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No Child Left Behind Act: implications and strategies for middle school science teaching

Kimberly A. Holmes  
University of Northern Iowa

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No Child Left Behind Act: implications and strategies for middle school science teaching

Abstract
The No Child Left Behind Act was enacted to ensure quality education for all students. Despite the constraints of the No Child Left Behind Act, the teacher has the responsibility to provide quality science education for the students. This paper will guide teachers in selecting instructional strategies that have been supported by research that closely meets the research-based standards provided by the No Child Left Behind Act.
NO CHILD LEFT BEHIND ACT: IMPLICATIONS AND STRATEGIES FOR MIDDLE SCHOOL SCIENCE TEACHING

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of the Requirements for the Degree

Masters of Arts in Education

Kimberly A. Holmes

University of Northern Iowa

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Thomas R. Berg
Director of Paper

John E. Henning
Reader of Paper

Laurence T. Escalada
Reader of Paper

Thomas R. Berg
Advisor

Michael D. Waggoner
Department Head
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Chapter I

Introduction

No Child Left Behind Act

On January 8, 2002, President George W. Bush signed into law the No Child Left Behind (NCLB) Act. The act is an update to the Elementary and Secondary Education Act (ESEA) of 1965, which was initially enacted to provide a framework and funding for education of students K-12 in American schools. Through federal funds, schools will have to improve student achievement on standardized assessments and close the achievement gap for disadvantaged students. The No Child Left Behind Act has four major components to address these needs:

1. improvement of teacher quality,
2. more accountability for teachers and school districts,
3. more flexibility for districts to spend funds as they see fit, and
4. use of research-based teaching strategies by teachers in the classroom.

No Child Left Behind supports instructional strategies or materials backed by scientific research. Federal funding will only be provided for programs shown to increase student learning and achievement.

As reported by President Bush and Congress, 82% of our 12th graders did not perform well on the science portion of the 2000 National Assessment of Educational Progress ("Science Achievement," 2005). Also reported by the 1995 Third International Mathematics and Science Study (TIMSS) is the fact that among U.S students, science achievement decreases from 4th through the 12th grade ("Science Achievement," 2005). NCLB contends the solution to this problem is for schools to use research-based methods of instruction ("Science
Researchers have provided scientifically proven methods of teaching reading and math since No Child Left Behind was introduced, but it seems to be a difficult task finding research-based teaching strategies specific to the science classroom supported by rigorous evidence. The NCLB website provides a rationale for reform in science education and the importance of using strategies that have been proven effective by rigorous research, but no links to sites that provide strategies and the proof of their effectiveness.

Instructional resources to use in the K-12 science classroom are plentiful; however, to comply with NCLB these resources must be research-based and include evidence that shows improvements in student achievement. These resources include textbooks, curricula, lesson plans, activities, and worksheets. With all of these nationally mandated laws and the lack of thorough data to support science instructional practices and resources, it is a challenge for a teacher to comply with NCLB when adopting and integrating these practices and resources into his or her classroom. Today’s science teacher needs to know how to increase students’ achievement by using proven practices that have been documented as being effective.

Testimonials for instructional products and materials that claim to produce significant gains in science achievement are in circulation; however, the “evidence” provided in reference to the guidelines of scientifically sound research needs to be examined. The following is a list of the criteria associated with reliable research according to No Child Left Behind standards; it

- uses the scientific method to prove a hypothesis,
- can be replicated, generalized, and
- has been accepted by peer review journal or panel. ("Investing In What Works," 2005).

Each of these criteria will be further discussed in this paper.
Another concern with NCLB is that the focus thus far for districts and schools has been developing science standards that are consistent with national science education initiatives. By the 2005-2006 school year, NCLB mandates that all states must have science standards that are aligned with the assessments that will be administered (Newsom, 2003). As a result, the primary focus in many districts may have been on creating science standards. By the 2007-2008 school year, all states must administer science assessments to students in at least one of the following grade levels: 3-5; 6-9; and 10-12 (Newsom, 2003). This leaves this school year to find and implement instructional strategies to help improve science achievement.

Development of Benchmarks and Standards

In 1993, the American Association for the Advancement of Science (AAAS) released Project 2061, which promoted scientific literacy in two different publications, *Science for All Americans* and *Benchmarks for Science Literacy* (AAAS, 1989). The Benchmarks were developed by teachers and administrators to outline what a student should know or be able to do in science, mathematics, and technology by the end of grades 2, 5, 8, and 12.

In 1995, The National Research Council developed the *National Science Education Standards* (NRC, 1996) for schools in an effort to improve science education. The National Standards defines what all students should know and be able to do in science K-12. The National Standards includes additional information for science teachers, such as:

- standards teaching science
- standards for professional development
- assessment standards
- content standards
- program standards
The National Science Education Standards focuses on changes teachers will have to make in their instructional practices in the science classroom. Scientific literacy is the goal of the National Science Education and the Benchmarks for Science Literacy.

Statement and Significance of the Problem

The problem then becomes a matter of time, money, and preparation for science teachers to arm themselves with the best practices in science teaching. Funds are needed to provide professional development and resources for teachers. No Child Left Behind Title II funding includes funds set aside originally to help reduce class size and fund science teacher training (Peterson & West, 2003). As of the present, Title II grants totaling $2.8 billion will be used for states and districts to provide professional development to ensure all teachers receive the training necessary to provide quality instruction (Peterson & West, 2003). The use of Title II grant money would certainly assist with teacher preparation and resources; however, the NCLB Act also requires “failing” schools to allow parents the option of transferring students to better performing schools, at the districts expense. The district must also provide free-tutoring, summer school, and any other supplemental education services deemed necessary ("A Brief Summary," 2005). To be in compliance with the NCLB Act school districts must reallocate funds such as those reserved for professional development for teachers or buying up to date materials (Peterson & White, 2005).

The No Child Left Behind Act was enacted to ensure quality education for all students. Despite the constraints of the No Child Left Behind Act, the teacher has the responsibility to provide quality science education for the students. This paper will guide teachers in selecting instructional strategies that have been
supported by research that closely meets the research-based standards provided by the No Child Left Behind Act.

