Nancy Larson® Science:

An Interwoven Approach to Elementary Science Instruction

Weaving Direct, Explicit Instruction with Guided Inquiry-based Applications

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"One cannot discover what one cannot conceive." (Hestenes, 1992, p. 3)

Introduction

How do elementary teachers ensure that young children internalize the basic science concepts they will learn? Is it from explicit teacher instruction or through inquiry and hands-on activities? Research and journal articles are replete with arguments supporting one or the other: direct/explicit instruction or inquiry learning. Research also supports the idea that both direct/explicit instruction and inquiry learning are important components of science education (Kuhn, 2007; Sun, Mathews & Lane, n.d.).

The purpose of this paper is to advance the concept that effective science instruction that engages young students in their learning about science should include a balance of direct, explicit instruction interwoven with age-appropriate inquiry. Nancy Larson® Science provides an instructional program that is delivered under the direction of a teacher who explicitly guides the novice learner through both direct instruction and hands-on inquiries in a coherent progression so students may gain a deeper understanding of scientific concepts and the nature of science. Archer and Hughes (2011) contend the importance of good teaching is critical to direct instruction and Cobern et al. (2009) conclude that "expertly designed instructional units, sound active-engagement lessons, and good teaching are as important as whether a lesson is cast as inquiry or direct" (p. 11). Nancy Larson® Science lessons are clearly written, are easy to follow, inform the novice teacher regarding science facts and inquiry procedures, and address both direct and inquiry learning.

As this paper will confirm, Nancy Larson® Science builds elementary students' knowledge and understanding of scientific content through a systematic progression of lessons that include both direct/explicit instruction and a combination of structured and guided inquiry appropriate for students in elementary grades. Nancy Larson® Science includes curriculum, materials, and instructional strategies that are developmentally appropriate and designed to help young students engage actively in their own learning.

The National Research Council (2007) contends:

> What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on their prior opportunities to learn. (p. 2)

Beginning in kindergarten, Nancy Larson® Science lessons build on key ideas that are prerequisite for subsequent lessons. By learning information in small, incremental steps, and engaging in hands-on activities, even very young children understand the concepts and are prepared for the next lesson in the progression.

Direct Instruction

The term "direct instruction" is associated with both specific programs that fall under the umbrella of Direct Instruction or DI (www.nifdi.org) and the more generic models of direct instruction based on the following principle: "When teachers explain exactly what students are expected to learn, and demonstrate the steps needed to accomplish a particular academic task, students learn more" (Direct Instruction, n.d., Instructional Principle). According to Steedly, Dragoo, Arefeh, and Luke (2008), "Explicit instruction, often called direct instruction, refers to an instructional practice that carefully constructs interactions between students and their teacher. Teachers clearly state a teaching objective and follow a defined instructional sequence" (p. 3). For the purpose of this paper, the similarity in the definitions for "direct" and "explicit" instruction provides the rationale for using the two terms interchangeably.

In the preface of their book *Explicit Instructions: Effective and Efficient Teaching,* Archer and Hughes (2011) state, "The effectiveness of explicit instruction has been validated again and again in research involving both general education and special education students…[and] is absolutely necessary in teaching content that students could not otherwise discover" (para. 1). Direct instruction is especially supportive of students with learning disabilities. (Archer & Hughes, 2011; Chall, 2000; Lillie, 2000). Gersten and Baker (1998) report their research shows "students need to be explicitly taught relevant facts and concepts (i.e., declarative knowledge) essential for meaningful involvement in problem-solving activities" (p. 31).

While there are variations, the basic components of direct instruction include: accessing prior knowledge, stating the goal, presenting the new material, posing questions, scaffolding, allowing for guided and independent practice, and providing periodic review (Direct Instruction, n.d.; Grossen & Burke, 1998; Huitt, 2005; Rosenshine, 1986). Huitt (2008) developed a transactional model that emphasizes "repeated interaction of teachers and students throughout the lessons" (p. 1). According to Chall (2000), "The methods with the highest positive effects on learning are those for which the teacher assumes direction, for example, letting students know what is to be learned and explaining how to learn it…" (p. 99).

Lessons in Nancy Larson® Science include all the components of direct instruction. Within each lesson the teacher

- begins with a review of the previous lesson (accessing prior knowledge): "In our last lesson we learned about the gases that make up the Earth's atmosphere and the atmosphere of the other planets."
- states what the students will learn in the current lesson (stating the goal): "Today you will learn about the layers of the Earth's atmosphere."
- presents the lesson (presenting new material) using multiple strategies, posing questions and scaffolding: "Follow along as I read paragraph one." "What is the layer of atmosphere closest to the surface of Earth called?" "Highlight the words '<u>where all weather occurs</u>' and '<u>where clouds form</u>.'"
- provides practice using a variety of activities that may include music, drama, reading, writing, and/or graphic organizers (guided practice): "We will use the information on

page 6 to draw a diagram of the layers of the atmosphere on page 7."

