Meta-Analysis of National Research Regarding Science Teaching

Prepared for

Texas Science Initiative of the Texas Education Agency
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Texas A&M University
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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 of professional development modules emphasizing effective strategies for teaching Science; online diagnostic instruments to aid teachers in student needs assessment; after-school and summer programs for struggling students; and the Master Science Teacher Certification Program.

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.
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Introduction to the Meta-Analysis

The Center for Mathematics and Science Education at Texas A&M University has undertaken a research project commissioned by the Texas Education Agency in order to improve the learning and academic performance of students in K-12 science so that they are prepared for post-secondary success. This portion of the research project, a meta-analysis of national research regarding science instruction, was initiated to establish a knowledge base of what methodologies have been shown to be effective and which ones have not been effective. The meta-analysis addressed the question: What teaching methodologies have been shown to improve student achievement in science? While this question may appear too broad for a meta-analysis, the broadness was intentional to encompass the breadth of science methodologies employed and the multitude of instruments used to assess student achievement. The findings of this study will be used to develop a publication to share this vital information with educators across the state and to provide the criteria for evaluation of instructional materials and professional development programs.

The methodology involved in this project consisted of six major phases: acquisition of studies, coding of studies, determining intercoder objectivity, establishing criteria for selection of studies, computation of effect size and establishing statistical methods and conducting analyses. The study acquisition phase involved searching for research reports as well as position papers, bibliographies, and other relevant references and collecting as many pertinent reports as possible for the meta-analysis. The first step of the study coding phase consisted of developing a coding instrument to identify all of the necessary types of information to be collected from each report in order to describe the interventions used in the studies. Each report was then screened to determine if it met the preliminary criteria for inclusion in the meta-analysis. Those studies meeting the preliminary criteria were then carefully coded using the coding instrument. The third phase, intercoder objectivity, involved the simultaneous coding of three studies by three members of the research team. A listing of the
stringent criteria for final selection of studies was the fourth phase of the project. The fifth phase of the methodology was the computation of effect sizes. The final phase involved the use of Comprehensive Meta-Analysis® (CMA) software and SPSS® statistical analysis software, to obtain results for display and interpretation.

This initial report is limited in scope due to the rigorous inclusion criteria necessitated by the time limits for completion. It is highly recommended that the following types of studies be included in future meta-analyses:

- International studies
- Correlational studies (data on two variables collected and summarized, showing the relationship between the variables)
- Studies dealing with attitudinal and motivational changes in students and teachers
- Studies dealing with special populations (English-language learners, special education, under-represented populations, etc.)
- Studies dealing with teacher professional development
- Studies dealing with learning in general (not just limited to science education)
Methodology

Acquisition of Studies

A broad search for reports of studies to be included in the meta-analysis resulted in the collection of over 390 studies including journal articles, conference papers, books, dissertations, government reports and unpublished papers. The majority of the reports were identified through searches of electronic databases, including ISI Web of Science, ERIC, ERIC EBSCO, ERIC FirstSearch, ERIC CSA (Cambridge Scientific Abstracts), Academic Search Premier, PsycINFO, and ProQuest Dissertations and Theses. Government web sites such as Berkeley National Laboratory, the Department of Education, and other science education sites such as the National Academies, National Science Resources, American Association for the Advancement of Science (AAAS), Education Development Center, and National Science Teachers Association provided reports, links to sources, and names of science programs. In addition, general Web searches using standard search engines such as Google and Google Scholar were conducted. Initial search terms included “science education” and “student achievement.” Subsequent searches were expanded by using various combinations of alternatives for achievement, such as “performance,” “success,” and “outcomes,” and by combining them with individual science disciplines such as “biology,” “chemistry,” “physics,” “physical science,” “earth science,” “ecology” and “environmental science.” Other terms such as “science teaching,” “hands-on science,” and “professional development” were also used in search strings. (See Appendix A for a listing of web sites and search terms employed.)

A request was sent by email to the National Association for Research in Science Teaching (NARST) listserv soliciting suggestions of published articles or reports that might contain useful research or for copies of unpublished research. Experts in the field of science education research were asked to review the bibliography and make suggestions. In addition, direct requests for information were sent individually to project directors of “exemplary and promising science programs” identified by the Department of Education Expert Panel on
Mathematics and Science Education. The programs contacted included the Biological Sciences Curriculum Studies (BSCS), Project ARIES, Project InSIGHT, Event-Based Science, Foundational Approaches in Science Teaching (FAST), Full Option Science System (FOSS), Great Explorations in Math and Science (GEMS), Modeling Instruction in High School Physics, Phenomena and Representations for the Instruction of Science in Middle Schools (PRISMS), and Science 2000+. Finally, reference lists from books, dissertations, studies and other meta-analyses were examined for potential studies to be included.

Coding of Studies

Characteristics of the studies (moderator variables) were coded in order to investigate the possible influence of some of these variables on effect size. Coded attributes included:

- study number and citation,
- publication type (refereed journal article, dissertation, unpublished report),
- study type (experimental – complete randomization, quasi-experimental – randomization used, quasi-experimental – no randomization, correlational),
- dependent variable [type of test, test name, number of items, content area(s)],
- independent variable (treatment name and description, control and/or alternate treatment),
- length of treatment/study,
- setting and characteristics,
  - schools (number of schools, if selected at random, if unit of analysis, public/private, urban/rural/suburban, size, % free lunch),
  - students (number of students, if selected at random, if assigned at random, if unit of analysis, gender, grade, ethnicity, socioeconomic status), and
  - teacher(s) (number of teachers, if volunteer or selected, age/experience, gender, certification,
• study results [effect size(s), \( \rho(s) \), \( t(s) \), \( F(s) \), eta square(s), omega square(s)],

• study design classification,
  o true random assignment of schools/students to treatment and control groups,
  o quasi-experimental with match of schools/students to achievement and demographics of comparison school/group,
  o quasi-experimental with covariate adjustment for prior achievement differences,
  o quasi-experimental comparison of schools/subjects based a claim of “similarity,”
  o quasi-experimental comparison of schools/subjects to regional, state, or national data,
  o quasi-experimental single-group pre-post comparison,
  o quasi-experimental treatment vs. control pre-post test, or
  o quasi-experimental multiple group ANOVA (Analysis of Variance).

Inter coder Objectivity

In order to establish intercoder reliability, three journal articles were selected at random and coded independently by the senior analyst and two members of the research team. For two of the articles, the degree of objectivity was 90%. Due to the non-inclusion of correlational studies in this meta-analysis, only two items were coded for the third article as the coders stopped after identifying the study as a correlational study. The remainder of the articles for this project was divided between the two members of the research team who coded their respective articles and then submitted them to the senior analyst. The senior analyst then read and coded all of the articles and any differences in coding values were resolved at the discretion of the senior analyst. All of the dissertation material was evaluated and coded by the senior analyst and two recent Ph.D. recipients who possess strong statistical backgrounds.
Criteria for Selection of Studies

In the initial search for studies, liberal criteria were employed and many reports, studies and articles were collected which proved to be unusable for this meta-analysis. For final inclusion in the meta-analysis, rigorous criteria which conformed to the charge from TEA were employed. Studies had to have:

- been published between January 1, 1980, and December 31, 2004,*
- been concerned with K-12 science education in the U.S.,
- used student achievement (or success, performance, etc.) as the dependent variable,
- used science education teaching strategies as independent variables,
- been experimental or quasi-experimental,
- reported effect size (ES) or the statistics necessary to calculate ES (means and standard deviations, $p$ values, ANOVA tables, etc.),
- not been totally correlational,
- been for general education students/classes (not deal exclusively with a special population), and
- not been included more than once (e.g., the same study reported in a conference paper and a journal article).

An indication of the number of studies that were not included and the reasons for non-inclusion are presented in Table 1.

