Texas Science Initiative Meta-Analysis of National Research Regarding Science Teaching

EXECUTIVE SUMMARY

Prepared for the
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September 2005

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An Introduction to the Texas Science Initiative

In 2003, the 78th Texas Legislature enacted HB 411 to improve science education at all levels and prepare Texas students for postsecondary success. Led by Governor Rick Perry, a community of education leaders and policy makers established a plan for the initiative, conducted a needs analysis of the current state of science education in Texas, and recommended action steps for responding to those needs with scientific research-based professional development, instructional strategies, and classroom materials.

The resulting group of programs, known as the Texas Science Initiative, strives to address these challenges through a number of ventures, including the creation and dissemination of professional development modules emphasizing effective strategies for teaching science; online diagnostic instruments to aid teachers in identifying student needs; after-school and summer programs for struggling students; and the Master Science Teacher Certification Program.

Executive Summary

In order to aid the Agency and the Commissioner in the creation of training materials and other resources to assist science teachers in developing expertise in effective instructional approaches, the Texas Education Agency commissioned Texas A&M University at College Station to conduct a meta-analysis of national science education research to identify the most effective science instructional tools and methods. The purpose of this meta-analysis is to define what has been shown to improve student achievement and to develop a publication designed to share that information with educators across the state. This research provides the basis for production of a rubric for evaluating state-invested and other science education professional development and instructional materials to ensure the integrity and reliability of those products. The identification and implementation of proven methods of science instruction is a key step in ensuring the success of Texas students in science achievement and will inform future policy decisions and resource investments of science education stakeholders and policy makers.

Reports were collected from science education journals, electronic library databases, government web sites, and individual research projects. The majority were found through searches of electronic databases such as ISI Web of Science, ERIC, and ProQuest Dissertations and Theses using a combination of search terms such as “science teaching” and “student achievement.” National science education researchers were asked for their recommendations of studies, which included reference lists from books and articles.

A coding document was developed to identify in detail the information needed to perform the meta-analysis. Intercoder reliability was then established. Studies that met the preliminary inclusion criteria were then coded, and those whose components met the criteria were included in the meta-analysis. Over 390 potential sources of information were identified and collected in a reference list, with 61 studies included in the final analysis.

For each achievement measure reported in the included studies, an effect size (ES) was calculated comparing the performance of a treatment group with that of a control group. Then mean effect size for each group of teaching strategies was calculated using Comprehensive Meta-Analysis® software from BioStat. An examination of the internal and external validity issues was accomplished by performing multiple linear regression of the moderator variables using SPSS® software.

Summary of Results

Conclusions from this meta-analysis can be framed based on the rankings of the effect sizes associated with the respective teaching strategies. A ranking of the strategies is presented in Table 1.

Table 1. Ranking of Teaching Strategies

Strategies	Effect Size	Rank
Enhanced Context Strategies (relating learning to students' previous experiences, knowledge or interests, e.g. using problem based learning, taking field trips, using the schoolyard for lessons, encouraging reflection)	1.4783	1
Collaborative Learning Strategies (arrange students in flexible groups to work on various tasks, e.g. conducting lab exercises, inquiry projects, discussions)	.9580	2
Questioning Strategies (varying timing, positioning, or cognitive levels of questions, e.g. increasing wait time, adding pauses at key student-response points, including more high-cognitive-level questions, stopping visual media at key points and asking questions)	.7395	3
Inquiry Strategies (student-centered, inductive instructional activities, e.g. using guided or facilitated inquiry activities, guided discoveries, inductive laboratory exercises, indirect instruction)	.6546	4
Manipulation Strategies (opportunities to work or practice with physical objects, e.g. operating apparatus, developing skills using manipulatives, drawing or constructing something)	.5729	5

Testing Strategies (changes in frequency, purpose, or cognitive levels of evaluation, e.g. providing immediate or explanatory feedback, using diagnostic testing, formative testing, retesting, testing to mastery)	.5052	6
Instructional Technology Strategies (use technology to enhance instruction, e.g. using computers, etc. for simulations, modeling abstract concepts, and collecting data, showing videos to emphasize a concept, using pictures, photographs, or diagrams)	.4840	7
Enhanced Material Strategies (modified instructional materials, e.g. rewriting or annotating text materials, tape recording directions, simplifying laboratory apparatus)	.2908	8

All of the innovative teaching strategies presented in the 61 studies exhibited a positive influence on student achievement. As indicated by Wise (1996), innovative science instruction is a mixture of teaching strategies and no one strategy is as powerful as using a combined strategies approach. Students exposed to a traditional approach of science instruction can and will exhibit achievement; however, meta-analysis results indicate that incorporation of other avenues of learning via innovative strategies significantly augments the degree of achievement.

Within the family of instructional strategies, Enhanced Context Strategies such as relating to previous learning, field trips, group discussion, games, simulations, and reflective learning seem to have the greatest impact. Collaborative Learning Strategies such as flexible heterogeneous groupings and interdisciplinary teaming also displayed a strong effect. The results are not influenced by the variety of study characteristics and setting, including grade level of students and subject area within science.

Enhanced Context Strategies requires teachers to make learning relevant to students by presenting material in the context of real-world examples and problems. The real world can be brought to students through technology and students may be taken out of the classroom into the real world through field experiences. This type of augmented instruction is aligned with the implications for teaching outlined in *How People Learn: Brain Mind, Experience and School* (Bransford et al. 2000):

1. Teachers must draw out and work with the preexisting understandings that their students bring with them;

2. Teachers must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge; and

3. The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas. Students should be encouraged to reflect on their learning through journaling and self-assessment activities and to take charge of their learning through inquiry.

When considering the meta-analysis of the 61 studies as a whole, one is forced to conclude that when science instruction is altered from the traditional or control approach, student achievement is enhanced. While this result is very important, it is not unexpected. *If students are placed in an environment in which they can (1) actively connect the instruction to their interests and present understandings, (2) experience success early in the learning process, and (3) have an opportunity to experience scientific inquiry, achievement will be accelerated.*

STAGE 4: Dissemination of Results

Results of the meta-analysis are being distributed statewide through presentations to interested stakeholders and through an effective science teaching strategies booklet for educators. Meta-analysis results are also being presented nationally at meetings of educational researchers.

Due to the restrictions imposed on this study by time limits for completion, it is highly recommended that future meta-analyses include additional types of studies, including international studies, correlational studies, and studies dealing with special populations, teacher professional development, attitudinal and motivational changes, course sequencing and learning in general.