- engages students in independent work that includes writing and completing a review work page (independent practice/periodic review): "Use the diagram on page 7 to complete the chart."

At the beginning of each lesson, the cycle is repeated and students review what they learned in the previous lesson (accessing prior knowledge and periodic review). "In our last lesson we learned…." Finally, students are assessed over the entire unit.

In their study of the effectiveness of direct and discovery learning involving 112 third- and fourth-grade students, Klahr and Nigam (2004) found:

> …not only that many more children learned from direct instruction than from discovery learning, but also that when asked to make broader, richer scientific judgments, the many children who learned about experimental design from direct instruction performed as well as those few children who discovered the method on their own. (p. 661)

Klahr and Nigam (2004) are not alone in their contention that teacher-directed lessons and guidance through explicit instruction are powerful tools for helping students learn science. According to Schwerdt and Wuppermann (2011), "…an emphasis on lecture-style presentation (rather than problem-solving activities) is associated with an increase—not a decrease in student achievement" (para. 6). While teachers using Nancy Larson® Science do not "lecture" to elementary students, they do present information in a direct/explicit manner that includes guided hands-on learning experiences appropriate for students who are at the beginning stages of learning science. Kirschner, Sweller and Clark (2006) assert, "Insofar as there is any evidence from controlled studies, it almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners" (p. 83). In their study of 31 low-income schools in Los Angeles, Poplin et al. (2011) found effective teachers were direct in their teaching. Further, Poplin et al. state clearly, "We need to be cautious about adopting complicated, trendy, and expensive practices. We need to re-evaluate our affection for cooperative/collaborative learning…as well as our disaffection with explicit direct instruction and strict discipline" (p. 43). In her book *The Academic Achievement Challenge: What Really Works in the Classroom*, Chall (2000) expresses a similar view "…a traditional, teacher-centered approach to education generally results in higher academic achievement than a progressive, student-centered approach" (p. 182).

How do students in elementary grades make sense of science and the nature of science? Crowther, Lederman and Lederman (2005) point not only to the nature of science in which "some laws in science have stood the test of time" but also to the fact that "different types of investigation provide different information and evidence concerning the natural world" (p. 51). In Nancy Larson® Science, students first learn scientific concepts and "laws" through direct, explicit instruction in which the teacher shares new information that is connected to and built upon previous lessons. The same information is the link to subsequent learning. Lessons focus not only on scientific information but also on literacy strategies, including vocabulary building. According to Elliott (2010), "Students enjoy demonstrating their comprehension of ideas by learning to use scientific terminology correctly" (para. 3). After initial instruction, the teacher involves students in hands-on activities. These activities, which include observations, data collection and interpretation, and experiments that are appropriate for the lesson, help students understand both the laws of science and the manner in which investigations can be interpreted. The combination of direct instruction with hands-on/inquiry learning allows students to deepen their understanding and make the connection between facts and experience.

An important feature of direct instruction is the methodical and sequential manner in which lessons are conducted (Direct Instruction, n.d.; Steedly et al., 2008). Such explicit instruction allows the teacher to teach important and necessary scientific content by concentrating on big ideas and key facts and avoiding misinformation. According to Munson (2011), "More and more research is emerging to suggest that we need to make the *content* of education the centerpiece of discussions about educational reform" (p. 14), and Michaels, et al. (2007) state, "Learning new facts is important in science education" (p. 41).

Inquiry Learning/Hands-On Science

According to Science Inquiry (n.d.):

> Inquiry is an interactive process that actively engages students in learning in meaningful ways. The process of inquiry is characterized by interactive, student-centered activities focused on questioning, exploring, and posing explanations. The goal of inquiry is to help students gain a better understanding of the world around them through active engagement in real-life experiences. (p. 1)

Colburn (2000) describes the spectrum of inquiry learning that includes:

> Structured inquiry—The teacher provides students with a hands-on problem to investigate as well as the procedures and materials, but does not inform them of expected outcomes.
>
> Guided inquiry—The teacher provides only the materials and problem to investigate. Students devise their own procedure to solve the problem.
>
> Open inquiry—This approach is similar to guided inquiry, with the addition that students also formulate their own problem to investigate. (p. 42)

While there is a place for all three types of inquiry, one of the benefits of structured inquiry is "it allows the instructor to teach students the basics of investigating as well as techniques of using various equipment and procedures that can be used later in more complicated investigations" (Just Science Now, n.d., Structured Inquiry). In Nancy Larson® Science, teachers use structured inquiry when young students need direct procedural instruction for conducting their hands-on applications.

