

# Scaffolding Science Inquiry Through Lesson Design

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This book is dedicated to all of the staff from Project SEED and CAPSI in Pasadena, California, where the genesis of the scaffolded guided inquiry took place, and to Elizabeth, Mercy, Yolanda, and Yvonne from the Valle's Imperial Project in Science for their leadership and hard work in making the ideas become practice with the teachers and children in Imperial County, California.

# Introduction

Classroom teachers, school principals, and school districts across the United States are facing an enormous challenge. Some believe that the national movement toward standards, assessment, and accountability emphasizing reading, writing, and mathematics, as measured by high-stakes standardized tests, threatens progress in science education (Jorgenson and Vanosdall 2002). School districts, under pressure to improve test scores in basic skills, allot the majority of the instructional day to reading, writing, and mathematics.

It is vital that teachers design classroom science instruction that students learn from and find meaningful. Often the outcomes of daily classroom instruction are not fully realized until several years later. There are lots of stories about students from backgrounds not usually associated with success in school who, because of an inspirational and motivational elementary school teacher, do well in high school and college and ultimately have rewarding careers in math, science, or engineering.

As a case in point, six years ago, I received the following letter.

*Dear Dr. Klentschy,*

*You may not remember me, but my name is Rosa Lopez. I met you at the parent institute two years ago. You were very busy cooking pancakes for us then, but I wanted to write you about my daughter, Maria. She is leaving Kennedy Middle School and will be attending Southwest High School next year. Her grandmother and I are very proud of Maria. She will be the first person in our family to attend high school.*

*Four years ago I noticed a real difference in my daughter. She became very excited about science at McKinley Elementary School. She would come home every day and would talk about science around the dinner table with me and her grandmother. We learned about her science lessons with electricity, magnets, plants, and motors. She even wrote to me in Salinas [California] when I was there picking lettuce. Maria now wants to be a scientist or a doctor. Her grades are all very good now. I just received her test scores in the mail and she is in the 90s in all of her subjects.*

*I wish to thank you and her teachers for the wonderful science program you started four years ago. It helped my daughter find a pathway for her life. One that will be brighter than mine, but ever so valuable to our poor community.*

*God bless you.*

*Sincerely,  
Rosa Lopez*

Maria's excitement over her scientific discoveries as a student at McKinley Elementary School, in El Centro, California, ultimately led her to the Stanford University School of Engineering, where she is a student today.

The science program Rosa Lopez mentions in her letter is the Valle Imperial Project in Science (VIPS), in Imperial County, California. Imperial County is a geographically isolated region of southeastern California bordered by Mexico on the south and Arizona on the east. It is one of California's largest counties in terms of area, but it is sparsely populated, and its residents are among the poorest in the state in terms of real income. Agriculture is the primary industry.

The students in Imperial County are predominately Hispanic English language learners, and most of them are eligible for the federal free and reduced-price lunch program. There are fourteen elementary and middle school districts. Six rural districts have only one school each; six districts have between three and six schools each; and there are two larger districts, one with eleven schools, the other with twelve. El Centro is the economic and administrative hub of the county, and the El Centro Elementary School District has nine elementary and two middle schools. El Centro is also the lead VIPS district.

The Valle Imperial project began in 1996 as a countywide collaborative partnership comprising the fourteen school districts; San Diego State University, Imperial Valley Campus; and the California Institute of Technology. It was funded by a grant from the National Science

Foundation. One of the project's goals was to increase the number of high school students enrolling in and successfully completing challenging high school science courses, becoming university science majors, and going on to careers in science, mathematics, engineering, and technology. The project focused on redesigning science lesson plans and instruction in elementary and middle school classrooms, based on the belief that early exposure to a high-quality elementary science program is key to being able to do well in challenging high school science courses and meet university entrance requirements.

The project designers recognized that understanding complex scientific reasoning takes time and that concepts and thinking skills are best embedded within each unit of instruction. This approach is consistent with the National Research Council's recommendations that students best learn complex science content when classroom teachers plan instruction that (1) activates student prior knowledge by linking the strange new (previously unencountered knowledge) to the familiar old (prior knowledge), (2) helps students develop a deep foundation of factual knowledge in the context of big scientific ideas, and (3) employs metacognitive learning approaches that help students "own" the material (National Research Council 1999, 2005).