Organization of the Paper

This paper is organized into four chapters.

- Chapter I introduces the No Child Left Behind Act and its effect on science instruction.
- Chapter I also identifies the problems created by the NCLB Act for districts, schools, and science teachers.
- Chapter II is a review of the literature on science reform, science standards and benchmarks, strategies that work in science teaching, criteria for scientifically sound research, and professional development for science teachers.
- Chapter III is an examination of standards used to evaluate research-based teaching strategies and will also include examples of a selection process of instructional materials developed in compliance with NCLB.
- Chapter III will conclude with an evaluation of the research included in chapter two on teaching strategies using the evaluative standards of NCLB.
- Chapter IV will conclude with my recommendations for science teachers and leaders in implementing reform initiatives and with a description of my future directions to enhance my professional growth.
Chapter II

Review of the Literature

Science Reform

During the past two decades the United States educational system has been subjected to reform across all grade levels and all disciplines. Studies have been completed and research data gathered to determine the direction education must take.

Recommendations have been made as to how science education can be improved to include all students and increase achievement. The social, political, economic, and cultural forces that drove the reform movement in the 1950's and 1960's were much different than those driving the reform movement today (Chiapetta, 1998). The need for a scientifically literate work force was a top priority in the era of Sputnik, launched by the Soviets in the 1950's. Sputnik ignited reform efforts in the science education of American schools (Yager, 2000). The goal then was to produce scientifically literate youths that could compete with other nations in technological advances. The inquiry approach to science education became the reform efforts panacea (Cain, 2002). By the end of the mid 70's public support for these reform efforts decreased and the interest and monies used to fund such inquiry based programs declined right along with it (Yager, 00). Then in the 1980's, science education was reviewed and placed under heavy scrutiny. In 1983, A Nation at Risk, published by the National Commission on Excellence in Education was the springboard for science reform in the 20th century (Cain, 2002). The reports showed that U.S. student's achievement was low compared to other nations. As a result, new reform efforts became a top priority of science organizations, scientists, and teachers. And now, once again, the nation has realized that a change is in order in science education. American children are falling behind in science and technology (Cain,
2002). We want students that can think, solve problems, and make decisions on evidence and reasoning (Yager, 2000). The need for the stronger economy and people to develop technologies for the United States is a driving force behind the science reform today. All ideas are aimed at creating a scientifically literate group of adults (AAAS, 1993). 'Students must learn fundamental scientific facts, concepts, principles, laws, theories, and models (Chiapetta, Collette, & Koballa, 1998). In order for this type of learning to occur for all kids across America, there must be some common core of knowledge required for all children. Teachers must have guidelines as to what a scientifically literate person should know.

Standards and Benchmarks

In 1985, Project 2061 was launched by the American Association for the Advancement of Science (AAAS) as a major reform initiative. Project 2061's primary goal was to provide assistance to teachers by providing a set of standards in science education. 2061 is the year Halley's Comet will be in view, its originators chose this date to indicate that reform is a long term project and that our adults of the twenty-first century would be witness to so many technological and scientific changes during this time span.

Teachers are important in reform efforts, as a result of knowing this, Project 2061 was created in the late 80's early 90's to provide further assistance with providing a set of standards in science education K-12. The committee composed of teachers, scientists, mathematicians, engineers, historians, and learning specialists were given the charge to develop Project 2061 into the framework for science education. The committee was asked to create a science/math/technology curriculum designed to shape the future of science education in America. The quest was for all Americans to become scientifically literate upon high school graduation. Project 2061 focused on what students
needed to know in each of the science areas, biology, chemistry, physical science, and earth/space science (Roseman, 1997). This gave teachers an idea of what concepts students needed to know across the board.

In 1993, the AAAS developed Benchmarks in Science Literacy as an additional resource for teachers K-12. Too much information was being covered in each area of science that was being taught. More depth in the study of the scientific disciplines was emphasized. The Benchmarks for Science Literacy set guidelines as to when certain content needed to be covered in K-12 science education. The common core of knowledge for all children and the initial phase of scientific reform for the next decade were now in place. Benchmarks is not a curriculum; it provides educators with a sequence of specific learning goals and a suggested timeline to progress towards science literacy.

In 1996, The National Science Education Standards were developed by The National Research Council to help improve education in science K-12. This document supports the idea that all citizens shall become scientifically literate (Chiapetta et al., 1998). The National Standards make it clear, that scientific literacy is the main goal of science reform efforts. The Benchmarks for Science Literacy and the National Science Education Standards are very similar in that both explain what all K-12 students need to know and be able to do in science. The Standards outline what students should know and be able to do and it includes standards for science teaching, professional development, assessment, content, and programs necessary to improve science education.
What Works in Science Teaching

Knowledge (Victor and Kellough, 2000) should be sought after by the student rather than receiving instruction through expository texts, lectures, and textbook reading. Students are to be actively engaged in problem solving, and students should be allowed to decide and design processes for their inquiry learning. Being allowed to identify, decide, design, and resolve problems is key to student’s achievement (Victor and Kellough, 2000).

The *National Science Education Standards* recommend replacing textbook taught lectures with inquiry-based teaching strategies. Students should be actively engaged in interesting topics, students should be allowed to collect and analyze data, participate in problem based learning exercises, design experiments to solve problems, and write up lab reports based on science problems. Research findings show the association between inquiry based science teaching and increases in science achievement (Wise & Okey, 1983; Stohr-Hunt, 1996; Anderson, 2002; Von Secker, 2002). Inquiry is also suggested by Wise (1996) in his publication *Strategies for teaching science: What works*. Along with inquiry, Wise (1996) compiled a list of strategies found most effective in the science classroom. These strategies include: (1) questioning, (2) focusing, (3) manipulation, (4) enhanced materials, (5) testing, (6) inquiry, (7) enhanced context strategies, and (8) instructional media. This meta-analysis supports use of inquiry strategies as a means of science instruction.
Scientific Inquiry

If a single word had to be chosen to describe the goals of science education during the thirty year period that began the late 1950's, it would have to inquiry (DeBoer, 1991). Project 2061 (AAAS, 1996) encourages science teachers to use scientific inquiry as a framework for teaching. Humans are naturally curious about the world around them; inquiry is a normal part of everyday life and should be incorporated into the science classroom. 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 (National Academy Press, 1996).

