paper in preparation, University of California, Berkeley.