HAS INQUIRY MADE A DIFFERENCE?
A SYNTHESIS OF RESEARCH ON THE IMPACT OF INQUIRY SCIENCE INSTRUCTION ON STUDENT OUTCOMES

Technical Report 2:
Conceptualizing Inquiry Science Instruction

The Inquiry Synthesis Project

Center for Science Education

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INTRODUCTION

This technical report introduces and explains a structure for describing inquiry science instruction. Such a structure was essential for this project, which addresses the research question, What is the impact of inquiry science instruction on student outcomes? Because there is great variability in definitions of "inquiry science" commonly used by practitioners, academics, and the public, it was imperative to develop a *systematic* way to code for the treatment—inquiry science instruction. The first section of this report briefly describes the theoretical and historical underpinnings of inquiry science instruction. The second section presents the rationale and process by which the research team derived a systematic way of capturing the variability of inquiry from past and present heterogeneous definitions in the field. The third section illustrates the operationalization of the rationale into a coding framework.

HISTORICAL OVERVIEW AND THEORETICAL UNDERPINNINGS

To understand the complexity of designing a process to describe inquiry science instruction, it is important to appreciate, in broad terms at least, the complex history of science education in this country, as well as the role that inquiry science teaching and learning has played.

The establishment of science instruction is grounded in the mid-19th century when science began to emerge as a possible subject in the general curriculum. At that time, the discussion about science instruction did not focus on the merits of particular instructional strategies as it does today but, rather, on whether science (as opposed to classical studies) should be included in the curriculum at all. One line of argument focused on the importance of education enhancing "mental discipline" and intellectual acuity. Another emphasized the importance of addressing practical matters that were applicable to the issues of the day. In each case, advocates of science education argued that science was best able to address both, and argued that what was needed "was a process that produced both useful knowledge and improved mental power at the same time. This was the contribution that science could make" (DeBoer, 1991, p. 6).

In contrast to the rationale for classical studies, advocates for science instruction articulated that its unique focus on observation, experimentation, and reasoning could best develop the mind and have practical applicability. They suggested that "only through the direct observation and classification of natural objects and direct study of natural phenomena would science retain its… role in developing the kind of mental discipline that other school subjects could not provide" (DeBoer, 1991, p. 10). According to science education historian George DeBoer, "the particular kind of science teaching that the scientists supported focused on the meaningful learning of science concepts derived from direct contact with the natural world. The laboratory was to be a place where skills in observation and inductive reasoning powers would be developed. Proficiency in scientific reasoning would free individuals from the dominance of authoritarian teaching and empower them to derive truth independently" (1991, p. 17). And yet, the science study most common at the time did not reflect these ideas. It was "primarily book-taught, with the recitation of memorized texts the mode of instruction" (DeBoer, 1991, p. 20). This era in science education laid the foundation for today's continuing debates about the goals of science instruction and the merits of particular instructional strategies.

As the turn of the century arrived, science became more established as a part of the curriculum. Over these years, prominent leaders in education of the time began to articulate some of the characteristics of science instruction that today are, in some measure, associated with inquiry instruction. Among these are the notion that knowledge must be acquired by the individual, that successful science instruction must attract the students' interests, that science instruction should engage the senses, and that science instruction should feature the laboratory and teach students to think. Still, there was no agreement on an accepted approach to science instruction. Over time, science educators debated many issues, including how to balance an emphasis on the science disciplines with the aspects of instruction that would engage the students in ways that were meaningful to them, how to balance the content of the subject matter and the applicability of that content to solve problems, and how to most effectively and appropriately use the laboratory. These debates have continued for 100 years and still persist.

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In the early 1960s, around 20 years prior to the date when the first studies eligible for inclusion in this synthesis would be published, the use of terms most closely associated with inquiry instruction became increasingly evident. Most notably, Joseph Schwab wrote *The Teaching of Science as Enquiry*, in which he advocated for science instruction that more accurately reflected the evolution of thinking about science itself. Schwab (1962) was less concerned with students developing habits of inquiry and emphasized, instead, using inquiry as a mode of teaching to portray science as inquiry. "In these classrooms, students would be led to dissect the textbook and lectures, to look for evidence for the validity of the claims of others, and to be active in a process of analysis. The teacher's job in such a classroom changed from one of presenting information and explaining concepts to one of teaching students how to ask questions, how to look for evidence, and how to evaluate the results of their enquiries" (DeBoer, 1991, p. 165). *Inquiry* learning, along with *discovery learning*, *teaching by problem solving*, *inductive methods*, and *hands-on exploration*, soon became commonplace terms in discussions of science education. In the 20 years of research included in this synthesis, all of these terms and others are used to describe instruction that could be categorized under the large umbrella of inquiry. It was against the backdrop of this history that this project set out to develop a system to describe inquiry instruction in a way that would respect and accommodate this variability.