Reform efforts are now focused on how to present the information effectively in the science classroom. Today the need for more inquiry and active involvement in the science classroom has been deemed imperative (NRC, 1996). In order to make any of these changes happen, teachers will have to change their instructional approaches to science education. Teachers need to know how to improve science teaching. The concern becomes how to teach science effectively and how to ensure science is truly for all.

According to the Standards, “inquiry into authentic questions generated from student experiences is the central strategy for teaching science (Edward, 1997). Inquiry focuses on how topics relate to student’s real life experiences.
Students must be allowed an opportunity to formulate and answer their own questions. In an inquiry classroom, one would see student-centered activities. Students will be designing experiments and testing their hypotheses and problem solving. Kids also use their life and real world experiences that they have had as a base for instruction. Through cooperative learning tasks, higher order thinking skills, demonstrations, and increased wait times, classrooms will become more student-centered and the students will become more actively involved and take ownership of their learning which will lead to an improvement in science process skills and overall achievement (Shymansky, 1996). Providing students with an opportunity to ask and answer questions themselves does not have to be seen as an impossible task. Once a teacher understands what inquiry based learning means and how to create such an environment, it will be simple and possible to implement in the classroom. Teachers and the way they teach are vital to science education reform.

Debate: Inquiry versus Traditional Textbook Approaches to Science Teaching

For many years, there has been a belief that kit-based instruction, centered on an inquiry approach, produces greater student achievement in science and possibly other curricular areas when compared to a more traditional textbook approach (Klentschy, Garrison, & Amaral 2002).

One study in particular (Klentschy et al., 2002) was done to investigate hands-on curriculum kits and how effective they can be in improving science education. This study reports the effects of kit-based instruction on 4th and 6th grade students. The Valle Imperial Project in Science was funded by the National Science Foundation in the summer of 1998 to determine how hands-on instruction affected student's performance on standardized tests. The schools
participating in the project all shared some of the same characteristics: they were provided high quality curriculum, support for the teachers by means of professional development, materials necessary for instruction, administrative support, and a means of assessment of student’s achievement. The comparison was between students that received inquiry based instruction versus those who did not.

The teachers in the project were given “research-based” instructional materials for science instruction. They were administered the science section of the Stanford Achievement Tests (SAT) after completion of the science curriculum the first year. It was found that the students who received the kit-based science instruction achieved better than those who were taught science using traditional approaches did.

As further support of this report, Brednerman (1983) did a quantitative analysis of 57 research studies and reported a 14-percentile point difference between kids in science programs versus those who were not, in favor of kit-based instruction. Shamansky (1990) also did a meta-analysis of 81 research studies on hands-on, activity-based programs and found that traditional approaches do not produce the student achievement results that inquiry science would.

Teachers using the textbook as a primary resource of science instruction goes back to the lack of knowledge base that they may have. Those teachers unfamiliar with their science content areas, due to lack of secondary training, may depend on the textbook to guide their instruction. The disadvantages of textbook instruction include the fact that they may contain difficult words and concepts that are too abstract and beyond the comprehension of middle school students. Other disadvantages are the fact that texts are too content oriented and there is a tendency to memorize facts and not make science applicable to
the real world around the students. Teachers may still use the textbook in an inquiry-based classroom as a reference for a common source of information.

Several other studies also report higher achievement scores for students that participate in an inquiry-based, hands-on science curriculum when compared to traditional textbook approaches (Bredderman 1983; Shamansky, 1990; Stohr-Hunt, 1996; Wise, 1996; Klentschy et al., 2002; Von Secker, 2002). However, hands-on does not imply inquiry-based instruction. On the other hand, inquiry-based instruction may imply hands-on. According to the NSES (1996), hands-on activities are not enough- students must also have minds-on experiences in the science classroom.

The National Science Education Standards encourages teachers to develop a student centered science classroom, by de-emphasizing the textbook and lectures as the sole means of teaching. Inquiry can bring the information in the textbook to life for the students. Teachers are not being asked to disregard the textbook or throw it out, but to provide students an opportunity to collect data, use appropriate lab techniques, ask questions, and research ideas to solve problems.

These instructional strategies will require a pedagogical shift in teacher instruction to an inquiry-based learning model. It is possible to do all of the things that proponents of inquiry-based instruction say will enhance learning in the science classroom, but the teacher has to change their teaching philosophy and strategical approach to science teaching.

The following quote gives teachers some insight into the direction science education may take in the wake of new reform efforts:

"Inquiry science means just that —learning from the materials and processes of the natural world through direct observation and experimentation. Professional scientists develop hypotheses and then
test these ideas through repeated experiments and observations. They cannot simply “know” that something is so; they must demonstrate it. The education of children in science must also provide for this kind of experience, not simply to confirm the “right” answer but to investigate the nature of things and arrive at explanations that are satisfying to children and that make sense to them”. (National Science Resources Center, 1988)

Strategies for Teaching Science

It is important to keep in mind that inquiry teaching not only requires a paradigm shift in teaching, but it also requires supplies and resources that not all teachers may have access to. The goal of this paper is to provide research-based strategies that are in compliance with NCLB, but in the same token, are possible for all teachers to implement in the classroom with minimal resources. Money may not be available for all teachers, schools, and/or districts to purchase materials or supplies for their classroom. This paper compiles strategies for those who do not have access to materials or the materials that are available in a limited supply. The strategies mentioned here rely on the teacher’s instructional strategies for implementation. Inquiry learning has several components to it, as noted by Wise and Okey (1983): use of graphic organizers, appropriate wait-time, and questioning skills have been shown to influence achievement in the science classroom. Those three instructional strategies require little if any materials, but instead involve instructional changes by the teacher. Wise (1996) reports an average effect size of 0.57 in favor of organizers or focusing strategies, an average effect size of 0.58 in favor of questioning strategies and
an average effect size of 0.90 in favor of increased wait time. These strategies are relevant in the inquiry-based classroom and have shown to increase student achievement in the science classroom (Lott, 1983; Wise & Okey, 1983; Cherif, 1993; Wise, 1996; Black, 2001; Anderson, 2002; DiCecco & Gleason, 2002)