*This time span encompasses the studies conducted since the major science education meta-analyses published in the early 1980s.
Table 1. Frequencies and Reasons for Non-Inclusion

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not fit time frame</td>
<td>*</td>
</tr>
<tr>
<td>Did not concern K-12 science education in the US</td>
<td>58</td>
</tr>
<tr>
<td>Did not use student achievement as DV and/or science education</td>
<td>97</td>
</tr>
<tr>
<td>methodologies as IV</td>
<td></td>
</tr>
<tr>
<td>Was not experimental or quasi-experimental (cannot be correlational)</td>
<td>41</td>
</tr>
<tr>
<td>Did not have ES or necessary data to calculate ES</td>
<td>62</td>
</tr>
<tr>
<td>Was not for general education students (concerned with special</td>
<td>25</td>
</tr>
<tr>
<td>populations)</td>
<td></td>
</tr>
<tr>
<td>Duplicated another study</td>
<td>6</td>
</tr>
<tr>
<td>Other (a meta-analysis report, bibliography, descriptive case study,</td>
<td>48</td>
</tr>
<tr>
<td>position paper, literature review, etc.)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>337</td>
</tr>
</tbody>
</table>

*A large number of studies were not collected because it was immediately obvious that they did not fit within the time frame.

Computation of Effect Size

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 group that received a control treatment. Basic effect size calculations were based on Cohen’s $d$ (Cohen 1988) using the formula:

$$ES = \frac{\overline{X}_T - \overline{X}_C}{S_C}$$

where $d$ is replaced with $ES$ and $\overline{X}_T$ is the mean for the experimental or treatment group, $\overline{X}_C$ is the mean for the control group, and $S_C$ is the standard deviation of the control group.

For studies which employed single group pre-post test designs, the effect size was calculated as

$$ES = \frac{\overline{X}_{post} - \overline{X}_{pre}}{S_{pre}}$$

Where $\overline{X}_{post}$ is the mean for the posttest, $\overline{X}_{pre}$ is the mean for the pretest, and $S_{pre}$ is the standard deviation for the pretest data. The above formulas were used in hand calculations of effect size for many of the articles in this meta-analysis.
These previously cited indicators of effect size are presented as Hedges’ \( g \) in the CMA\(^\circledR\) and involve the following formula:

\[
ES = \frac{X_r - X_c}{S_p}
\]

where \( S_p^2 = \frac{(n_r - 1)^2 S_r^2 + (n_c - 1)^2 S_c^2}{n_r + n_c - 2} \) which is the pooled variance.

In cases in which effect sizes had to be calculated indirectly, that is from \( t \), procedures recommended by Hedges and Becker (1986) were employed:

\[
ES = t \sqrt{\frac{2}{n}} \quad \text{(for equal ns)} \quad \text{and} \\
ES = t \sqrt{\frac{1}{n_r} + \frac{1}{n_c}} \quad \text{(for unequal ns)}.
\]

For the multiple groups ANOVA research designs, the transformation formula used to convert \( F \) to \( ES \) was:

\[
ES = \sqrt{F} \sqrt{\frac{n_r + n_c}{n_r n_c}}
\]

where \( F \) is the obtained ANOVA test statistic and \( n_r \) and \( n_c \) represent respective sample sizes.

If a sample size was less than 30, the standardized mean difference effect size was adjusted by the following formula:

\[
ES' = ES \left[ 1 - \frac{3}{4N - 9} \right]
\]

Calculation of the standard error of each estimate of effect size was accomplished using the following approximation formula:

\[
se = \sqrt{\frac{n_1 + n_2}{n_1 n_2} + \frac{(ES)^2}{2(n_1 + n_2)}}
\]

with \( w = \frac{1}{se^2} \) as the weighting factor for \( ES \).

In order to meet the meta-analytical assumption of independence of effect sizes, only one effect size indicator per study should be represented in an
analysis. If a study used several different outcome measures (for example, some of the dissertations), then there would be more than one effect size for that study. In the present meta-analysis, multiple effect sizes per study were averaged in two ways. If a study used the same subjects with more than one dependent variable (student achievement tests):

- a weighted mean effect size was calculated whenever the sample sizes were very divergent (e.g., $n=15\sim80$), and
- an unweighted mean effect size was calculated whenever the sample sizes were equal or approximately equal.

These averaging procedures resulted in one effect size for each study.

**Statistical Methods and Analyses**

In this study, the software used for calculating the meta-analysis for standard research design studies was Comprehensive Meta-Analysis® from BioStat. This software can produce Cohen’s $d$, Hedges’s $g$, $Q$ values, confidence intervals, fixed effects, random effects, and heterogeneity testing results. An examination of the internal and external validity issues associated with this meta-analysis was accomplished using multiple linear regression of the moderator variables. This latter analysis was performed using SPSS® statistical analysis software.
Results

The results obtained in this investigation are presented in the following sections: (1) Description of Studies, (2) Meta-Analysis Validity Issues, (3) Meta-Analysis for All Studies, (4) Meta-Analysis for Studies Classified by Treatment Categories, and (5) Analysis of Moderator Variables.

Section 1: Description of Studies

Characteristics and Frequencies of the Selected Studies

A breakdown of the characteristics of the studies selected for the meta-analysis is presented in Tables 2 and 3. These characteristics have the potential to influence the effect sizes obtained from the studies.
### Table 2. Frequencies of Variable Characteristics for Included Studies

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Number of Cases</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Publication Year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985 – 1989</td>
<td>7</td>
<td>11.3</td>
</tr>
<tr>
<td>1990 – 1994</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>1995 – 1999</td>
<td>15</td>
<td>24.2</td>
</tr>
<tr>
<td>2000 – 2004</td>
<td>30</td>
<td>48.4</td>
</tr>
<tr>
<td><strong>Publication Type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refereed Journal Article</td>
<td>40</td>
<td>64.5</td>
</tr>
<tr>
<td>Dissertation</td>
<td>18</td>
<td>29.0</td>
</tr>
<tr>
<td>Unpublished Report</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Type of Study</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Complete Randomization)</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>Quasi-Experimental</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Randomization Used)</td>
<td>33</td>
<td>53.2</td>
</tr>
<tr>
<td>(No Randomization)</td>
<td>26</td>
<td>41.9</td>
</tr>
<tr>
<td>Correlational</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Test Content Area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>17</td>
<td>27.4</td>
</tr>
<tr>
<td>Chemistry</td>
<td>12</td>
<td>19.4</td>
</tr>
<tr>
<td>Physics</td>
<td>5</td>
<td>8.1</td>
</tr>
<tr>
<td>Earth Science</td>
<td>7</td>
<td>11.3</td>
</tr>
<tr>
<td>Science</td>
<td>21</td>
<td>33.9</td>
</tr>
<tr>
<td><strong>Study Rating</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental, trt* vs. control</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>Quasi-, match</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Quasi-, similar</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Quasi-, single-group pre-post</td>
<td>14</td>
<td>22.6</td>
</tr>
<tr>
<td>Quasi-, trt* vs. control pre-post</td>
<td>27</td>
<td>43.5</td>
</tr>
<tr>
<td>Quasi-, ANOVA</td>
<td>17</td>
<td>27.4</td>
</tr>
<tr>
<td><strong>Totals (for each variable)</strong></td>
<td><strong>62</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

*trt = treatment group
The study characteristic Length of Treatment is displayed in Table 3. This variable was presented separately because the many levels of this attribute result in numbers of cases that are too small to make any definitive conclusion.

Table 3. Length of Treatment

<table>
<thead>
<tr>
<th>Length (Months)</th>
<th>Number of Cases</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.10</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>.25</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>.50</td>
<td>5</td>
<td>8.1</td>
</tr>
<tr>
<td>.75</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>1.00</td>
<td>8</td>
<td>12.9</td>
</tr>
<tr>
<td>2.00</td>
<td>12</td>
<td>19.4</td>
</tr>
<tr>
<td>3.00</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>4.00</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>5.00</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>7.50</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>8.00</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>9.00</td>
<td>6</td>
<td>9.7</td>
</tr>
<tr>
<td>12.00</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>Missing</td>
<td>10</td>
<td>16.1</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>62</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Dependent Variable

The dependent variable (DV) of this meta-analysis, student achievement, can be referred to by many names (student performance, success, outcomes) and may be evaluated with a multitude of assessment tools. The types of assessments used in the studies and their frequencies are presented in Table 4.

Table 4. Dependent Variable (Test Type)

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Number of Cases</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Standardized-Multiple Science</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Standardized-Single Science</td>
<td>6</td>
<td>9.7</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Standardized-Multiple Science</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Standardized-Single Science</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other type test</td>
<td>47</td>
<td>75.8</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>62</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
In any attempt to synthesize results from different studies, consideration must be given to the validity and reliability of the different forms of the dependent variable (DV) that will be used. In this meta-analysis of studies of science education, 5 different forms of achievement assessment were subjected to scrutiny.