Wetzel (2009) affirms that inquiry provides students opportunities to be engaged and to learn the life-long skill of problem solving. Bybee and Van Scotter (2006/2007) declare that for students to know and comprehend science, they must be actively involved in hands-on activities that allow them to investigate, question and participate in discussions.

Haury and Rillero (1994) summarize the benefits of hands-on learning. Among the benefits are "increased learning; increased motivation to learn; increased enjoyment of learning; increased skill proficiency, including communication skills; increased independent thinking and decision making based on direct evidence and experiences; increased perception and creativity" (Questions and Answers No. 2, Summary). Beginning with the kindergarten program, Nancy Larson® Science engages students in both structured and guided inquiry/hands-on science that provide (1) the guidance necessary to avoid misconceptions and erroneous conclusions and (2) the prerequisite experiences that will later support their open inquiry investigations.

Prior Knowledge

When considering any instructional model, it is important to examine research relative to prior knowledge as it relates to learning. Because of the significance of prior knowledge, numerous researchers discuss the importance of accessing prior knowledge based on students' experiences as well as building background knowledge through instruction. A few of those researchers include Corcoran, Mosher and Rogat (2009); Grossen and Burke (1998); Hall (2009); Jones (1986); Kuhn (2007); Laplant (1997); Mayer (2004); Roschelle (1995); Rosenshine (1995); Strangman and Hall (2004); and Vosniadou (2001). Associating prior and new information provides students with the connections they need for building new knowledge. Sometimes teachers help students access their prior knowledge based on their culture, their experiences, and their prior learning (Jones, 1986). Other times teachers develop prior knowledge upon which more information will be built. According to Rosenshine (1995), a rich reservoir of knowledge in which individual pieces of information are connected helps the learner associate new information with stored knowledge from prior experiences and learning. "Education is a process of developing, enlarging, expanding, and refining our students' knowledge structures" (Rosenshine, 1995, p. 262). Roschelle (1995) asserts, "New knowledge does not replace prior knowledge, rather new knowledge re-uses prior knowledge. Re-use is made possible by a process in which prior knowledge is refined, and placed in a more encompassing structure" (Section 1, para. 6).

While all students benefit from instruction that activates their prior knowledge and experiences, this is a critical component of instruction both for students who are identified for special education services and for students for whom English is a second language. In discussing the Sheltered Instruction Observation Protocol (SIOP), Haynes (n.d.) advises, "Concepts should be directly linked to students' background experience. This experience can be personal, cultural or academic" (Building Background).

According to Grossen and Burke (1998), "Students with learning difficulties may lack prerequisite skills or may not understand instructional vocabulary. This necessary background knowledge must be taught or 'primed' before understanding of new material can occur" (Part II. Prime Background Knowledge).

While the importance of building new knowledge on prior learning is widely recognized, teachers must be aware of and address the fact that many times students have no knowledge upon which to build new knowledge, have preconceptions, or have misinformation that could impede their correct understanding of new information. (Blosser, 1987; Schwartz & Bransford, 1998; Vosniadou, 2001; and Wandersee, 1986). Hall (2009) addresses the importance of the accuracy of students' prior knowledge and its use to "increase the likelihood that students will be successful on new tasks…" (Essential Instructional Design Components, para. 6). Smolleck and Hershberger (2011) explain that "…children often come to school with conceptions that are often inconsistent with commonly held views of scientific concepts, skill and phenomena" (p. 4). Consequently before beginning a lesson, it is imperative that the teacher focuses on correct information that undergirds the current lesson.

Recognizing the importance of accurate prior knowledge, every lesson in Nancy Larson® Science begins with a review of what students have learned in previous lessons. For example, the lessons on "Investigating Changes in Our Atmosphere" in Nancy Larson® *Science 3*, begin with a statement related to previously learned facts: "In our earlier science lessons, we learned about the states of matter…what are the states of matter?"

Coherent Progression of Materials and Lessons

The importance of a coherent progression of science lessons is addressed in the research on effective science instruction. Bybee and Van Scotter (2006/2007) explain that coherence involves the manner in which content and processes are connected over one or more years. Marx (2008) states, "Curriculum coherence is an analytic construct and is defined in terms of how topics align, the depth at which they are to be learned, and the sequence within and across grades" (p. 102).