Graphic Organizers

A graphic organizer is a visual representation of the relationship between ideas and concepts presented in the science classroom (Callison, 2000). Students are allowed to construct a graphic depiction of the relationship of new and old ideas and information. This may include similarities and differences between topics or prior knowledge about the topics. Students can be given a graphic organizer prior to learning a new concept to help formulate a relationship between new ideas and their prior knowledge. A teacher may also choose to use an organizer upon completion of the lesson to help students outline the information that they have learned or to organize ideas and concepts. DiCecco and Gleason's (2002) work shows that the use of graphic organizers can lead to an increase in student recall of material presented to them in class. Callison provides examples of teaching organizers: expository and comparative organizers. The expository organizer provides students with a way to organize new concepts, new vocabulary terms, or any information students will need to assist them with the assimilation of new material. The comparative organizer could be used for material already familiar to students, but is still useful in that it adds clarity to the students learning. Organizers may be used to show relationships between ideas, assist with recall or retelling, show cause and effect
relationships and improve comprehension skills (Callison, 2002). Examples of graphic organizers that could be used in the science classroom for any grade level and any content are illustrated in the following figures. In Table 1, the K-W-L table (Ogle, 1996) is a good tool to help students plan or map out a unit of study. The K-W-L can be used as a pre-lesson strategy, during the lesson, and after the lesson. It helps the student track their individual progress and helps them become more cognizant of their learning.

Other examples of organizers (Callison, 2000; Fisher, 2001; DiCecco & Gleason, 2002) include concept maps as shown in Figure 2. A concept map is also a set of ideas and facts that relate to a certain topic with links between the facts. The teacher or student may select the fact or concept for the organizer. The student's task is to create a cluster of words or pictures that are linked with the key word or concept. Students should be allowed to express their ideas in writing or pictures to show the relationship between ideas. Listed on the following pages are examples using middle school earth science concepts taken from my own science classroom.
### Table 1 KWL Chart

<table>
<thead>
<tr>
<th>What I Know Already</th>
<th>What I Want to Know</th>
<th>What I Learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar is Latin for sun</td>
<td>Who first discovered eclipses?</td>
<td>Lunar- earth in between sun and moon.</td>
</tr>
<tr>
<td>Lunar is Latin for moon</td>
<td>How often do eclipses occur?</td>
<td>Umbra- darkest part of shadow.</td>
</tr>
<tr>
<td>Sunlight is being blocked</td>
<td>What is the position of the</td>
<td>Penumbra- largest part of shadow.</td>
</tr>
<tr>
<td>Involves earth, moon, sun</td>
<td>earth, moon, sun?</td>
<td></td>
</tr>
</tbody>
</table>

### Eclipses

**Solar Eclipse**
- The moon is in between sun and earth, casting a shadow on the earth.
- Only people in the umbra will experience total solar eclipse.
- Parts blocked out

**Lunar Eclipse**
- Earth is in between sun and moon, casting a shadow on the moon.
- Moon must be in full moon phases for a lunar eclipse.

**Types of Eclipse**

Venn Diagram: Compare and Contrast Ideas. Write contrasting information in separate circles. Write comparisons in overlap.
Figure 1B
Sequential Organizer

New Moon → Waxing crescent → First quarter

Waning gibbous → Full Moon → Waxing Gibbous

Third quarter → Waning Crescent

Figure 1C
Conceptual Organizer

KEY TERM OR CONCEPT
Planets in our solar system
In order from the sun
Figure 1D
Hierarchical Organizer

SOLAR SYSTEM MOTIONS
  → REVOLUTION
  → RETROGRADE ROTATION
  → ROTATION
  → APPARENT MOTION
  → REAL MOTION

Figure 1E
Cyclical Organizer

CLOSE ENCOUNTERS
  → METEOR
  → COMET
  → METEOROID
  → COMA
  → METEORITE
  → ASTEROID
Questioning Techniques

During the course of any inquiry-based learning experience, teachers and students will be asking a variety of questions for a variety of purposes (Cain, 2002). Questioning can be a fundamental component of inquiry-based science education. It requires little or no materials to complete and engages the students in thinking. Good questioning will guide the students thinking, increase student metacognition and student involvement, activate prior knowledge, check for understanding, and encourage higher order thinking skills (Mayer, 2002).

The best source for examples of questioning and the levels of questioning would be Bloom’s Taxonomy (1965). The levels of questioning range from knowledge, comprehension, application, analysis, synthesis, and evaluation. Wise and Okay (1983) recommends higher level questioning in the science classroom. As reported by Black (2001), teachers spend nearly half of their class periods asking kids questions. However, are the questions meaningful and interesting enough to capture the student’s attention? Cherif (1993) provides 6 essential questions to ask students in an inquiry classroom:

- What do you think will happen?
- What actually happened?
- How did it happen?
- Why did this happen?
- How can we find out which of these hypotheses is the most reasonable?
- How can you relate this investigation to your daily life?

Inquiry is about seeking knowledge and trying to understand concepts by asking questions, making observations, investigating phenomenon, analyzing and
evaluating data. The questions asked in the classroom should be higher-order-level questions. For assistance, Bloom's Taxonomy provides guidance for teachers and how to develop a classroom with higher level questions. Developing questioning skills is a necessity for the teacher. Some thought and consideration must be involved in preparing questions for the students. The following are pointers on asking good questions.