RATIONALE AND PROCESS FOR ARRIVING AT INQUIRY DESCRIPTION

As the brief history of science education and inquiry science instruction illustrates, *inquiry* is a complex set of ideas, beliefs, and pedagogies that, over the past 40 years, has achieved much attention with little agreement. Differing schools of thought regarding its characterizing features have evolved over time, and even within these schools of thought, at any point in time there is variation. Given this variability, and because this synthesis seeks to understand the impact of inquiry science instruction as reported in studies conducted over the past 20 years, it was evident that attempting to select a definition of inquiry as a standard for assessing the science instructional treatment in the studies would inappropriately constrain the studies that could be included. Any single definition of inquiry would necessarily reflect the thinking of a particular school of thought at a particular moment in time and would not accommodate the range of studies otherwise eligible for inclusion, thus reducing the variation researchers intentionally sought to preserve. Therefore, for the purposes of this synthesis, it was essential to develop a strategy that would *describe* the inquiry science instructional treatment and its variations rather than limit it.

Developing a framework for describing inquiry instruction that was sensitive to the many ways it had been understood and enacted over time was a complex, lengthy, and iterative process. It included reviewing relevant history with a focus on literature that had been written over the course of the past 30 years in order to understand the evolution of inquiry science education and instruction. Many varied sources were consulted, including documents from the Exploratorium Institute for Inquiry, the Council of State Science Supervisors, the National Science Foundation, the National Research Council, the National Association for Research on Science Teaching, and a range of curriculum materials, books, and articles (a list of selected resources used for this review is included at the end of this report.) This was a critical part of the development process, because the protocol developed from this process had to be responsive to instruction that was enacted in the recent and the more distant past. The goal was to arrive at a set of descriptive characteristics that was parsimonious yet inclusive of the essential characteristics of inquiry science instruction that were consistent over time and across perspectives.

In addition to reviewing the resources, the project team periodically sought the input of advisors either individually or through group meetings. In these conversations, advisors suggested several characteristics of inquiry science instruction that could be considered characteristic, core elements including the notion that students experience personal engagement with phenomena; that students focus on key science concepts; and that there must be some level of student ownership in the learning experience. Keeping under consideration the representation of inquiry in the literature, these and other identified aspects of inquiry science instruction were refined and reshaped through a continuing developmental process.

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Another part of the process entailed adjusting the characteristics of inquiry included in the framework to the appropriate level of specificity. Initially, the team identified very detailed aspects of instruction that reflected the many complexities of designing and implementing instruction, teacher-student interactions, and student learning. However, for the purposes of this study, the description of inquiry science instruction was limited by the information available in the collected studies. Thus, it was important to ensure that the framework and available information were compatible. The team conducted preliminary reviews of collected studies in order to ascertain the level of detail evident, and in some cases, portions of the framework were combined into somewhat broader categories that were more appropriately matched to the data available.

Through continuing conversations among the team and advisors, numerous cycles of protocol development, field testing, and revision, the team arrived at the framework described below (see Table 3 for the complete framework).

DESCRIBING INQUIRY SCIENCE INSTRUCTION

The description framework has three sections:

Section I, "Presence of Science Content," describes the *science content* that students are studying. The categories and descriptions of science content used are those articulated in the *National Science Education Standards* of the National Research Council and include physical science, life science, earth/space science, and inquiry as content.

Section II, "Type of Student Engagement," describes the range of *ways students experience the science content*—manipulating materials, observing scientific phenomena, observing demonstrations, and/or using secondary sources that include reading materials, the Internet, discussions, lectures, and data collected by others.

Section III, "Elements of the Inquiry Domain present in the Components of Instruction," comprises two parts that together describe *how students are learning the science content*. The first part, "Components of Instruction," includes five typical features of science instruction found in reviewed resources—question, design, data, conclusion, and communication. They are displayed in Table 1 below, with a brief description of each component.