Other researchers also address coherence. Heritage (2008) discusses how learning progressions help teachers "build explicit connections between ideas for students that thread the development of increasingly complex forms of a concept or skill together" (p. 4). Salinas (2009) explores two different approaches to learning progressions, both of which involve a sequence of learning, refers to multiple definitions of "leaps" or learning progressions. He summarizes progressions as providing "…increases in sophistication of thinking, whether advancing toward expert knowledge or generalizing conceptual understandings" (p. 2).

Newman, Smith, Allensworth, and Bryk (2001) state, "We found a strong positive relationship between improving coherence and improved student achievement" (p. 305). Other researchers who address coherent instruction and/or learning progressions include Corcoran, et al. (2009); National Research Council (2007); Schmidt (2002); Smith, Wiser, Anderson, and Krajcik (2006); and Stevens, Shin, and Krajcik (2009). Most research on the topic speaks to the issue of depth of learning key ideas that are related and taught over a time. Stevens et al. (2009) include the importance of instructional strategies, curriculum, materials, students' prior knowledge and experiences, and assessment as part of learning progressions.

Shin, Stevens, Short, and Krajcik (2009) explain:

> Intra-unit coherence results from developing integrated understanding by focusing on a few key science ideas rather than superficially covering many unrelated ideas in a single unit. Inter-unit coherence means that these same key ideas are addressed in multiple units within and across disciplines to construct integrated knowledge of those ideas across units and years. (p. 2)

The sequential alignment of key topics is a governing factor in Nancy Larson® Science. Information is presented in a sequence that builds on the key ideas of science, moving from the broad picture to details related to the key idea. For example, in *Science 3*, instruction focuses on "structure in nature." Lessons are connected to the big idea of structure in nature through sequential lessons that provide students with explicit and implicit knowledge that is both robust and developmentally appropriate. Students begin *Science 3* by learning about the structure of the solar system and the structure of matter. In subsequent lessons they study the structure of the Earth's atmosphere followed by the structure of the Earth's layers, the structure of soil, and the structure of plants and animals.

In order for students to understand the role of chemistry in natural structures, they are introduced to the Periodic Table of the Elements. Students are not expected to memorize the table, only to understand how chemical elements and compounds are nature's building blocks. This learning and understanding of elements is interwoven through the progression of lessons helping students comprehend the structures of the atmosphere, the Earth's layers, soil make-up, and plant photosynthesis.

In addition to the teacher-directed instruction, lessons include hand-on activities in which students compare and contrast information, prepare graphs, determine effects, conduct research, and perform experiments. Periodic reviews and assessments are also included throughout the lessons and units.

Student Engagement

According to Vosniadou (2001):

> Learning at school requires students to pay attention, to observe, to memorize, to understand, to set goals and to assume responsibility for their own learning. These cognitive activities are not possible without the active involvement and engagement of the learner. Teachers must help students to become active and goal-oriented by building on their natural desire to explore, to understand new things and to master them. (p. 8)

Through the use of direct/explicit instruction, the teacher can provide the support and direction students need in order to attend to the essential content. Students are engaged throughout the entire lesson by being asked to respond both individually and as a group. (Direct Instruction, n.d.) Student engagement is key in Nancy Larson® Science. In every lesson the teacher keeps students attending to the content by continually posing questions, instructing students to highlight key vocabulary and information, and having the students follow along as the teacher reads a brief but important passage from the lesson. The level of interest in learning is supported by students' natural curiosity. As Moore (2010) tells us, "The more students know, the more they want to know" (para. 8).

The pace of Nancy Larson® Science lessons, the learning strategies, and the activities motivate elementary students to take responsibility for their own learning, a key point among researchers who posit that it is the student who must construct the meaning (Direct Instruction, n.d.; Kuhn, 2007). Mestre (2001) states, "Although teachers can facilitate learning, research indicates that students must do the learning themselves" (p. 48). The good news comes from Metz (2008) who inspires confidence in our students' abilities in her statement, "Fortunately, there is strong evidence that elementary school children are much more capable of engaging in the practice of science than curricular trends presume" (p. 139).

Making Connections

Making connections is a way of helping novice learners expand their understanding as well as motivating them to have a deep interest in science. Teachers using Nancy Larson® Science explicitly weave in a variety of connections through conversations, hands-on experiences, research projects, and experiments that complete the learning experience. Following are examples from literature and research-supported connections from Nancy Larson® *Science 3:*

Connect with students by motivating them to think of themselves as scientists (Michaels, Shouse & Schweingruber, 2007). "This year you will be scientists when you observe, record information, ask questions, and work to find answers." Students identify themselves as a geologist, botanist, physicist, or meteorologist depending on what is being studied. The teacher states, "Scientists who observe and study the Earth's atmosphere are called meteorologists. Write your name on the cover [of your meteorology booklet] next to the word 'Meteorologist.'"