- Questions should be clear and brief
- Introduce questions one at a time
- Give appropriate wait time
- Use Bloom's taxonomy
- Give immediate feedback
- Provide a safe classroom where it is okay to make a mistake
- Allow group responses
- Provide lots of encouragement
- Allow students to ask as many questions as they would like
- Do not judge worth or accuracy of students explanations
- Allow them to test their own ideas
- Permit students to interact with peers

Bloom’s Taxonomy

Blooms Taxonomy may serve as a guide for instructional strategies. The following table contains information about Bloom's levels of questioning and example questions teachers may use to transition from low-level cognition to higher-level cognition. Higher-level questions are open-ended, interpretive, evaluative, inferential, and involve synthesis of information and mental manipulation.
Table 1 BLOOMS TAXONOMY

<table>
<thead>
<tr>
<th>Taxonomy level</th>
<th>Active verbs</th>
<th>Examples of Products/related activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Tell, Describe, Name, Recall, Choose, List, Define, Identify, Relate, State, Remember, Report, Recognize, Match, Memorize, Reproduce, Label</td>
<td>□ Define a vocabulary word. □ Who, What, Where, When of . . . □ Identify the main parts of . . . □ Recall the names of five explorers of the New World. □ Memorize the capitals of the U.S.</td>
</tr>
<tr>
<td>Comprehension</td>
<td>Show, Explain, Summarize, Find, Review, Interpret, Restate, Translate, Describe, Paraphrase, Change, Give the main idea, Give examples, Convert</td>
<td>□ Write a summary of the story. □ Describe different kinds of bicycles. □ Explain the importance of knowing about? □ Review a magazine or newspaper article and tell the class about it.</td>
</tr>
<tr>
<td>Application</td>
<td>Apply, Solve, Illustrate, Paint, Use, Put in order, Practice, Show, Draw, Solve, Employ, Demonstrate, Prepare, Report, Collect, Act out, Construct, Relate, Record</td>
<td>□ Demonstrate an experiment for your science book. □ Make a model, puzzle, diorama, map, diagram, or picture of . . . □ Construct a learning center. □ Sculpture, dramatize, paint, or sketch a scene from a favorite book or movie.</td>
</tr>
<tr>
<td>Analysis</td>
<td>Compare/Contrast, Survey, Dissect, Outline, Classify, Investigate, Detect, Separate, Same/Different, Arrange, Distinguish, Categorize, Differentiate, Calculate, Research, Diagram, Subdivide</td>
<td>□ Arrange members on a family tree. □ Design a diagram, graph, chart, questionnaire, or survey using information you have collected on a topic. □ Make a time line of a book or time period. □ Compare items listed in two Chocolate Chip Cookie recipes.</td>
</tr>
</tbody>
</table>

Knowledge, the lowest level of Bloom’s Taxonomy is remembering of previously taught material; students recall facts and simply recognize information.

Knowledge level questions ask who, what when, where, how, and why.

Questions teachers may use to evoke knowledge level questions:

- What happened....?
- How many....?
- List main events....
- Recite a poem or passage from....
Comprehension is understanding the meaning of material; explaining in one's own words. A teacher may ask a student to summarize a report, write something in their own words, write a brief outline, or explain what will happen next.

Application involves the student's ability to use learned material in a new situation. Questions one might ask:

- Do you know another instance where...?  
- What factors would you change if...?  
- Can you develop a set of directions about...?  
- Can you create a diorama of important events from...?  
- Can you construct a model of...?  
- Can you create a puzzle/game of ideas...?  

Analysis is breaking down material into parts; understanding, clarifying, and drawing conclusions. Questions and activities teachers may use at this level:

- How was this similar to...?  
- Can you distinguish between...?  
- What was the problem with...?  
- Can you compare and contrast...?  
- Design a diagram/graph illustrating concepts.  
- Write a commercial to sell products.  

Synthesis is combining ideas to form a new whole. Questions and activities teachers may use at this level:
- Can you design a ….?
- Compose a song about….?
- Can you see a solution to….?
- What would happen if….?
- Can you create a new way to ….?
- Devise a way to…..
- Design a book, magazine, or record cover for …
- Create a new product…

The highest level of Bloom's Taxonomy is evaluation. Evaluation involves judging the value of something based on select criteria; providing support with reason. Questions and activities teachers may use at this level:

- Do you agree…?
- What do you think about…?
- How effective are …?
- Do you believe…?
- Can you defend your position about…?

For the teacher, questioning is not a strategy that requires extra materials or manipulatives, it is a shift in pedagogy. Effective questioning will require a teacher to evaluate the effectiveness of the questions asked and simply chose questions from the higher cognitive level of Bloom's Taxonomy. When it comes to questioning techniques, Bloom's Taxonomy has been around for years and there are revisions to his levels of higher cognitive questioning (Mayer, 2002; Raths, 2002; Pintrich, 2002). Questioning is an effective and inexpensive way to
use inquiry in the science classroom (Wise & Okey, 1983; Cherif, 1993; Black, 2001; Mayer, 2002; Pintrich, 2002; Raths, 2002).

**Wait Time**

In Wise and Okey's work (1983), effective wait time showed the greatest gains in achievement over all other science teaching strategies. Wait time is defined as the amount of time a teacher allows students to formulate their answer before he/she re-asks the question, answers the question themselves, or asks another student to answer. Studies (Wise & Okey, 1983; Tobin, 1984; Riley, 1986; Rowe, 1987) show that an increase in wait time of 3 to 5 seconds makes a difference in the quality and quantity of student responses and increases student achievement. Mary Budd Rowe (1987), a pioneer in wait time studies, suggests that if a teacher simply waits 3 or more seconds after asking a question he/she can expect longer answers, more correct answers, and more volunteers. To take it a step farther, if the teacher waits another 3 to 5 seconds after the students response the student may elaborate on their answer, give an example, or ask additional questions for clarity. Rowe (1996) says increasing the wait time increases the length of the student's answers and has also been shown to significantly increase achievement on standardized tests over students in short wait time settings. Rowe states that inquiry is key to success in the science classroom, but Rowe goes on to state that with inquiry in the classroom involves giving a teacher and child time to think and evaluate; the key point here, being time. Kids are given time to trust the content they have learned and to trust themselves. Rowe (1996) and Tobin (1984) both agree that giving a student
those few extra seconds to process and think will positively effect their
achievement. Again, this is another strategy that should be easy to implement; it
involves no materials and no manipulatives. The teacher simply adjusts the time
given for responses.