When students link the familiar old to the strange new in a series of individual lessons related to a standard, they form subconcepts, and these subconcepts, linked together, lead to a conceptual understanding of big ideas in science. Metacognitive approaches to learning ownership (graphic organizers, Venn diagrams, cause-and-effect flowcharts, and so on), long used in literacy instruction to encourage students to think about their own thinking, can also be applied successfully in science instruction.

VIPS staff members began by analyzing the existing state-adopted curriculum to discover how it aligned with the National Science Education Standards (National Research Council 1996) and the state science content standards California was then drafting. (They were implemented in 1998.) They found a poor match. They also found that English language learners could only access the state-adopted curriculum through supplemental workbooks.

They then went on to determine what kind of instruction would best deliver an aligned curriculum. Although the general population and even some educators often think of classroom inquiries as unstructured, open-ended activities, the National Research Council

(2005) maintains that inquiry follows a path from teacher centered to student centered: (1) the teacher demonstrates a science concept; (2) the teacher introduces questions that prompt students to investigate a science concept and processes that allow them to do so (directed inquiry); (3) the teacher introduces a science standard and lesson goals, and the students formulate a question, predict an answer to the question, devise a plan for answering the question, collect data, link claims to evidence, and draw conclusions (guided inquiry); and (4) the students create and investigate their own questions (open/full inquiry). The National Research Council reiterated these views in 2000:

Investigations can be highly structured by the teacher so that students proceed toward known outcomes, such as discovering regularities in the movement of pendulums. Or investigations can be free-ranging explorations of unexplained phenomena. . . . The form that inquiry takes depends largely on the educational goals for students, and because these goals are diverse, highly structured and more open-ended inquires both have their place in science classrooms. (National Research Council 2000, 10–11)

Given the current era of standards, assessment, and accountability, the project directors felt that guided inquiry would give teachers the opportunity to address the science content standards and at the same time give students opportunities to gain a deeper understanding of the required content and develop complex science reasoning skills.

But we soon realized that guided inquiry is a complex process severely hampered when students lack content knowledge, inquiry experience, and classroom resources. In addition, students are often unable to create meaningful inferences from the data they collect. In light of these limitations, we felt that student understanding could best be achieved through *scaffolded* guided inquiry (with science notebooks and classroom discussion the primary scaffolding tools) presented in predesigned lessons structured around an intended curriculum (standards), an implemented curriculum (what is taught), and an achieved curriculum (what students learn).

This book examines how lessons built around classroom discussion and science notebooks help students avoid misconceptions as they make meaning during inquiry and thus develop a deeper understanding of complex science concepts and the ability to reason scientifically. Thus, two important features were joined to form a powerful instructional tool. A research-based planning template is used to



structure and make coherent the design of instruction, and the tools of focused classroom discussion and student science notebooks are used to enhance instructional delivery. Chapters 1 and 2 describe the structure of the research-based planning template and the tools (classroom discussion and science notebooks) necessary to scaffold guided inquiry. Chapters 3–7 focus on planning the lessons using this template for the intended curriculum and presenting those lessons as the implemented curriculum using classroom discussion and science notebook strategies. Examples of student work and specific writing and discussion prompts are included. Chapter 8 focuses on the achieved curriculum and discusses strategies for providing feedback to students that will extend their thinking, correct their misconceptions, and deepen their ability to reason scientifically. The final chapter, Chapter 9, summarizes several studies showing results that have been achieved using this instructional model.

# Using a Research-Based Template to Plan Classroom Instruction

# 1



**T**he current national and state focus on standards, assessment, and accountability due to the No Child Left Behind legislation challenges most classroom teachers to utilize instructional planning instruments and lesson design models that provide standard specific instruction and to gather evidence of student proficiency through both student work and testing. Instructional programs emphasizing inquiry are often criticized for being too open ended. The critics of this approach feel that inquiry often lacks a well-defined alignment to specific content standards and does not provide a reliable means of assessment.