The most often-encountered form of achievement assessment was local teacher- or researcher-developed tests. It is assumed that the instruments constructed by these individuals would possess acceptable levels of logical relevancy since tests were formulated to match the instructional units that were being investigated. The degree of reliability of the teacher-made instruments is unknown as most of the authors did not provide information regarding this characteristic. Therefore, it was necessary to assume that this form of assessment (local type test) was conducted with adequate levels of reliability.

For the 15 studies that used standardized national or local assessments of either multiple or single content areas, an indication of validity was usually not reported but the authors referred to the original developers of the instruments when discussing validity. Most authors gave indications of strong content and construct validity for these forms of assessment. In terms of reliability for these tests, the range of values reported was .70 to .94. Since these assessment tools have been widely used and evaluated, the validities and reliabilities are well within recommended tests and measurement guidelines.

Independent Variables

In order to explore some of the heterogeneity of effect sizes among the studies, the various treatment conditions were cast into treatment categories. Rather than operationally define treatment description categories based on the studies used in this meta-analysis, an established set of teaching strategy categories (Wise, 1996) was modified and employed. The modified list of treatment description categories includes the following:
• **Questioning strategies.** Teachers vary 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, posing comprehension questions to students at the start of a lesson or assignment).

• **Focusing strategies.** Teachers alert students to the intent of the lesson or capture their attention (e.g., providing objectives or reinforcing objectives at the middle or closing of lesson, using advance organizers).

• **Manipulation strategies.** Teachers provide students with opportunities to work or practice with physical objects (e.g., operating apparatus, developing skills using manipulatives, drawing or constructing something).

• **Enhanced materials strategies.** Teachers modify instructional materials (e.g., rewriting or annotating text materials, tape recording directions, simplifying laboratory apparatus).

• **Testing strategies.** Teachers change the frequency, purpose, or cognitive levels of testing/evaluation (e.g., providing immediate or explanatory feedback, using diagnostic testing, formative testing, retesting, testing to mastery).

• **Inquiry strategies.** Teachers use student-centered, inductive instruction that is less step-by-step and teacher-directed than traditional instruction (e.g., using guided or facilitated inquiry activities, guided discoveries, inductive laboratory exercises, indirect instruction).

• **Enhanced context strategies.** Teachers relate learning to students’ previous experiences or knowledge or engage students’ interest through relating learning to the students’/school’s environment or setting (e.g., using problem based learning, taking field trips, using the schoolyard for lessons, encouraging reflection).

• **Instructional technology strategies.** Teachers 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).

- **Direct instruction for teaching process skills.** Teachers explicitly guide students through a sequence of tasks (e.g., designing experiments, using microscope, making measurements).

- **Collaborative learning strategies.** Teachers arrange students in flexible groups to work on various tasks (e.g., conducting lab exercises, inquiry projects, discussions)

A rating sheet (Appendix D) consisting of the treatment categories and a 5-point Likert-type rating scale was developed to sort each study into an appropriate category. Three science educators*, each possessing 20-30 years of public school science instruction experience, read a description of the treatment condition of each study. They then ranked each of the treatment strategies from 1-5 for the study. The strategy category receiving the highest ranking response for a given study was chosen as the treatment category for that study. It should be noted that while ten strategies are listed, only eight were included in the analysis because no studies meeting the criteria were found for **Focusing strategies** or **Direct instruction for teaching process skills.** The analysis of the effect sizes for the different treatment categories is presented in the section concerning Comprehensive Meta-Analysis® (CMA) outcomes. (Table 8)

*These educators were a convenience sample, selected for their expertise in science education and their availability.
Section 2: Meta-Analysis Validity Issues

In this meta-analysis, internal validity is concerned with study quality issues that might influence the effect size obtained for science instruction strategies. Four variables related to internal validity were examined in this study: (a) publication type, (b) type of study, (c) study rating, and (d) dependent variable or achievement test categories.

A reflection of the average effect size, variability and number of studies for each category of these potential threats to internal validity is presented in Table 5.

Table 5. Internal Validity Influences on the Effect Size of Science Instruction Methodologies

<table>
<thead>
<tr>
<th>Publication Type</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refereed Journal Article</td>
<td>.91343</td>
<td>.684264</td>
<td>40</td>
</tr>
<tr>
<td>Dissertation</td>
<td>.28439</td>
<td>.607646</td>
<td>18</td>
</tr>
<tr>
<td>Unpublished Report</td>
<td>1.03267</td>
<td>1.194027</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Study</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental (complete randomization)</td>
<td>.83467</td>
<td>.375075</td>
<td>3</td>
</tr>
<tr>
<td>Quasi-experimental (randomization used)</td>
<td>.52571</td>
<td>.677656</td>
<td>33</td>
</tr>
<tr>
<td>Quasi-experimental (no randomization)</td>
<td>.99608</td>
<td>.775332</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Rating</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental, trt vs. control</td>
<td>.82450</td>
<td>.618718</td>
<td>2</td>
</tr>
<tr>
<td>Quasi-, match</td>
<td>1.55100</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Quasi-, similar</td>
<td>.51000</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Quasi-, single-group pre-post</td>
<td>1.39831</td>
<td>.827382</td>
<td>13</td>
</tr>
<tr>
<td>Quasi-, trt vs. control pre-post</td>
<td>.43407</td>
<td>.574647</td>
<td>27</td>
</tr>
<tr>
<td>Quasi-, ANOVA</td>
<td>.65566</td>
<td>.632238</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Standardized-Multiple Science Content</td>
<td>1.12367</td>
<td>.722053</td>
<td>3</td>
</tr>
<tr>
<td>National Standardized-Single Science Content</td>
<td>.58083</td>
<td>.155080</td>
<td>6</td>
</tr>
<tr>
<td>Local Standardized-Multiple Science Content</td>
<td>.18150</td>
<td>.000707</td>
<td>2</td>
</tr>
<tr>
<td>Local Standardized-Single Science Content</td>
<td>.92350</td>
<td>.504390</td>
<td>4</td>
</tr>
<tr>
<td>Other type test</td>
<td>.73568</td>
<td>.807000</td>
<td>46</td>
</tr>
<tr>
<td><strong>Totals (for each influence)</strong></td>
<td>.73368</td>
<td>.736919</td>
<td>61</td>
</tr>
</tbody>
</table>

*These numbers are 1 less than previously presented due to exclusion of an outlier study.
Because of the diversity in number of studies when these internal validity concerns are fractionated, it is not prudent to address each level separately because the number of studies for each will be few. The influences of these characteristics as a whole are addressed in the section on multiple regression.

External validity deals with generalization issues, such as whether the effect of science instruction strategies could be generalized to other populations or situations. In this study, four variables that might influence external validity were examined: (a) publication year, (b) test content, (c) grade level, and (d) treatment categories.

A reflection of the average effect size, variability and number of studies for each category of these potential threats to internal validity is presented in Table 6.
Table 6. External Validity Influences on the Effect Size of Science Instruction Methodology

<table>
<thead>
<tr>
<th>Publication Year</th>
<th>Mean ES</th>
<th>Mean SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-1984</td>
<td>.61422</td>
<td>.466598</td>
<td>6</td>
</tr>
<tr>
<td>1985-1989</td>
<td>.33086</td>
<td>.163185</td>
<td>7</td>
</tr>
<tr>
<td>1990-1994</td>
<td>1.14650</td>
<td>.543101</td>
<td>4</td>
</tr>
<tr>
<td>1995-1999</td>
<td>.70471</td>
<td>.884399</td>
<td>14</td>
</tr>
<tr>
<td>2000-2004</td>
<td>.81003</td>
<td>.792026</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Content</th>
<th>Mean ES</th>
<th>Mean SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>.48466</td>
<td>.755617</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1.01078</td>
<td>.847695</td>
</tr>
<tr>
<td>Physics</td>
<td>.53680</td>
<td>.258843</td>
</tr>
<tr>
<td>Earth Science</td>
<td>.36643</td>
<td>.504522</td>
</tr>
<tr>
<td>Science</td>
<td>.95940</td>
<td>.719718</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Mean ES</th>
<th>Mean SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary (K-8)*</td>
<td>.65888</td>
<td>.680486</td>
</tr>
<tr>
<td>High School (9-12)</td>
<td>.76027</td>
<td>.761513</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment Categories</th>
<th>Mean ES</th>
<th>Mean SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questioning strategies</td>
<td>.73913</td>
<td>.529271</td>
</tr>
<tr>
<td>Manipulation strategies</td>
<td>.86213</td>
<td>.825688</td>
</tr>
<tr>
<td>Enhanced materials strategies</td>
<td>.41336</td>
<td>.480139</td>
</tr>
<tr>
<td>Testing strategies</td>
<td>.49250</td>
<td>.099702</td>
</tr>
<tr>
<td>Inquiry strategies</td>
<td>.62533</td>
<td>.706671</td>
</tr>
<tr>
<td>Enhanced context strategies</td>
<td>1.42517</td>
<td>1.050396</td>
</tr>
<tr>
<td>Instructional media strategies</td>
<td>.79160</td>
<td>.774321</td>
</tr>
<tr>
<td>Collaborative learning strategies</td>
<td>.58853</td>
<td>.590639</td>
</tr>
<tr>
<td>Totals (for each influence)</td>
<td>.73368</td>
<td>.736919</td>
</tr>
</tbody>
</table>