The questioning technique and “wait time” go hand in hand. Teachers that
learn to ask effective questions in the science classroom and give their students
time to provide thoughtful responses to the higher level questions are giving their
students a chance to become better thinkers and have more confidence in
themselves; this will require teachers to make a conscious effort to change the
way they teach science. The aforementioned strategies are a start to providing
inquiry based teaching in the science classroom. As teachers, it should be noted
that sometimes little changes in the way we teach can make a big difference.
Something as simple as asking students to make predictions prior to making
observations and explaining these predictions could be thought provoking for the
student. If simply rephrasing questions or giving an extra second has been
proven effective in the science classroom, isn’t it worth the time to give our
students a better chance at being confident in their ability to answer higher level
questions and confident in themselves to be successful in the science
classroom?

Scientifically Sound Research

If it is believed that inquiry-based science instruction will produce the
desired achievement results in science; teachers must have access to materials
and resources to create this approach to learning in the classroom. Informed
teachers, administrators and school leaders must have a certain set of criteria in place to evaluate research reports on what works in the science classroom. The methods and materials used must be research-based and shown to improve academic performance according to the No Child Left Behind mandate. Science education supply vendors and instructional science programs provide testimonials about their effectiveness, but when determining if a program will meet the requirements of NCLB, quantitative results are desirable. One must know how to evaluate a program or a strategies claim of being research based.

What constitutes good research? According to No Child Left Behind (Identifying and Implementing, “2005), when reviewing a research report or study, the following components need to be taken into consideration:

Scientific Method- does the study provide a clear hypothesis with an expected answer to a research question? Does the study state a hypothesis about how two or more variables are related? The study must also include a treatment group and a control group that proves the resource will cause an increase in achievement.

Replicated- will other studies find the same result for those instructional strategies? Do other studies already exist that repeat the investigation and find the same results?

Generalized- can the findings be applied to other students? Will other groups outside of the tested students see the same results? Can the results be extended to differing levels, cultures, etc.?

Meets Rigorous Standards- has a peer review panel or expert panel
accepted the design, measures, and analysis of collected data and conclusions?

Convergent findings- do other findings from several other studies agree with the conclusion?

The No Child Left Behind government-supported website provides extensive information into the characteristics of research-based strategies. Research backed by strong evidence of effectiveness should consist of randomized control. The students must be randomly assigned to treatment groups using unbiased methods. This allows one to account for other variables that may affect the results. Qualitative factors are included as a measure as well as quantitative. As far as qualitative characteristics, a study backed by strong evidence will provide the following information:

- description of the intervention
- who administered the intervention
- who received the intervention
- how much did it cost
- how the intervention differs from the control
- the logic of the expected outcome
- validity of the outcome

Quantitative features include being done at more than one site, a typical public school, teachers as administrators (no researchers), more than one randomized control trial, and show the size of effect. The size of effect must be unlikely to change due to chance.

Educational research involves collecting information on a problem or
hypothesis. The data is then analyzed and the evidence is applied to prove or disprove the hypothesis. We are being held responsible and accountable more now than ever before, we need to be proactive in educational research (Hittleman, 2006). Teachers will need to serve as researchers to find effective strategies to use in the science classroom. Professional development for science teachers will be essential in restructuring science education and raising science achievement.

Professional Development

A shift in teaching pedagogy is needed to implement these teaching strategies. Moving from recitation and direct instruction from a textbook may not be as easy for some teachers (Marx, et al., 2004). A teacher will need professional instruction to develop new curriculum, evaluate scientifically based research, and bring new ideas into the classroom. A teacher may need to seek out professional development activities offered by the local school district or universities. An additional resource would be local chapters of professional organizations such as the National Science Teachers Association, or affiliates of it. If the district does not offer any, the teacher may need to be responsible in finding their own professional development opportunities. Contact local universities, community leaders, or the science education coordinator for the district for assistance. The help is out there, especially in the wake of No Child Left Behind, but teachers need to be proactive to find the opportunities. One goal of education should be to increase teachers understanding of their content matter and provide teaching strategies (Lee, Hart, Cuevas, & Enders, 2004).
There will need to be an increase in the number of teachers that volunteer for these professional development opportunities and this will require their commitment and dedication to the profession.

Lee et al. (2004) suggests that providing teachers with professional development increases their ability and willingness to develop hands-on activities and more student centered instruction. Teachers in this study also had more positive views about their content matter thus gaining new-found confidence in teaching and preparing lesson plans. This kind of enthusiasm by the teacher may be passed on to the students and perhaps have a positive effect on students as well. More professional development should be provided by school districts to ensure teachers receive proper preparation, otherwise reform efforts and new science curriculum may in ineffective. Teachers are to be life long learners and should be given an opportunity to continue learning about what works in science education.

*The National Science Education Standards* are not just for students; it also includes standards of professional development for science teachers, administrators, and provides guidance for community involvement. The NSES (1996) holds teachers responsible for their own professional development. Science teachers will need professional development to implement new science curriculum and strategies in the classroom.

The professional development standards for teachers consist of four key components:

- Learning science content through inquiry
• Applying knowledge of science, learning, pedagogy, and students to science teaching.

• Encouraging teachers to be lifelong learners.

• Professional development should be coherent and integrated.

The goal of a professional development program should be to show science teachers how to replace lecture classroom with inquiry teaching and learning. The program should also integrate science with the knowledge of what students should learn and how they learn the information best. NSES (1996) also believes a program should promote collaborative learning; internal and external experts to assist with teachers knowledge acquisition, and support from the local area collegial community. The universities and school districts must also play a key role in providing quality professional development for teachers. Teachers should be reflective learners and provide staff development for each other. No longer is the teacher the target of reform, but instead a leader of change.
Chapter III

Standards to Evaluate Research-Based Strategies

This chapter will provide an examination of the standards used to evaluate research based strategies.

Iowa Professional Development Model

For assistance to the science teacher, the Iowa Professional Development Model K-12 (Iowa Professional Development Model, 2005) online, provides reviews of research articles on instructional strategies/models, program, materials, or interventions. The IPDM consists of a team of 40 educators including teachers from various schools, professors from local universities, educational consultants from local area education agencies, and Iowa's Department of Education. The team members were asked to participate based on the extent of their knowledge in the content area, their willingness to participate in research of this nature and willingness to review and discuss research specific to the science content. According to the IPDM website, team members were giving training on reviewing research and using a specific criteria for evaluation of the research provided for instructional strategies.