As a result of states adopting science content standards to meet federal mandates, it has become an increasing challenge for schools

and classroom teachers to develop complex scientific reasoning abilities among the students rather than just a recitation of science facts. To have a real understanding or to be able to make real meaning of the big ideas in science, students need to be able to extend their ability to explain these concepts and their relationship to big ideas in science in their own words and based upon their own experiences. Using an alignment model or a lesson design model to plan guided inquiry that addresses both the need for content understanding and the development of complex scientific reasoning abilities will provide classroom teachers with the structure necessary to accomplish this task.

The designers of the Valle Imperial Project in Science (VIPS) model recognized that development of complex scientific reasoning takes time and that to be effective every science unit should be embedded with a lesson design that addresses the development of science concepts and thinking skills. This thinking was consistent with the recommendations from the National Research Council (1999, 2005). The structure of the VIPS lesson design model and classroom instruction focuses on maximizing student opportunity to develop complex scientific reasoning. The ability of students to actually make meaning or understand the goals of what the intended lesson was trying to achieve are essential to student learning.

The goal of every classroom teacher should be for students to make meaning and develop deep science conceptual and procedural understanding from classroom science experiences. Often this goal is difficult to achieve due to a disconnect between what should be taught, what actually *is* taught, and what students learn in the design of classroom instruction (Marzano 2003). These breakdowns in curriculum alignment and student learning may be a function of poor lesson design and planning or from teachers' "leap of faith" that the science curriculum materials that they use are aligned.

The research-based components of the VIPS lesson design provide teachers with a planning structure and provide practical suggestions to support student success. Research on how students learn science indicates that the development of deep conceptual understanding in science requires time and can be enhanced through providing supports, scaffolds, and prompts that guide students to enhance their scientific reasoning abilities (National Research Council 2005). Thus, classroom teachers must guide the inquiry process in order to develop,

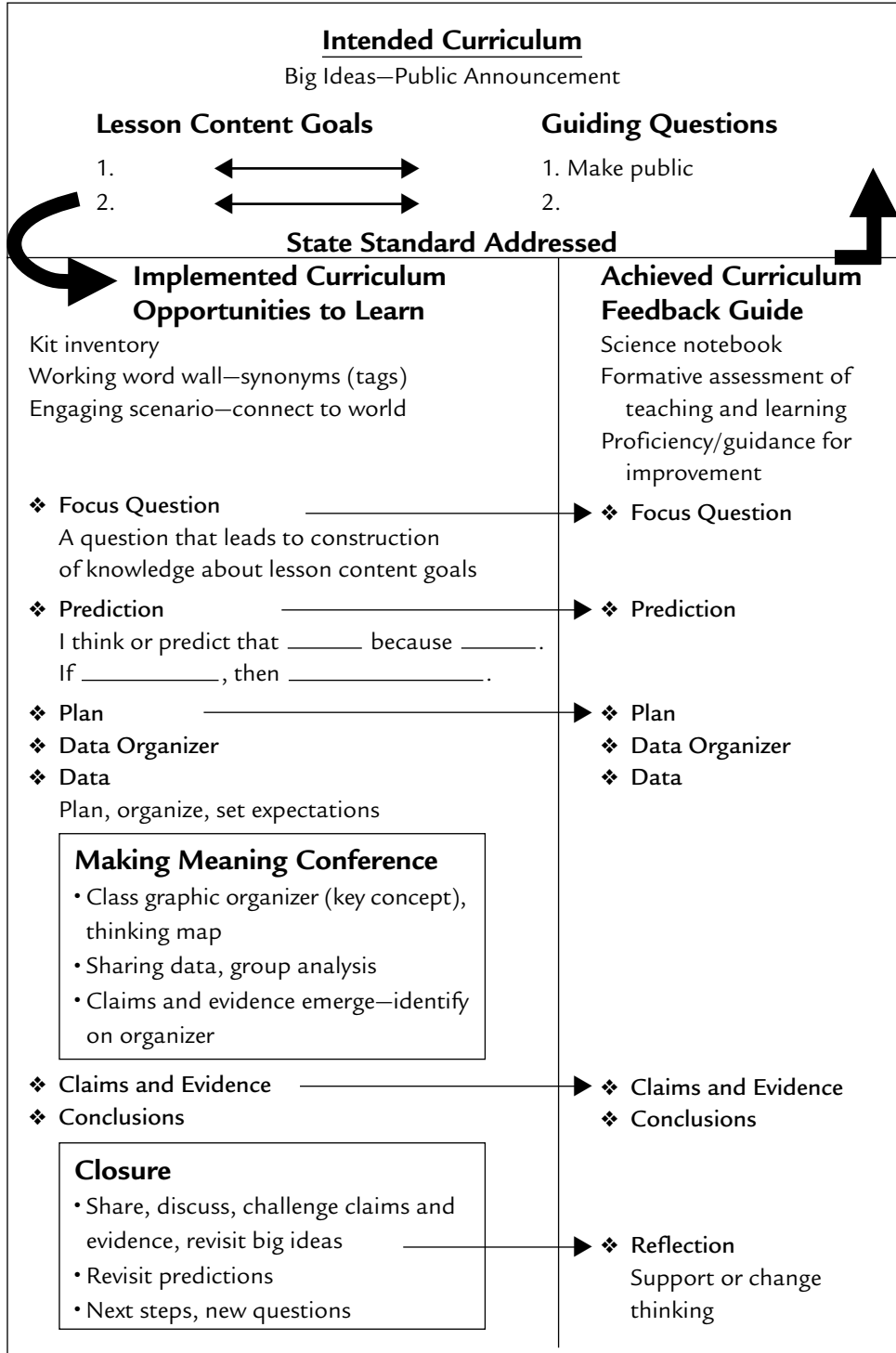
in their students, both deep conceptual understanding and the reasoning ability to formulate explanations based upon evidence.