Table 1

COMPONENTS OF INSTRUCTION	QUESTION	DESIGN	DATA	CONCLUSION	COMMUNICATION
	Establishment, identification, or generation of a **question** to guide student work	Establishment, identification, or generation of a framework, plan or **design** to gather data that will answer an investigation question	Gathering, recording, and/or structuring **data**	Generation of **summaries, interpretations, explanations,** or **implications** from the data	Oral, visual, or written **communication** about data, results, or other aspects of an investigation

The second part, "Elements of the Inquiry Domain," lies at the heart of understanding the inquiry science instruction treatment. It includes three distinct elements: student responsibility for learning, student active thinking, and student motivation. Together, these elements comprise the "Inquiry Domain" and are illustrated in Table 2 below.

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Table 2

INQUIRY DOMAIN ELEMENTS	STUDENT RESPONSIBILITY FOR LEARNING	STUDENT ACTIVE THINKING	STUDENT MOTIVATION
	Students make decisions, identify where they need help and what they are confused about, keep self and others on task, assist with others' learning, contribute to advancing group knowledge	Students do intellectual work, generate ideas, take risks, use logic, make deductions, crystallize ideas, brainstorm, engage in active questioning, link ideas, use prior knowledge	Students display/express interest, involvement, curiosity, enthusiasm, perseverance, eagerness, focus, concentration, pride

Inquiry science instruction is characterized and shaped by expectations for student growth within any of the elements. For example, *student responsibility for learning* relates to the students' role as learners; therefore, inquiry instruction that embodies this element demonstrates the expectation, for example, that students will participate in making decisions about how and what they learn, keep themselves and others on task, identify where they and others need help in the learning process and ask for that help, and/or contribute to the advancement of group knowledge. *Student active thinking* refers to how students engage with the content itself. Thus, inquiry instruction that exemplifies this element demonstrates, for example, the expectation that students will use logic, think creatively, build on prior knowledge, and/or make deductions. Finally, *student motivation* is about students' personal investment in the learning process; inquiry instruction within this element intentionally builds on and develops students' curiosity, persistence, concentration, and/or focus.

USING THE FRAMEWORK TO IDENTIFY AND DESCRIBE INQUIRY SCIENCE INSTRUCTION

This section describes the application of the framework (see Table 3) in the process of coding the nature and extent of inquiry science instruction present in a study.

When coding a study, researchers identify the content the students are expected to learn, the ways they engage with that content (Sections I and II of the framework), and the extent to which the instruction they experience embodies elements of inquiry (Section III of the framework). Sections I and II entail making decisions about the presence/absence of content and types of engagement. Section III entails making decisions about the presence or absence of each component of instruction and then, when a component of instruction is present, the degree to which that instruction emphasizes the elements of inquiry. Thus, the research team identifies the degree to which the instruction described in the studies emphasizes *student responsibility for learning*, *student active thinking*, and *student motivation.* When coding for responsibility for learning and student active thinking, the categories of *no emphasis*, *some emphasis*, *a lot of emphasis*, or *not reported* are used and identified for each component. Student motivation, however, is unique in that it is more difficult to align with a single component of an intervention. As a result, the emphasis given to it is noted across the instruction as a whole. These categories are intended to capture the degree to which the instruction demonstrates the *expectation* that students will rely on and use those skills that are associated with their role as learners (student responsibility for learning), their engagement with the science content (student active thinking), and their commitment/persistence (student motivation). Degrees of *emphasis* enable researchers to express their best estimation of the nature of instruction, without suggesting a more precise measurement than was possible given the limitations of the studies' descriptions.