*When classifying by traditional grade levels, i.e., K-5 as elementary, 6-8 as middle school, the numbers of studies were quite small, therefore these groups were collapsed to the levels presented.
Section 3: Meta-Analysis for All Studies

In order to explore the 62 effect sizes obtained in this study, box plots obtained from SPSS® were constructed. Box plots are used to graphically portray observations that would be judged to deviate substantially from typical values. The first box plot is exhibited in Figure 1.

Figure 1. Box Plot of ES for Total Data (N=62)

Based on this analysis, study #91 was identified as an extreme outlier, meaning that its value is substantially different from the median value. The data for achievement means that were presented in the article were judged to be suspect by the senior analyst. Therefore, this particular report was excluded from the analysis and a new box plot was constructed.

Figure 2 illustrates that after removal of the extreme outlier study, two studies are identified as mild outliers. These studies were not excluded from the meta-analysis since they were within the ±3 ES range.
Figure 2. Box Plot for Data with Extreme Outlier Removed (N=61)

A pictorial representation of the distribution of effect sizes for this meta-analysis is shown in Figure 3.

Figure 3. Histogram for the Obtained Effect Sizes (N=61)
Figure 3 reveals that the largest number of effect sizes occurs in the range of .00 to .50. With the exception of the indicated most frequent range, the distribution of effect sizes is relatively normally distributed.

Based on the box plots and histogram, the data after removal of the extreme outlier was judged to be acceptable for further analysis. A summary of the analysis of effect sizes for the total data set is presented in Table 7. The complete output associated with this analysis is given in Appendix F.

Table 7. Meta-Analysis Result for All Studies

<table>
<thead>
<tr>
<th></th>
<th>N Total</th>
<th>Effect Size</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td>.6696</td>
<td>.6594</td>
<td>.6797</td>
<td>128.9552</td>
<td>.0000</td>
</tr>
</tbody>
</table>

Based on the results across approximately 160,000 observations of students, there is an effect of science instruction methodology on student achievement. The effect size of .6696 translates to a treatment performance level that would be located at the 75 percentile of the control group. This effect size was judged to be statistically different from .00 as indicated by the probability value associated with the $t$ statistic.
Section 4: Meta-Analysis for Studies Classified by Treatment Categories

The analyses of the effect sizes for the treatment categories were effectuated using Comprehensive Meta-Analysis®. A summary of the results of these analyses is presented in Table 8. For comparison purposes, the results for the total group are also exhibited in the table. The complete output for the analyses is exhibited in Appendix F.

<table>
<thead>
<tr>
<th>Treatment Categories</th>
<th>N Total</th>
<th>Effect Size</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>t-Value</th>
<th>Q-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>61 Studies</td>
<td>.6696</td>
<td>.6594</td>
<td>.6797</td>
<td>128.9552</td>
<td>1582.088</td>
</tr>
<tr>
<td>Questioning Strategies</td>
<td>279</td>
<td>.7395</td>
<td>.4927</td>
<td>.9863</td>
<td>5.8992</td>
<td>11.8593</td>
</tr>
<tr>
<td>Manipulation Strategies</td>
<td>1240</td>
<td>.5729</td>
<td>.4565</td>
<td>.6893</td>
<td>9.6546</td>
<td>104.8797</td>
</tr>
<tr>
<td>Enhanced Material Strategies</td>
<td>2450</td>
<td>.2908</td>
<td>.2100</td>
<td>.3716</td>
<td>7.0540</td>
<td>61.5499</td>
</tr>
<tr>
<td>Inquiry Strategies</td>
<td>145722</td>
<td>.6546</td>
<td>.6440</td>
<td>.6651</td>
<td>121.6432</td>
<td>364.4912</td>
</tr>
<tr>
<td>Enhanced Context Strategies</td>
<td>7235</td>
<td>1.4783</td>
<td>1.4167</td>
<td>1.5399</td>
<td>47.0629</td>
<td>147.5931</td>
</tr>
<tr>
<td>Instructional Technology Strategies</td>
<td>1962</td>
<td>.4840</td>
<td>.3916</td>
<td>.5764</td>
<td>10.2746</td>
<td>80.1969</td>
</tr>
<tr>
<td>Collaborative Learning Strategies</td>
<td>641</td>
<td>.9580</td>
<td>.7773</td>
<td>1.1388</td>
<td>10.4083</td>
<td>26.8652</td>
</tr>
</tbody>
</table>

Several interesting and informative results are presented in Table 8. First, the effect sizes for all of the treatment categories exceed the lower effect size benchmark value of .20. Second, two treatment categories, Enhanced Context Strategies and Collaborative Learning Strategies, exceed the upper effect size benchmark value of .80. Third, all of these effect sizes would be judged to be significantly different from zero. The treatment category of Enhanced Material Strategies exhibited an effect size that would be classified as small.
The 95% confidence intervals for the treatment categories are displayed graphically in Figure 4 on the following page.
Figure 4. Graphic Representation of 95% Confidence Intervals for Treatment Categories and Total Data

<table>
<thead>
<tr>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>.20</td>
</tr>
<tr>
<td>Questioning Strategies</td>
</tr>
<tr>
<td>Manipulation Strategies</td>
</tr>
<tr>
<td>Enhanced Material Strategies</td>
</tr>
<tr>
<td>Testing Strategies</td>
</tr>
<tr>
<td>Inquiry Strategies</td>
</tr>
<tr>
<td>Enhanced Context Strategies</td>
</tr>
<tr>
<td>Instructional Technology Strategies</td>
</tr>
<tr>
<td>Collaborative Learning Strategies</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Figure 4 clearly shows that the treatment category of Enhanced Context Strategies is more efficacious than the other strategies. Many of the confidence intervals for the other treatment strategies contain overlapping ranges.

The central tendency values for the 8 treatment strategies are displayed in bar chart form in Figure 5.

Figure 5. Mean Effect Sizes for Treatment Categories and Total Data

*Note: C1=Questioning Strategies  
C2=Manipulation Strategies  
C3=Enhanced Material Strategies  
C4=Testing Strategies  
C5=Inquiry Strategies  
C6=Enhanced Context Strategies  
C7=Instructional Technology Strategies  
C8=Collaborative Learning Strategies

When making decisions based on the results of meta-analysis, one is always concerned with what is known as the “file drawer problem.” This problem refers to the idea that only studies that result in an effect are included in a meta-analysis. Studies that did not uncover an effect are usually filed away by the researchers and are not
available for inclusion. A calculation that attempts to address this concern is the *Failsafe N* ($N_{fs}$). The obtained numerical value from this statistic is an estimate of the number of non-significant “file drawer” studies that would need to be obtained and included in a meta-analysis before a statement of no effect would be given to the completed meta-analysis. *Failsafe Ns* for the total data set and the studies in the treatment categories are exhibited in Table 9.