The lesson design model VIPS developed uses a scaffolded guided inquiry approach for lesson planning. Using this approach, classroom teachers can address the need to systematically focus on a sequential set of instructional units all aligned to state content standards over several years to develop practice on the part of students in the use of the scaffolds through a consistent instructional approach. This approach provides classroom teachers with a lesson design that guides inquiry using scaffolds that are designed to place the focus of instruction on the actual intended curriculum through the implemented curriculum and attain the development of student understanding of the science content described within the standards and the development of complex reasoning abilities, such as analyzing and interpreting data or formulating claims from evidence collected during an investigation.

A planning model for scaffolded guided inquiry is a valuable structure for the alignment of the three critical elements of lesson planning—intended, implemented, and achieved curricula. By using a consistent approach to lesson planning and implementation, students are provided with *sameness* or consistency. Because students need to generate their own meaning regarding the science content being learned, the psychological principle of sameness is important. Marzano (2003) states that sameness is critical to the process of learning. When students are presented with processes that are similar through the consistent exposure to writing and discussion scaffolds or prompts, students learn how to do inquiry and develop the ability to make evidence-based explanations from their science investigations. This requires that teachers plan the learning experiences for children with careful thought. These learning experiences also need to be sequenced over several units and years because students need time and practice to learn how to do inquiry. It is therefore important for teachers to have the support of a lesson design model that is based on student success and carefully crafts an alignment between the intended curriculum, the implemented curriculum, and the achieved curriculum and is consistent in its approach to scaffolding.

Figure 1–1 depicts the lesson design model and the built-in scaffolds for guided inquiry that aligns the intended, implemented, and achieved curricula. Each of the three components of this model are introduced next and are discussed in subsequent parts of this book.

**Figure 1–1 Aligned Planning Model**



# Key Elements of the Intended Curriculum

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The model begins with what we call the *intended curriculum* or that which is expected to be taught. The intended curriculum identifies the big ideas of science and the specific district, state, or national science content standards that are to be addressed within a given lesson. The intended curriculum also specifically identifies the content goals that the lesson should achieve and the guiding questions that help students focus on the inquiry that will help them achieve the goal of the lesson. In order to be effective, the guiding questions must be aligned with the lesson content goals. This alignment of the lesson content goals with the guiding questions will also provide classroom teachers with an effective means of establishing criteria for student success in the lesson. The alignment defines what students should know and be able to do by the end of the lesson and provides clarity to the planning process for classroom teachers in terms of what should be learned by students as a result of the lesson.