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Table 3

<table>
<tr><td>Presence of Science Content
(Section I)</td><td colspan="4">• Science as inquiry
• Life science
• Physical science
• Earth and space science</td></tr>
<tr><td>Type of Student Engagement
(Section II)</td><td colspan="4">• Students manipulate materials
• Students watch scientific phenomena
• Students watch a demonstration of scientific phenomena
• Students watch a demonstration that is NOT of scientific phenomena
• Students use secondary sources
• Not reported</td></tr>
<tr><td colspan="2">(Section III)</td><td colspan="3">Elements of the Inquiry Domain</td></tr>
<tr><td rowspan="21">Components of Instruction</td><td></td><td>Student Responsibility for Learning</td><td>Student Active Thinking</td><td>Student Motivation</td></tr>
<tr><td rowspan="4">Question</td><td>Not reported</td><td>Not reported</td><td rowspan="7">No emphasis</td></tr>
<tr><td>No emphasis</td><td>No emphasis</td></tr>
<tr><td>Some emphasis</td><td>Some emphasis</td></tr>
<tr><td>A lot of emphasis</td><td>A lot of emphasis</td></tr>
<tr><td rowspan="4">Design</td><td>Not reported</td><td>Not reported</td></tr>
<tr><td>No emphasis</td><td>No emphasis</td></tr>
<tr><td>Some emphasis</td><td>Some emphasis</td></tr>
<tr><td>A lot of emphasis</td><td>A lot of emphasis</td><td rowspan="7">Some emphasis</td></tr>
<tr><td rowspan="4">Data</td><td>Not reported</td><td>Not reported</td></tr>
<tr><td>No emphasis</td><td>No emphasis</td></tr>
<tr><td>Some emphasis</td><td>Some emphasis</td></tr>
<tr><td>A lot of emphasis</td><td>A lot of emphasis</td></tr>
<tr><td rowspan="4">Conclusion</td><td>Not reported</td><td>Not reported</td></tr>
<tr><td>No emphasis</td><td>No emphasis</td></tr>
<tr><td>Some emphasis</td><td>Some emphasis</td><td rowspan="6">A lot of emphasis</td></tr>
<tr><td>A lot of emphasis</td><td>A lot of emphasis</td></tr>
<tr><td rowspan="4">Communication</td><td>Not reported</td><td>Not reported</td></tr>
<tr><td>No emphasis</td><td>No emphasis</td></tr>
<tr><td>Some emphasis</td><td>Some emphasis</td></tr>
<tr><td>A lot of emphasis</td><td>A lot of emphasis</td></tr>
</table>

THE NATURE OF INSTRUCTION, INQUIRY SATURATION, AND THE INQUIRY THRESHOLD

Applying this framework to each study achieves three purposes. First, it clarifies the *nature of instruction.* Because this synthesis is driven by the questions that practitioners have raised about whether inquiry science instruction has merit, it is vital to deliver a clear description of the specific instructional strategies that resulted in particular outcomes. This framework will allow the analyses to produce such descriptions.

Second, the framework will lead to an articulation of the level of *inquiry saturation* that is exhibited in each instructional intervention. This descriptive approach suggests that some instructional interventions have more presence of the elements of inquiry than others. For example, teachers in one study may have placed *a lot* of emphasis on student active thinking and student responsibility for learning in the design, collection, and analysis components of instruction while teachers in another study may have only placed *some* emphasis on student active thinking in the communication component of instruction. This difference would suggest a greater saturation of inquiry instruction in the first instructional treatment than in the second. Those treatments exhibiting the highest degree of emphasis on the greatest number of elements of inquiry in the greatest number of components will be situated at the *high saturation* end of the continuum, and those with the lowest degree of emphasis in the least number of components at the *low saturation* end of the continuum. This distribution of inquiry saturation will enable this project to answer questions such as whether there is a minimum level of inquiry necessary to produce certain kinds of effects on student outcomes, or if there is a particular constellation of inquiry elements and instructional components associated with particular outcomes.

Finally, a continuum of inquiry instruction suggests that there is a point on the continuum below which the instruction cannot be defined as inquiry at all—an *inquiry threshold.* Some studies will not be included in the dataset for this synthesis because the instructional intervention examined contains no element of inquiry science instruction as described in the framework. For the purposes of this synthesis, to ensure the analyses do not exclude studies that should be included, the "bar" set for the inquiry threshold is deliberately low. If there is at least *some* emphasis on any element of the inquiry domain in any component and science content is explicitly taught, the study crosses the inquiry threshold and is included in the subsequent stage of coding. In light of ongoing debates about the nature of inquiry science instruction, there are educators who will take issue with this low bar. However, the intention is not to define what inquiry is and is not but, rather, to accommodate all instruction that has been referred to as inquiry in the field in order to understand the range of instruction that encompasses elements of inquiry and examine the student outcomes that are associated with the variation in instruction.