### Table 9. Failsafe N for Total Data and Treatment Description Categories

<table>
<thead>
<tr>
<th>Data</th>
<th>ES</th>
<th>N</th>
<th>$N_{fs}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>.6696</td>
<td>61</td>
<td>756</td>
</tr>
<tr>
<td>Questioning Strategies</td>
<td>.7395</td>
<td>3</td>
<td>42</td>
</tr>
<tr>
<td>Manipulation Strategies</td>
<td>.5729</td>
<td>8</td>
<td>84</td>
</tr>
<tr>
<td>Enhanced Material Strategies</td>
<td>.2908</td>
<td>12</td>
<td>58</td>
</tr>
<tr>
<td>Testing Strategies</td>
<td>.5052</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Inquiry Strategies</td>
<td>.6546</td>
<td>12</td>
<td>145</td>
</tr>
<tr>
<td>Enhanced Context Strategies</td>
<td>1.4783</td>
<td>6</td>
<td>172</td>
</tr>
<tr>
<td>Instructional Technology Strategies</td>
<td>.4840</td>
<td>15</td>
<td>130</td>
</tr>
<tr>
<td>Collaborative Learning Strategies</td>
<td>.9580</td>
<td>3</td>
<td>55</td>
</tr>
</tbody>
</table>

Based on the estimates presented in Table 9, the only questionable treatment category effect size in terms of a file drawer problem is for Testing Strategies. If 19 non-significant results were found in file drawers, a decision of no effect for this strategy would be stated. The resultant $N_{fs}$ for the overall data would lead one to conclude that a decision to deny an effect is not probable given that approximately 756 non-significant studies would be needed to reverse the decision about the overall effect.
Section 5: Analysis of Moderator Variables

The moderator variables were placed in a multiple regression analysis to determine the influence of all the coding components on the effect size data. A summary of the SPSS® results is presented in Tables 10 and 11 and the complete printout is exhibited in Appendix G.

Table 10. Regression Analysis for Moderator Variables

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>4.243</td>
<td>9</td>
<td>.471</td>
<td>1.102</td>
<td>.383</td>
</tr>
<tr>
<td>Residual</td>
<td>17.536</td>
<td>41</td>
<td>.428</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>21.778</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11. Regression Analysis: Dependent Variable: Effect Size (N=61)

<table>
<thead>
<tr>
<th>Moderator Variable</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of study</td>
<td>.151</td>
<td>1.052</td>
<td>.297</td>
</tr>
<tr>
<td>Grade Level</td>
<td>.067</td>
<td>.474</td>
<td>.638</td>
</tr>
<tr>
<td>Treatment Categories</td>
<td>.036</td>
<td>.254</td>
<td>.801</td>
</tr>
<tr>
<td>Publish Type</td>
<td>-.233</td>
<td>-1.591</td>
<td>.118</td>
</tr>
<tr>
<td>Study Rating</td>
<td>-.181</td>
<td>-1.279</td>
<td>.207</td>
</tr>
<tr>
<td>Test Content</td>
<td>.064</td>
<td>.438</td>
<td>.663</td>
</tr>
<tr>
<td>Dependent Variable</td>
<td>.066</td>
<td>.488</td>
<td>.628</td>
</tr>
<tr>
<td>Publication Year</td>
<td>.117</td>
<td>.696</td>
<td>.489</td>
</tr>
<tr>
<td>Length of Treatment</td>
<td>.342</td>
<td>1.532</td>
<td>.133</td>
</tr>
</tbody>
</table>

Note. $R^2 = .167$. The effect size outlier had been excluded in this analysis.

From the results of the regression analysis, it can be seen that the F ratio associated with this data indicates that there is not a relationship between the moderator variables and the dependent variable of effect size. The beta weights for the regression were all judged to be non-significant. This means that the effect sizes obtained in this meta-analysis are not influenced by the fact that the studies have different levels of these potentially contaminating attributes.
Conclusions

What teaching methodologies have been shown to improve student achievement in science? 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 12.

Table 12. Ranking of Teaching Strategies

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Effect Size</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced Context Strategies</td>
<td>1.4783</td>
<td>1</td>
</tr>
<tr>
<td>Collaborative Learning Strategies</td>
<td>.9580</td>
<td>2</td>
</tr>
<tr>
<td>Questioning Strategies</td>
<td>.7395</td>
<td>3</td>
</tr>
<tr>
<td>Inquiry Strategies</td>
<td>.6546</td>
<td>4</td>
</tr>
<tr>
<td>Manipulation Strategies</td>
<td>.5729</td>
<td>5</td>
</tr>
<tr>
<td>Testing Strategies</td>
<td>.5052</td>
<td>6</td>
</tr>
<tr>
<td>Instructional Technology Strategies</td>
<td>.4840</td>
<td>7</td>
</tr>
<tr>
<td>Enhanced Material Strategies</td>
<td>.2908</td>
<td>8</td>
</tr>
</tbody>
</table>

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 utilizing 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 settings including grade level of students and subject area within science.
The teaching strategy category that exhibited the largest effect size was Enhanced Context Strategies. Teachers 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. (p. 19)
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. (p. 20)
3. The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas. (p. 21) Students should be encouraged to reflect on their learning through journaling and self-assessment activities.

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.
References


Studies Included in Meta-analysis*


Frederick, L. R., & Shaw, E. L., Jr. (1998, November 4-6). Examining the effects of science manipulatives on achievement, attitudes, and journal writing of elementary science students. Paper presented at


Lavoie, D. R. (1999). Effects of emphasizing hypothetico-predictive reasoning within the science learning cycle on high school student’s process skills and conceptual understandings in biology. *Journal of Research in Science Teaching, 36*(10), 1127-1147. (64)


* Number in parentheses at end of citation is study number.
Appendix A
Web Sites and Search Terms
Web Sites

Berkeley National Laboratory (http://www.lbl.gov/Science-Articles/)
Department of Education (http://www.ed.gov/index.jhtml)
National Academies (http://www.nas.edu/)
National Science Resources (http://www.nsrconline.org/)
American Association for the Advancement of Science (AAAS) (http://www.aaas.org/programs/education/)
Education Development Center (http://main.edc.org/)
National Science Teachers Association (http://www.nsta.org/resources)

Search Terms

authentic science & achievement
authentic science & student achievement
authentic science & student outcomes
authentic science & student performance
biology & achievement
biology & student achievement
biology & student outcomes
biology & student performance
chemistry & achievement
chemistry & student achievement
chemistry & student outcomes
chemistry & student performance
constructivis* & science & student outcomes
constructivis* & science & teaching
constructivis* & science & teaching & achievement
constructivist & science
constructivist & science & student achievement
constructivist science & achievement
constructivist science & student achievement
constructivist science & student outcomes
constructivist science & student progress
discovery learning & achievement
discovery learning & student achievement
discovery learning & student achievement
earth & student achievement
earth & student achievement & science
earth & student outcomes
earth & student outcomes & science
earth & student performance
earth & student performance & science
earth science & achievement
ecology & student achievement
ecology & student outcomes
ecology & student outcomes & science
ecology & student performance
elementary school science & achievement
environmental education and student*
environmental science and student performance
hands-on science & achievement
hands-on science & outcome*
hands-on science & performance
hands-on science & student achievement
hands-on science & student outcome*
hands-on science & student performance
middle school science & achievement
physic* & student achievement
physic* & student achievement & science
physic* & student outcomes
physic* & student outcomes & science
physic* & student performance
physic* & student performance & science
physic* science & achievement
physic & achievement
professional development & achievement & science
professional development & science
professional development & science teaching
professional development & student achievement & science
science & achievement
science & class* performance
science & curriculum assessment
science & education & treatment & control & (achievement or outcome* or success)
science & student achievement
science & student outcome
science & student performance
science & student progress
science & student success
science education & achievement
science education & curriculum assessment
science education & progress
science education & student achievement
science education & student outcome
science education & student performance
science education & student progress
science education & student success
science learning & achievement
science learning & student achievement
science learning & student outcome
teaching methods & science & achievement
teaching methods & science achievement
Appendix B
Bibliography of Studies and Articles


Keller, B. J. (1997). *Effect of three different types of high school class schedules (traditional, rotating block, and accelerated block) on high school biology achievement and on differences in science learning environments*. Unpublished Ph.D., University of North Texas, United States -- Texas.


Smith, J. R. (2004). *Differences in student achievement between block period schools and nonblock period schools in the state of Mississippi.* Unpublished Ph.D., The University of Southern Mississippi, United States -- Mississippi.


Triona, L. M., & Klahr, D. (2003). Point and click or grab and heft: Comparing the influence of physical and virtual instructional materials on elementary school students' ability to design experiments. *Cognition And Instruction, 21*(2), 149-173.