Connect with accessing prior knowledge (Rosenshine, 1995, and others). "In our earlier science lessons, we learned about the states of matter…what are the states of matter?"

Connect with setting a goal for learning (Moss, et al., 2011). "Today you will learn about the gases that make up the Earth's air, or atmosphere. You will also learn about the atmosphere of the other planets."

Connect with telling students what they will be learning next (Moss, et al., 2011). "In our next science lesson, we will learn about the layers of the Earth's atmosphere." (Also, a systematic curriculum that builds on information in a sensible way.)

Connect with graphic organizers (Hall & Strangman, 2002). "Label the gases in the Earth's atmosphere on the circle graph below" and "Complete the Venn diagram by placing the gases shown in the box in the correct section of the diagram."

Connect with one-variable experiments that students set up (Klahr and Nigam, 2004). The teacher introduces the requirements for conducting an experiment.

Materials you will need to use to conduct this experiment

Steps or procedures you will use to conduct this experiment

Hypothesis: What is your prediction about what will happen in this experiment?

Collecting data

Analyzing data

Drawing conclusions

Connect with peers working together (Haynes, n.d.). "I will assign partners to work together to find the names of the gases that make up most of the atmosphere of each of the planets."

Connect with application of what students have learned using higher-order thinking skills (Haynes, n.d.). "Astronomers have studied the atmosphere of the planets. Why would life on Mars be more likely than life on Venus?"

Connect with math (Frykholm & Glasson, 2005). "Let's add the percentages [of the Earth's gases] together…what is the sum? One hundred percent is the same as one whole."

Connect with the importance of asking questions (Holt, 2000). Nineteen questions are asked of students during Lesson 42—each question focuses on an important concept related to matter and asking students to think about and reflect on what they are learning.

Connect with literacy and learning strategies (Elliott, 2010). "What is the title of this booklet?" "Which words should we highlight to remember what a meteorologist does? In the second sentence, highlight the words 'observe, measure, and report the weather.' In the third sentence, highlight the words 'predict the weather.'"

Connect with vocabulary enhancement (Elliott, 2010). "What state of matter is the air around us? Each of the planets has gases that surround it. These gases are called the planet's atmosphere. Today you will learn about the gases that make up the Earth's air, or atmosphere."

A Balanced Approach

According to Roth and Garnier (2006/2007) who studied results from the 1999 Trends in International Mathematics and Science Study (TIMSS) video study that compared math and science instruction in the United States and four higher achieving countries (Czech Republic, Japan, Australia, and the Netherlands), the other countries "strongly focused on developing science content and connecting that content to activities, in contrast to the fragmented variety of pedagogical approaches and activities that characterized U.S. science lessons" (p. 21). Based on their findings, they conclude:

> The TIMSS video study results challenge us to think more deeply about the role of science content in hands-on, inquiry teaching and to question how schools can better link such hands-on, inquiry teaching to the development of science content understanding. Those directing science education policy in the United States need to

> look into science professional development and teacher education programs and ask, is our emphasis on 'inquiry' unintentionally obscuring the importance of understanding science ideas? (p. 22)

Lessons in Nancy Larson® Science focus on both direct instruction for robust content and interweave hands-on and inquiry learning, thus providing students with a well-rounded and firmly grounded science learning experience. Michaels, et al. (2007) contend that "in science, content and process are inextricably linked" (p. 17). This interdependency is addressed by Schauble (1996) who states, "…appropriate knowledge supports the selection of appropriate experimentation strategies, and systematic and valid experimentations support the development of more accurate and complete knowledge" (p. 118). Sun, Mathews and Lane (n.d.) also address the importance of both explicit learning from instruction and implicit learning from experience as essential to learning.

In discussing the importance of allowing all students to be active learners with sufficient guidance to ensure they appropriately combine new knowledge with prior learning, Mayer (2004) asserts, "Children seem to learn better when they are active and when a teacher helps guide their activity in productive directions" (p. 16). Considering students with special needs, Gersten and Baker (1998) state, "the combination of explicit instruction and use of real world applications increases transfer and retention for many students with learning disabilities" (p. 30).

Metz (2008) concludes that "Robust domain knowledge is intimately connected with robust inquiry and vice versa" (p. 141). The balance of direct and inquiry learning in which direct instruction informs inquiry is clearly advantageous for elementary students who are learning science. Such a balance is found in Nancy Larson® Science, which interweaves direct instruction of scientific facts and principles with hands-on activities and inquiry learning to provide the instructional fabric that supports and motivates students and gives them a deeper understanding and appreciation of science.

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