The framework was designed to generate a description of the inquiry science instruction in each study that produced the student outcomes of interest. However, capturing an "image" of instruction is a complex task, often made more difficult by the limitations of the descriptions in the study narratives. Instruction, even when seen firsthand, is often difficult to categorize, and using secondary data (i.e., written accounts of instruction) increases the imprecision of these descriptions. Therefore, the coding protocol based on the descriptive framework reflects the research team's most reasoned judgments, based on all of the evidence provided in a study, as to the nature of the instruction at work. The team employs a process of consensual coding to ensure that any one coder's individual judgments are in accord with the judgments of at least two other team researchers. More detail on the inquiry-science-instruction coding protocol is available in *Technical Report 5: Operationalizing the Inquiry Science Instruction Coding Process.*

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ADDITIONAL INFORMATION

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REFERENCES

Camins, A. H. (2001). Dimensions of inquiry. *FOSS Newsletter,* 18. Retrieved June 6, 2002, from http://lhsfoss.org/newsletters/archive/FOSS18.InquiryDimensions.html

DeBoer, G. (1991). *A history of ideas in science education.* New York: Teachers College Press.

Schwab, J. J. (1962). The teaching of science as enquiry. In J. J. Schwab & P. F. Brandwein, *The teaching of science*, Cambridge, MA: Harvard University Press.

APPENDIX: SOURCES USED IN FORMING THE INQUIRY FRAMEWORK

Atkin, J. M. & Black, P. (2003). *Inside science education reform: A history of curricular and policy change.* New York: Teachers College Press.
Bredderman, T. (1983). Effects of activity-based elementary science on student outcomes: A quantitative synthesis. *Review of Educational Research, 53* (4), 499–518.
Bybee, R.W. (1985). The Sisyphean question in science education: What should the scientifically and technologically literate person know, value and do—as a citizen? In R.W. Bybee (Ed.), *Science-technology-society* (pp. 79–93). (1985 NSTA Yearbook). Washington, DC: National Science Teachers Association. http://www.lhs.berkeley.edu/FOSS/FOSS 18.InquiryDimensions.html.
Council of State Science Supervisors. (2001). *Rubric for evaluating essential features of classroom inquiry in instructional materials*. Hartford, CT: Author.
DeBoer, G. (1991). *A history of ideas in science education*. New York: Teachers College Press.
Doris, E. (1991). *Doing what scientists do: Children learning to investigate their world.* Portsmouth, New Hampshire: Heinemann.
Duschl, R. (1990). *Restructuring science education: The importance of theories and their development*. New York: Teachers College Press.
Flick, L. (1995, April). *Complex instruction in complex classrooms: A synthesis of research on inquiry teaching methods and explicit teaching strategies*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA. (ERIC Document Reproduction Service No. ED 383 563)
Harlen, W. (2001). *Primary science: Taking the plunge.* (2nd ed.) Portsmouth, New Hampshire: Heinemann.
Haury, D. L. (1993) Teaching science through inquiry. *ERIC/CSMEE Digest.* (ERIC Document Reproduction Service No. ED 359 048)
Loucks-Horsley, S., Kapitan, R., Carlson, M. D., Keurbis, P. J., Clark, R. C., Melle, G. M., Sachse, T. P., & Walton, E. (1990). *Elementary school science for the 90's.* Andover, MA and Alexandria, VA: The NETWORK and Association for Supervision and Curriculum Development.
National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington, DC: National Academy Press.
National Science Foundation (1999). *Foundations: Inquiry: Thoughts, views, and strategies for the K–5 classroom* (NSF 99-148). Arlington, VA: National Science Foundation.
National Science Foundation (1997). *The challenge and promise of K–8 science education reform.* Volume 1 of Foundations: A monograph for professionals in science, mathematics, and technology education. Washington DC: National Science Foundation.
National Science Foundation. (1999). *Inquiry: Thoughts, views, and strategies for the K–5 classroom.* Volume 2 of Foundations: A monograph for professionals in science, mathematics, and technology education. Washington DC: National Science Foundation.
Neuman, D. B. (1993). *Experiencing elementary science.* Belmont, CA: Wadsworth Publishing.
Shymansky, J., Kyle, W., & Alport, J. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching, 20* (5), 387–404.

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