The IPDM created a pyramid image as a research continuum. IPDM provides reviews of meta-analysis and summaries of research in science education. The reviews focus on research design and may serve as a valuable resource for teachers as they prepare themselves professionally to improve science instruction and implement research-based strategies.

(IPDM, 2006)
Level 5-Gold Standard

- Equivalent to quality research as outlined by No Child Left Behind
- Random assignment of students to treatment/control group
- Control of internal validity
- Findings are greatest in student effect size

Level 4- Strong Evidence

- No random assignment of students
- Apparent threats to internal validity controlled

Level 3- Promising

- Weak experimental design, effect consistently replicated
- True experimental conditions, many strategies used, but positive results

Level 2- Marginal

- A one time study
- Non-peer reviewed
- Individual teacher experiment

Level 1- No Empirical Evidence

- Provides rationales, but no data to support findings
- Reports of gains, but includes no documentation
- Reports gains in an entire district or state, but used high stakes test or sanctions; difficult to know what accounted for changes
- Testimonials provided by product makers.

Analysis for Selecting Research-Based Instructional Strategies and Programs

The *Iowa Professional Development Model* (2006) provides a framework for analyzing the research that exists in science teaching. The following is the outline provided on *IPDM’s* website to review the research:
What is the name/title of the instructional strategy/model, program, material, or intervention? What was the research question? What was the intended outcome or goal?

Describe the strategy/model, program, material, or intervention.

Describe the design of the study (sample question, assignment to treatment, controls, length of intervention, etc.)

What instruments were used to collect data and what metric(s) (effect size, tests of significance, etc.) were used to report results? (Include all measures of dependent variable as well as implementation, attitudes, etc.)

Briefly describe and summarize the results of the study.

Did the study include an evaluation of how the intervention was implemented? Did implementation data address both the frequency of use as well as the integrity of the implementation?

Were gains in student achievement reported?

Replication: Did the study cite previous tests of the treatment? Is this study a replication of an earlier study?

Summary:

Rating: Design (scale: 1-5)

This framework of questions may be used by teachers to evaluate the research found in different instructional strategies in the science classroom. The model could be seen as a starting point of professional development for science teachers. It is not the only model available, but the IPDM model tries to align itself with the criteria set by the No Child Left Behind act. It may be used as an evaluative tool by teachers to assist them in finding research based strategies that the NCLB act would support financially in the schools.

Using the aforementioned criteria as a guide, the teaching strategies
suggested in chapter 2 have been evaluated. Uses of advanced organizers, questioning techniques, and wait time all have research data that supports their effectiveness in the classroom. The IPDM model of evaluation was used to select these instructional strategies as part of this paper. This chapter will conclude with a summary of the research on each of these strategies and how they stand as being scientifically research-based and appropriate for the science classroom. It should once again be noted that that pyramid continuum is used to evaluate research design, but if improvement in achievement is noted, the intervention may be seen as an effective instructional strategy for classroom use.

The title of the first study is The effect of inquiry teaching and advances organizers upon student outcomes. Lott (1983) presents a meta-analysis of 39 studies between 1957 and 1980. This study included three grade groups 4-6, 7-9, and 10-12. The study is a comparison between inductive reasoning and deductive reasoning in instruction and the use of advance organizers. Since this was a meta-analysis, the instructional strategies/models, programs, materials, or interventions were varied. The mean effect size was used to evaluate the instructional strategy, microcomputer programs were used to show the relationship between effect size and the strategy used.

The study did not include an evaluation as to how the intervention was implemented; it did not address the frequency of the use or integrity of the implementation. No gains were reported in student achievement, but some of the individual studies may have. The study did cite previous tests of treatments and made references to other studies.

The results of the study show that the inductive approach has a positive effect at the middle level where higher levels of thought, experiences, and outcome demands by the teacher were expected by the teacher (Lott, 1983). Although there was little effect on achievement with regards to advanced
organizers in Lott’s meta-analysis, it was shown that advanced organizers were more effective in urban settings than rural settings. Reviewed by the Science Content Network in 2003, this study received a 5 for an overall rating.

“The effects of teachers’ wait time and knowledge comprehension questioning on science achievement” is the next article for review. Completed by Joseph P. Riley (1986), this study investigates the effects of wait-time and cognitive questioning techniques on students achievement in science. The study included 129 students from grade two through five randomly assigned to participating teachers. The teachers were given scripted lessons that provided specific questions and pre-determined wait times. Bloom’s Taxonomy was used as a guide for questions during the 30 minute lessons.

At the end of the lesson, an achievement test that consisted of 25 items was used to evaluate the student’s achievement. The study showed that students given longer wait times after questions scored significantly higher than those in the control group; also, students given higher level questions outscored the control group on achievement tests as well. The study included an evaluation of how the intervention was implemented; it did address the frequency of the use and integrity of the implementation. Gains were reported in student achievement. The study did not cite previous tests of this treatment.

Overall this study received a 3 as a rating. Riley (1986) does show an increase in achievement for the treatment groups and is careful in controlling the application of the treatment, the reviewers felt the short length of time involved in use of the treatment was one of it’s greatest weaknesses. This study also did not provide pervious tests or cite work from other studies. This review panel is not evaluating the treatment or the outcome, results, but the design of the study itself. This should not be looked at as a failed strategy, but perhaps one could find other studies in support of increased teacher wait-time and higher level
questions with a better research design. The evaluative criteria described here is
to assist teachers in finding true research-based strategies with strong evidence,
and the research design does affect the validity of the findings.