Appendix C

Literature Coding Document
CODING OF LITERATURE FOR SCIENCE INITIATIVE META-ANALYSIS

1-3 Study number & citation


5. Type of study: 1 Experimental (complete randomization)  
2 Quasi – experimental (randomization used)  
3 Quasi-experimental (no randomization)  
4 Correlational

6. Dep. Var.: 1 National Standardized Multiple Science content  
2 National Standardized Single Science content  
3 Local Standardized Multiple Science Content  
4 Local Standardized Single Science Content  
5 Other type test

7. Ind. Var.: TRT. Name__________________________________________________________ 
TRT. Description______________________________________________________________ 
TRT vs ________________________________________________________________ 
Course ___________________________

8. Length of TRT: _______ Months _______ Years

9. Setting & Characteristics:
   A. School(s): # of schools___, Selected at random? 1 Yes 2 No, Unit of analysis? 1 Yes 2 No
      1 Public 2 Private, 1 Urban 2 Rural
      1 Small (n=_____), 2 Med (n=____), 3 Lrg (n=____)
      % Free Lunch__________

   B. Students: # of students___, Selected at random? 1 Yes 2 No
      Assigned at random? 1 Yes 2 No, Unit of analysis? 1 Yes 2 No
      1 Mixed Gender 2 Female 3 Male
      1 Same Grade 2 Multiple Grades
      Grade _____ n=___, Grade _____ n=___, Grade _____ n=___, Grade _____ n=___
      1 Mixed Ethnicity 2 Single ethnic grp
      1 Mixed Socio 2 Single Socio, Primary Socio Status____________________

   C. Teacher(s): # of teachers_____, 1 volunteer 2 selected
      Teacher(s) description: Age/Exp________Gender______ Certification__________

10. Study results: Effect size (s) ____, p(s) ___, t(s) ___, F(s) ___, Eta Square(s) ___, Omega Square(s) ___

11. Study rating: 1 True random assignment of schools/students to TRT and Control
    2 Quasi-experimental with match of schools/students to achievement and demographics of comparison school
    3 Quasi-experimental with covariate adjustment for prior achievement
    4 Quasi-experimental comparison of schools/subjects based on a claim of similar
    5 Quasi-experimental comparison of schools/subjects to region, state, or national data
    6 Quasi-experimental single-group pre-post comparison
    7 Quasi-experimental treatment vs. control pre-posttest
    8 Quasi-experimental multiple group ANOVA

12. Notes/comments:
Appendix D
Treatment Description Category Classification Form
Study Treatment Category Rating

Study Number: __________       Judge: 1, 2, 3

1: unknown or not mentioned
2: mentioned
3: a small portion of the treatment
4: moderate portion of the treatment
5: largest portion of the treatment

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Notes/comments:
Appendix E
Treatment Description Summaries
Summary of Treatment Description

#1 Treatment Name
web-based, constructivist-oriented homework assignment.

Treatment description
web-enhanced assignments covering DNA structure and function, Genetics and Microbiology
Members of the experimental group participated in online homework activities for approximately eight weeks. The activities included participation in (a) online simulations, (b) asynchronous discussions, (c) Webquests, (d) cooperative concept map construction activities using synchronous chat technology, (e) online quizzes, and (f) personal, biweekly journaling activities.

#4 Treatment Name
Studio Model (both synchronously & asynchronously)

Treatment description
Studio Model and the use of supplemental on line materials/Tech & cooperative groups
There are two characteristics surrounding the usage of the Studio Model. The first is the use of the technology (both synchronously and asynchronously) to give students the ability or means to see concepts or materials in multiple perspectives. The second is the integration of cooperative group activities. The cooperative group structure used for this study was the Student Team-Achievement Division (STAD).

#6 Treatment Name
The University of Alabama's Integrated Science (IS) Program enhanced with PowerPoint technology

Treatment description
The University of Alabama's Integrated Science Program enhanced with PowerPoint technology. Resources provided by the IS program include telecasts, teacher manuals, student books, science kits, and teacher professional development.

#609 Treatment Name
The University of Alabama's Integrated Science Program (IS)

Treatment description
The University of Alabama's Integrated Science Program (IS) Resources provided by the IS program include telecasts, teacher manuals, student books, science kits, and teacher professional development.

#7 Treatment Name
Computer-assisted instruction (CAI)

Treatment description
Computer software for animal and plants adaptation in desert. The Digital Field Trip to the Desert (2000) simulation software, designed by Digital Frog International Inc., on fourth-grade students’ achievement and attitudes toward desert issues. The software is designed as a tool that may be used by students individually or in small groups at their own pace with minimum amount of supervision.

#21 Treatment Name
Constructivist Based Instruction

Treatment description
Constructivist based instruction--application of students’ prior knowledge; human experiences and values, both culturally and socially determined, were incorporated into the classroom; student empowerment; critical thinking; opportunities were given students to exercise a degree of control over their learning environment; enable students to evaluate their own conceptual development.
#25 Treatment Name
Web-Based Physics Software Program

Treatment description
Web-Based Physics Software Program "The Physics Classroom". This program consists of three modules or sections: study topics, multimedia section, and quiz room.
The multimedia section contains many animations. These animations visualize many ideas and misconceptions in order to make learning easy and dispel many preconceptions.
The quiz room contains many quizzes related to study topics and gives deep understanding of each lesson. Each question in the quiz has a link to the related lesson if there is problem with understanding or solving this question.
The web-based physics program was incorporated with the normal lecture. 30% of class time was allocated to using this tutorial program, and 70% of class time was used for normal lecture.

#29 Treatment Name
Integrated Science (IS) Curriculum Program

Treatment description
Integrated, activity-based science curriculum. Resources provided by the IS program include telecasts, teacher manuals, student books, science kits, and teacher professional development.

#30 Treatment Name
Dynamic particle models--both static & dynamic

Treatment description
Computer assisted instruction
Cooperative learning group analysis and teacher-directed class discussion.
Dynamic class used both static and dynamic particle models and explanations in dynamic classes.
Dynamic classes acted out particle motion. Dynamic classes watched particle movement and collisions illustrated with computer animations.

#300 Treatment Name
Dynamic particle models--both static & dynamic

Treatment description
Computer assisted instruction
Cooperative learning group analysis and teacher-directed class discussion.
Dynamic class used both static and dynamic particle models and explanations in dynamic classes.
Dynamic classes acted out particle motion. Dynamic classes watched particle movement and collisions illustrated with computer animations.

#32 Treatment Name
Multiple teaching strategies

Treatment description
Multiple teaching strategies (teachers modify their teaching style to fit the many different types of students)
The teachers were trained in the use of learning activities that require the utilization of four or more teaching strategies in class on a regular basis. Those strategies include activities such as simulations, role-playing, use of manipulative, computer, or other learning activities.

#33 Treatment Name
Multisensory instruction
Treatment description
instructional strategy and student's perceptual preferences
The multisensory unit included five instructional stations established in different sections of the classroom to allow students to learn by: (a) manipulating Flip Chutes, (b) using Electroboards, (c) assembling Task Cards, (d) playing a kinesthetic Floor Game, (e) reading an individual Programmed Learning Sequence. Audio tapes and scripts were provided at each section. Students circulated in groups of four from station to station. Students reviewed with the multisensory resources for 15 minutes prior to the posttest.

#36 Treatment Name
Laboratory experiences

Treatment description
the use of laboratory experiences to introduce classroom discussion and included lab-based performance activities to assess achievement
The laboratory activities presented a question and required that the student provide an answer to that question based on the collection and analysis of data. Emphasis was placed on the need to record accurate descriptions and measurements and to analyze data mathematically and graphically.

#38 Treatment Name
Constructivist informed pedagogy

Treatment description
Constructivist informed pedagogy manipulative
The constructivist teacher employed a lesson plan that was less didactic and used cooperative learning groups. Open-ended laboratory investigations, a high amount of technology, and a higher amount of student-initiated dialog among themselves as well as with the instructor. The constructivist teacher was also concerned with the identification of misconceptions, the use of probing questioning, and the learning cycle. Constructivist learning can be equated with the student’s gaining a higher level of inquiry regarding the work of science, connecting science with their own lives, and grasping main science concepts.

#39 Treatment Name
Computer-enhanced instruction (CEI)

Treatment description
Computer-enhanced instruction (CEI) using A.D.A.M. The Inside Story (1997) anatomy software. Students in the CEI class used A.D.A.M. The Inside Story (1997) software and worked in groups of three at the computers during normal class time. Students in both treatment and control classes received the same lectures, textbook reading assignments, study guides, prepared notes, and written assignments. In contrast to the control group class where the teacher functioned primarily as a disseminator of knowledge, the teacher functioned more as a facilitator in the CEI class.