## Key Elements of the Implemented Curriculum

The next phase of the lesson design models is the *implemented curriculum*. This is where the meat of the inquiry lies and where much of the activity of investigative science happens. The implemented curriculum has four phases, each designed to maximize student opportunity to learn.

The first phase, Set the Stage for Learning, is the unit or lesson opening that integrates research-based tools such as a kit inventory, working word walls, and vocabulary development. These tools provide a basis for introducing the unit and are the first step for students in developing fluency and contextual use of scientific vocabulary.

The second phase, Formulate Investigable Questions and Predictions, opens with high-interest scenarios that lead to student engagement in the lesson. The engaging scenarios are written in such a way to pose a problem that must be solved through an investigation.

The engaging scenarios may also be serialized throughout a unit of study and may be used to connect lessons. From these high-interest scenarios, students determine “what they want to find out” by formulating focus questions that address the problem posed in the engaging scenario. In this phase, science notebooks and discussion are used to help develop and record students’ questions and predictions. This phase lays the groundwork for investigative science on the part of the student.

The third phase of the implemented curriculum is Plan and Conduct the Investigation. Using small-group and class discussion, students devise a plan of action to answer the question created in Phase 1, utilize science notebooks to develop graphic organizers to record their observations and data collection, conduct the investigation, and record their collected data or observations in their science notebooks. This phase is critical in helping students create both a general and specific plan of action that will guide them through the investigation.

The fourth phase, Make Meaning, helps students make claims based upon their gathered evidence through the use of discussion and the entries in their science notebooks. Students are guided in the drawing of conclusions, reflecting on their experiences, and the development of new questions. Each of these phases are specifically planned to integrate the tools of writing and discussion as key components for students to gain meaning from the science lesson.

## Key Elements of the Achieved Curriculum

The last element of the lesson design model is the *achieved curriculum*. The achieved curriculum is directly aligned to the intended and implemented curricula. Each of the four phases of the implemented curriculum specifically guides the students to discuss key elements of the investigation and then to make appropriate notebook entries. There is a direct relationship between the implemented curriculum component and the associated notebook entry.

Student science notebooks are indicators of what is achieved in the lesson. By reading the entries, the classroom teacher can determine

if an alignment was consistent with the intended and implemented curricula. Student science notebooks also serve as tools to reflect individual student learning, class progress, and the effectiveness of the lesson. An important element to measure the degree of attainment in the achieved curriculum is the development of a feedback guide that is specific to the intended and implemented curricula. The student science notebook then becomes an effective formative assessment tool that teachers can use to see if the students are actually making the connection between what teachers were hoping to teach and what they actually taught.

This lesson design model is filled with guided inquiry scaffolds that are based on the belief that by scaffolding guided inquiry classroom experiences and the alignment of standards, meaningful instruction and student understanding will be attained. Students will actually understand the concepts that the teacher is trying to address in the intended curriculum. Classroom discussion and student science notebooks are the tools utilized in this alignment process to help students attain deep understanding of the required science content and to develop complex science reasoning abilities. This alignment also addresses the three guiding principles of how students learn science (National Research Council 2005) by embedding and scaffolding the activation of prior knowledge into the prediction, focusing on the connection of lessons and concepts to lead students to an understanding of the big ideas in science, and by developing metacognitive awareness in students through the use of graphic organizers, Venn diagrams, and other visual devices that assist students in making evidence-based explanations of their conceptual understanding of the science content taught in their classrooms.

The planning structure for alignment must be supported with tools for students such as science notebooks and small-group and classroom discussion to fully attain the depth of understanding that students need in order to become proficient learners. The tools of science notebooks and small-group and class discussion and their importance for students are fully presented in Chapter 2.