The IPDM team also reviewed *Meta-analysis of the Effects of Various
Science Teaching Strategies on Achievement* by Kevin Wise and James Okey
(1983). The goal of the meta-analysis was to compile data on twelve different
teaching techniques and identify the ones shown to improve students’
achievement in science. The following were the teaching strategies included in
the study: audio-visual, focusing, grading, inquiry-discovery, manipulative,
modified, presentation mode, questioning, teacher direction, testing, wait-time,
and miscellaneous. The miscellaneous techniques made reference to those
strategies that were not classifiable. Students used in this meta-analysis ranged
in grades six through twelve and each study had a control group and enough
data to include effect size. The studies covered all science content areas and
spanned thirty years. The study involved lengths of time that varied from 2 hours
up to 50 hours. Students were used from all types of school settings and
backgrounds. The effect size was used for measurement purposes and was
tested by regular classroom assessments, observations and interview of
teachers and students. Although the study did not report gains in achievement in
all twelve strategies and did not cite previous tests or treatments, it should be
noted that the design and the educational importance received a rating of 5 by
the Science Content Network review panel. The overall design of the study was
acceptable by the gold standards and the study did provide some important
information for science teachers. Wait time, focusing, and questioning
techniques were all shown, based on effect size, to have a positive effect on
science achievement.

This shows that the research process is ongoing and more work needs to be
done in the field of educational research to find strategies that will work for all
students in any type of school setting.
Chapter IV

Summary and Conclusion

Recommendations for Science Teachers

There are options for science teachers and resources to assist them in finding research-based strategies to implement in the classroom, but it will require professional development and the desire to continue learning the best practices in teaching science. Teachers must arm themselves with the knowledge and research about science education to improve science achievement in their classrooms. Even the best teachers will continually add to their certification and take classes to stay informed about the changes in science education and the best ways to reform it.

If we are to be lifelong learners as recommended by the National Science Education Standards, then we must actively pursue what research has to offer. The IPDM has put together a starting point for evaluating educational research, the NCLB website also includes information teachers may use to become informed about the happenings in educational research. As we approach the 2007-2008 school year and we come closer to the time when all states will have to administer tests in science, more information will be available to science teachers and school leaders. Until that time, we must be proactive at being decision makers in what works in science education.

Teachers can use their own science classroom as a laboratory to engage in action research for what works in science by using the strategies that have been shown so far to increase student achievement. Increasing wait-time, altering questioning techniques, and use of graphic organizers are just a few techniques that can be used in the classroom. If expense is a concern, one should find strategies such as those listed here that only require a change in your teaching philosophy and not in your monthly classroom expenditures. Inquiry
science teaching, which is supported by many, does not have to involve expensive lab materials, consumable goods, and other materials. As described, it involves techniques and strategies in teaching, something that is so vital in the wake of budget cuts and reductions in educational expenses.

Our children deserve the best possible education; we owe it to them to continue learning to be better teachers and how to become more effective in education. Our performance on standardized tests and national science achievement tests show that we are lagging behind other nations (Shen, 2005). If what we are doing now is not working, then reform efforts are truly needed.

I recommend that teachers get involved in selecting instructional strategies for their classrooms. The best place to start would be to contact the science coordinator for your school district and see what they have researched and the direction they are planning to take in science reform. My district has enlisted the help of its master science teachers who may be familiar with innovative science teaching strategies to serve on committees to help create the curriculum and provide professional development to the science teachers.

It would be in a teachers' best interest to be on the committee or help springboard a committee for the school district so that science teachers will be well ready to implement strategies that work. Good teachers generally use the strategies listed as part of this paper in their classrooms anyway, so for many teachers the changes will be minimal. Change is good and our children need to be challenged and made to think.

Future Plans

As part of my own professional development, I plan to continue my education by pursuing my PhD. in Curriculum and Instruction. I want to know what I can do to challenge my students more; I want to continue to compile strategies that are research-based and create curricular material for science
teachers. I know that science education can be improved. I know that science teachers are key to changing the way students learn science and science teachers can improve science education for all students. I have used the strategies addressed in this paper and I see first hand the difference it makes in the classroom environment and in student's comprehension of the content.

College SpringBoard

My district currently uses College SpringBoard for math and language arts instruction. CollegeBoard, founded in 1900, is a non-profit examination board that manages tests such as the Scholastic Aptitude Test (SAT), PSAT, College Level Examination Program (CLEP), and Advanced Placement (AP) courses for high school students. CollegeBoard was established to assist high schools with bridging the gap between high school and college. CollegeBoard consists of approximately 5000 schools, colleges, universities, and educational organizations. The National Science Foundation is listed as one of CollegeBoard's sponsors (Introducing SpringBoard, 2006).

CollegeBoard has now developed a program for grades 6-12 to help prepare students for college called SpringBoard. SpringBoard helps prepare middle school students for the transition to high school and college by providing teachers with instructional strategies that are research-based and promote analytical thinking and problem solving amongst the students. SpringBoard claims to help schools and districts close achievement gaps and raise achievement for their students through the use of instructional strategies that actively engage students and challenge them in reading, writing, oral proficiency, collaboration, and problem solving. SpringBoard uses several of the strategies listed in this paper that are backed by research, such as the use of graphic organizers, use of K-W-L charts to activate prior knowledge, and questioning activities (Delgado, 2006). These strategies can be used in the science
classroom as well. Because of these instructional strategies, I have witnessed an increase in ability in my own students. The science teachers in my building have not received the resources yet and have not received the training from SpringBoard, but by working closely with the language arts and math teachers I have been given valuable and useful strategies that are backed by research and help my students with the science content. Professional development is important to the success of the implementation of instructional strategies and my current school district provides time for teachers that have received instructional strategies to work with those who have not. I want to be one of the teachers selected by the Principal and Science Coordinator for the district to be trained a SpringBoard facilitator. I am positioning myself for that assignment by staying in contact with the coordinator and sharing what I do in my classroom and my research from his paper. I am excited and I look forward to continuing to be the best science teacher my students could have. They deserve the best.

The No Child Left Behind act may seem impossible to some; it may seem that there is no right answer to the best way to teach science or the best way to increase achievement. The wrong answer is not to try at all.

If you always do what you’ve always done, you’ll always get what you’ve always gotten. - Unknown Author
References


Iowa Professional Development Model; Content Network. Retrieved July 12, 2005, from [http://www.state.ia.us/educate/ecese/tgt/tc/prodev/science.html](http://www.state.ia.us/educate/ecese/tgt/tc/prodev/science.html)