#41 Treatment Name
Inquiry-based instruction

Treatment description
Predominately inquiry-based instruction
Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Teachers in non-block scheduled schools assigned more extended projects and student research; discuss their ideas and opinions. Teacher used cooperative learning and small group work more frequently in block scheduled classes.
#47 Treatment Name
Interactive CD tutorial

Treatment description
CD tutorial for frog dissection
Digital Frog is an interactive CD-ROM that incorporates full-motion video, animations, sounds, narration, in-depth text, full color photographs and a comprehensive workbook in three modules – Dissection; Anatomy, and Ecology. The dissection module uses a tutorial approach with the dissection proceeding in a step by step presentation manner. User can access multimedia files to view a frog dissection being performed, but does not actually "perform" a dissection themselves.

#470 Treatment Name
Desktop Microworld

Treatment description
CD tutorial for frog dissection
The Desktop Microworld environment was built around Operation Frog on CD with other programs serving as auxiliary forms of instructional delivery. Operating Frog contains a tutorial simulation of the dissection of a frog, male or female. Operation Frog allows students to actually perform the dissection, not just view it.

#48 Treatment Name
Technology (GIS)-supported mapping Project Based Learning (PBL) unit

Treatment description
PBL, used GIS mapping technology for data analysis. The control group used a PBL science unit with paper mapping to support data analysis activities, while the experimental group used a PBL-GIS model. Experimental classrooms used ESRI’s ArcExplorer II as a desktop GIS application, with base data (roads, rails, hydrography, and airports) identical to the control group. All experimental classrooms had equal access to technology and related materials in a single, communal lab.

#50 Treatment Name
Scientific Writing Heuristic (SWH)

Treatment description
Students used the SWH student templates to guide their written work for laboratory activities. (writing format for 3 lab activities; meaning-making pedagogy)

#500 Treatment Name
Scientific Writing Heuristic and Textbook group (STG)

Treatment description
Students in these sections used the SWH for their laboratory activities; however, their written project to summarize the practical activities was different. They were asked to write their summary in the form of a textbook explanation for their peers. (writing format for 3 lab activities; meaning-making pedagogy)

#57 Treatment Name
Integrated Video Media

Treatment description
Integrated video media-World of Chemistry. These micro-units include teacher lesson guides associated with each 30-min World of Chemistry videotape designed to enable the teacher to stop the videotape approximately every 5-7 min for a teacher-student question-answer interaction time.

#60 Treatment Name
Design-Based Science (DBS)
DBS has much in common with other inquiry-based programs.

**Treatment description**
Students engaging in design projects to learn science: *Extreme structures*

**#600 Treatment Name**
Design-Based Science (DBS)
DBS has much common with other inquiry-based programs.

**Treatment description**
Students engaging in design projects to learn science: *Environmentally safe batteries*

**#601 Treatment Name**
Design-Based Science (DBS)
DBS has much common with other inquiry-based programs.

**Treatment description**
Students engaging in design projects to learn science: *Safer cellular phones*

**#64 Treatment Name**
HPD-LC (hypothetico-prediction-discussion learning cycle)

**Treatment description**
Adding a prediction/discussion phase to learning cycle. Two hypothetico-predictive problem sheets were prepared for each HPD-LC lesson. Each sheet required the student to make prediction in writing or graphically, and to support it with an explanatory reason (i.e., hypothesis), also in writing.

**#70 Treatment Name**
advance questioning

**Treatment description**
Basic lesson (B), Basic + orienting questions (B+Q), Basic+orienting questions+rationale (B+Q+R) conceptual orienting questions plus rationale.

**#75 Treatment Name**
*Molecular Workbench* (a two-dimensional molecular dynamics application written in Java software)
molecular dynamic system vs. *Pedagogica*, a control environment

**Treatment description**
online molecular dynamics mode: States of Matter

**#750 Treatment Name**
*Molecular Workbench* molecular dynamic system Vs. *Pedagogica*, a control environment

**Treatment description**
online molecular dynamics mode: Atoms in Motion

**#78 Treatment Name**
Center for Learning Technologies in Urban Schools (LeTUS)

**Treatment description**
Inquiry-based and technology-infused curriculum units (standards based curriculum, prof. developed, 4 units taught): Air

**#780 Treatment Name**
Center for Learning Technologies in Urban Schools (LeTUS)
**Treatment description**
Inquiry-based and technology-infused curriculum units (standards based curriculum, prof. developed, 4 units taught): Water

**#781 Treatment Name**
Center for Learning Technologies in Urban Schools (LeTUS)

**Treatment description**
Inquiry-based and technology-infused curriculum units (standards based curriculum, prof. developed, 4 units taught): Helmets

**#782 Treatment Name**
Center for Learning Technologies in Urban Schools (LeTUS)

**Treatment description**
Inquiry-based and technology-infused curriculum units (standards based curriculum, prof. developed, 4 units taught): Big Things

**#90 Treatment Name**
Concrete (hands-on) instruction vs. formal instruction

**Treatment description**
Concrete instruction was organized around the learning cycle approach and involved an emphasis upon hands-on activities; three phases: exploration, conceptual invention, and discovery (or application).

**#91 Treatment Name**
HASP (Hands-on Activity Science Program) inquiry-based program

**Treatment description**
Incorporated exemplary curriculum using modules, Full Option Science System (FOSS), incorporating manipulatives into elementary science

**#98 Treatment Name**
Science/Technology/Society (STS) format

**Treatment description**
Use societal issues as organizers for their study; study science in more community/citizenship activities rather than focus on knowledge and process

**#142 Treatment Name**
Kids as Global Scientists Weather (KGS) Program consists of a systematic, curricular approach to fostering students’ deep conceptual understanding of weather content

**Treatment description**
The use of a suite of learning tools designed specifically with inquiry science in mind. Tools include KGS curriculum, KGS software. (Urban teachers)

**#1420 Treatment Name**
Kids as Global Scientists Weather (KGS) Program consists of a systematic, curricular approach to fostering students’ deep conceptual understanding of weather content

**Treatment description**
The use a suite of learning tools designed specifically with inquiry science in mind. Tools include KGS curriculum, KGS software. (Maverick teachers)
#150 Treatment Name
“Local Systemic Change Initiatives” (LSC)

Treatment description
Professional development (changing teaching practices, strengthening teacher content knowledge, and providing hands-on science materials for classrooms), hands-on act, kits

#166 Treatment Name
Level of group cooperation

Treatment description
Cooperative goal structure (role assignment & nonrole assignment)
For the role assignment group, each student was assigned a specific role (i.e., manager, investigator, and recorder) but students in both traditional and nonrole assignment groups were not assigned a role.

#170 Treatment Name
Detailed assignments

Treatment description
Detailed assignments (favoring field independence and induction) employed block diagrams and stepwise direction. Nondetailed assignments (favoring field dependence and deduction) virtually lacked these.

#229 Treatment Name
Alternative science teaching methods

Treatment description
Traditional (lecture, drill, practice) vs. teacher-constructed self-teaching manipulatives vs. student-constructed self-teaching manipulatives

#245 Treatment Name
Instructional Strategy change

Treatment description
Middle school interdisciplinary team strategy

#247 Treatment Name
Hands-on lab activities

Treatment description
Cell biology unit with hands-on lab activities

#276 Treatment Name
Hands-on laboratory method

Treatment description
Students manipulated lab apparatus in small groups

#278 Treatment Name
Resequencing general science content

Treatment description
Revising the order of textbook chapters, in order to clarify content structure and establish interrelationships among major concepts. (content arranged into interrelated pattern)

#281 Treatment Name
Wait-time after teacher questioning
Treatment description
Teachers assigned wait-times of 1, 3, & 5 sec.

#2810 Treatment Name
Wait-time after teacher questioning

Treatment description
Teachers assigned wait-times of 1, 3, & 5 sec.

#285 Treatment Name
Single-sex & mixed sex cooperative interaction

Treatment description
In the cooperative conditions, subjects were instructed to work together as a group, completing the task as a group with all members sharing one set of materials and helping each other. They were instructed to make sure that each member was involved, and that they should check to make sure every member knew the materials and could explain the answers on the group’s data sheets.

#369 Treatment Name
Scope, Sequence and Coordination (SS&C) project

Treatment description
Extension from Chautauqua Model, constructivist learning model (CLM): invitation phase, exploration phase, coordination, implementation phase. integrated science; hands-on/minds-on ; problem centered

#433 Treatment Name
Concrete Instruction (learning cycle) First-hand experience

Treatment description
During the exploration phase of the learning cycle, students were usually provided with concrete materials and written directions for their use in gathering data about the concept to be learned. These direction sheets provided guidelines to help the students observe, compare, measure, and experiment, as they interacted with the selected concrete materials.

#434 Treatment Name
Concrete-the learning cycle inquiry

Treatment description
The instruction of the inquiry group was based upon the teaching concept designed and implemented by the Science Curriculum Improvement Study and called the learning cycle. Hands-on exploration, conceptual invention, discovery.

#439 Treatment Name
Science-Based Reading Strategies

Treatment description
Teachers implemented an in-depth science teaching program by expanding the lesson plans in their science textbook, Journeys in Science, to emphasize an integrated approach to science concept instruction through hands-on science activities, science process skills, and science textbook/ tradebook reading assignments.

#448 Treatment Name
Supported Inquiry Science (SIS), constructivist learning theory

Treatment description
SIS principles: 1. provide a safe environment for expressing emerging or divergent ideas. 2. Design curricula and instruction to focus on a unifying concept. 3. Elicit students’ alternative conceptions and provide opportunities for them to examine conflicting evidence and reconstruct their ideas over time. 4. Use recursive, whole-class coaching to help students elaborate and revise their understanding. 5. Integrate opportunities for students to work with new material individually as well as in whole-class and small-group work. 6.–8.

### #451 Treatment Name
Concept Relatedness

**Treatment description**
Instructional materials consisted of an explicit study, a reading supplement, and an activities supplement. The experimental study guide began with an introduction which explained how concepts and principles are important in the learning process and how to prepare a concept map. In addition, it included conceptual cues which reminded students of the importance of major concepts to related activities and readings.

### #452 Treatment Name
Constructing Physics Understanding Project (CPU): Lead CPU Students

**Treatment description**
Computer-based modular curriculum activities: The CPU project produced modular content units and computer software, to support an environment where students, individually, in small groups, and as a whole class construct knowledge in physics.

### #4520 Treatment Name
Constructing Physics Understanding Project (CPU): Beginning CPU students

**Treatment description**
Computer-based modular curriculum activities: The CPU project produced modular content units and computer software, to support an environment where students, individually, in small groups, and as a whole class construct knowledge in physics.

### #455 Treatment Name
Diagnostic-Prescriptive Teaching

**Treatment description**
Teacher-managed diagnostic-prescriptive assistance: Using progress checks (diagnostic tests) and review activities (prescriptive remediation) developed for this study.

### #457 Treatment Name
Modified Mastery Learning strategy

**Treatment description**
Instruction for all classes was characterized by a blend of lecture, question-answer sessions, laboratory work, demonstrations, and audio-visual materials. Teacher-directed remediation and student-directed remediation (diagnostic quizzes and remediation activities).

### #467 Treatment Name
Computer-animated dissection techniques

**Treatment description**
Use CD-ROM dissection tool "Dissection Works"

### #468 Treatment Name
Full Option Science System (Foss)
Treatment description
Use science manipulatives, hands-on/minds-on activities

#475 Treatment Name
Simulation before dissection (SBD) vs. dissection only (DO)

Treatment description
Combinations of actual & simulated frog dissection
Appendix F
Comprehensive Meta-Analysis Output
## Meta Analysis

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Favors A  Favor B
## Meta Analysis for Student achievement Q1

### Basic statistics

Number of outcomes = 3  
Number of individual cases = 279

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### Meta Analysis for Student achievement Q2

#### Basic statistics

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Number of individual cases = 1240

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### Meta Analysis for Student achievement Q3

**Basic statistics**

Number of outcomes = 12  
Number of individual cases = 2450

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Meta Analysis for Student achievement Q4

Basic statistics

Number of outcomes = 2
Number of individual cases = 166

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Meta Analysis for Student achievement Q5

Basic statistics

Number of outcomes = 12
Number of individual cases = 145722

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## Meta Analysis for Student achievement Q6

### Basic statistics

Number of outcomes = 6  
Number of individual cases = 7235

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## Meta Analysis for Student achievement Q7

### Basic statistics
Number of outcomes = 15  
Number of individual cases = 1962

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### Meta Analysis for Student achievement Q8

**Basic statistics**

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Number of individual cases = 641

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## Meta Analysis for all studies

### Basic statistics

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Number of individual cases = 159695

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Appendix G
Regression Output
Regression without Length of Treatment

Variables Entered/Removed

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<th>Variables Removed</th>
<th>Method</th>
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<td>Enter</td>
</tr>
</tbody>
</table>

a. All requested variables entered.
b. Dependent Variable: Effect Size

Model Summary

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<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
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<td>.167</td>
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a. Predictors: (Constant), Publication Year, Dependent Variable, gradescode, Publish Type, Treatment Categories, Study Rating, Type of study, Test Content code

ANOVA

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a. Predictors: (Constant), Publication Year, Dependent Variable, gradescode, Publish Type, Treatment Categories, Study Rating, Type of study, Test Content code
b. Dependent Variable: Effect Size
Regression with Length of Treatment

### Variables Entered/Removed

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#### a. All requested variables entered.

#### b. Dependent Variable: Effect Size
### Model Summary

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a. Predictors: (Constant), Length of TRT (month), Treatment Categories, gradescode, Type of study, Publish Type, Study Rating, Test Content code, Dependent Variable, Publication Year

### ANOVAa

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a. Predictors: (Constant), Length of TRT (month), Treatment Categories, gradescode, Type of study, Publish Type, Study Rating, Test Content code, Dependent Variable, Publication Year

b. Dependent Variable: Effect Size

### Coefficientsa

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</table>

a. Dependent Variable: Effect Size
Appendix H
Formulas
1. \( ES = \frac{\bar{X}_T - \bar{X}_C}{Sc} \) where pre-tests were assumed to provide equivalent groups

\( \bar{X}_E = \) mean of experimental group (post-test)
\( \bar{X}_C = \) mean of control group (post-test)
\( Sc = \) standard deviation of control group

2. Hedge’s \( d \) used in Comprehensive Meta-Analysis software

\[
ES = \frac{\bar{X}_T - \bar{X}_C}{S_p} \quad \text{where} \quad S_p^2 = \frac{(n_T - 1)S_T^2 + (n_C - 1)S_C^2}{n_T + n_C - 2}
\]

3. \( ES = t \sqrt{\frac{2}{n}} \) for \( n_T = n_C = n; n = \) sample size of each group

4. \( ES = t \sqrt{\frac{1}{n_T} + \frac{1}{n_C}} \) for unequal \( n \)

5. \( ES = \sqrt{F} \sqrt{\frac{n_T + n_C}{n_T n_C}} \)

6. \( ES' = ES\left[1 - \frac{3}{4N-9}\right] \) small sample size \((N<30)\) adjusted with bias correction formula

7. \( se = \sqrt{\frac{n_1 + n_2}{n_1 n_2} + \frac{(ES)^2}{2(n_1 + n_2)}} \)

8. \( w = \frac{1}{se^2} \)

9. Weighted average effect size: \( \overline{ES} = \frac{\sum (w \times ES)}{\sum w} \)

10. Standard Error \( (se) \) of the \( \overline{ES} \), \( se_{\overline{ES}} = \sqrt{\frac{1}{\sum w}} \)

11. Z-test for the \( \overline{ES} \), \( Z = \frac{\overline{ES}}{se_{\overline{ES}}} \)

12. 95% Confidence Interval

\[
Lower = \overline{ES} - 1.96\left(se_{\overline{ES}}\right)
\]
$$Upper = \overline{ES} + 1.96\left(\text{se}_e\right)$$

13. Testing Homogeneity of Effect Size

$$Q_T = Q_B + Q_W$$

$$Q_T = \sum_{i=1}^{k} w_i (ES_i - \overline{ES})^2$$

$$Q_B = \sum_{j=1}^{n} w_j (ES_j - \overline{ES})^2$$

14. Failsafe $N$ or $N_{fs}$

$$N_{fs} = N \cdot \frac{\left(\overline{ES} - \overline{ES}_c\right)}{\overline{ES}_c}$$

where $N$ = # of studies in the meta-analysis

$\overline{ES} =$ average $ES$ for the studies in the meta-analysis

$\overline{ES}_c =$ criterion $ES$