Documenting Opportunities for Students to Meet New Challenges: Understanding the Alignment Between the ISIOP and the NGSS

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Introduction

The release of the *Framework for K–12 Science Education* (National Research Council [NRC], 2012) and the *Next Generation Science Standards* (NGSS) (NGSS Lead States/Achieve, 2013) raises the bar for the practice of science education. Over the past two decades, much of the vision of the NGSS has been present in science education reforms. For example, across the field of education there has been a growing emphasis on inquiry and teaching process skills. There has also been an increasing focus on designing curriculum materials and professional development to include the identification of patterns or topics such as energy. While these trends are congruent with the NGSS, to fully adopt the vision of the NGSS, schools and school systems must consider new ways to elevate the importance of scientific and engineering practices while integrating them with core disciplinary ideas and cross-cutting themes. Movement toward meeting the expectations of the NGSS will present new challenges and opportunities for professionals across the field, from practitioners to program developers and researchers.

Some scholars have begun to consider the challenge of NGSS-related assessment, which includes not only understanding the extent to which students meet the learning objectives specified by the NGSS but also determining the opportunities for students to engage with the content and practices envisioned in these standards (NRC, 2014). In recent years, researchers and program developers have worked to understand teacher practice and optimal methods for teaching science, as well as the most effective ways to implement reform-oriented or inquiry-based approaches. Today, however, these science education stakeholders, as well as practitioners, need appropriate tools with meaningful indicators to describe and provide insight into the extent to which components of instruction that may be associated with NGSS-aligned outcomes are present in classrooms. The *Inquiring into Science Instruction Observation Protocol (ISIOP)* (Minner & DeLisi, 2012) is one tool that EDC researchers developed and revised just prior to the release of the NGSS. As the impact of the NGSS emerges across the nation, products such as the ISIOP could support efforts to document and understand the extent to which teacher instructional practices provide opportunities for students to engage with NGSS-aligned topics and skills and could serve to inform the design of interventions that align with and advance the implementation of the NGSS.

EDC researchers developed the ISIOP based on an extensive literature review and current understandings regarding best practices and inquiry science instruction, and it aligns with the *National Science Education Standards* (NSES) (NRC, 1996). Although the constructs and vision of the ISIOP are similar to the NGSS, the developers did not explicitly design the tool to align with the constructs presented by the authors of the *Framework for Science Education* or the NGSS. Therefore, this paper presents findings from an analysis by two EDC researchers, Jackie DeLisi and Erica Fields, that explored the vision and expectations established by both the NGSS and the ISIOP to determine the extent to which these two documents are aligned. The goal of this exploration was to identify the ways in which researchers can use ISIOP constructs and indicators to document the extent to which teachers' practice reflects the NGSS standards. We first provide a brief overview of the ISIOP and the NGSS, as well as our methods for considering the alignment between the two. Next we describe our findings, followed by some brief conclusions that summarize the overall insights we gained, and present implications for future work with the ISIOP and classroom observation tools.

Overview of the ISIOP and the NGSS

The ISIOP is a classroom observation protocol that researchers can use to quantify the varied activities and teacher instructional moves present during a lesson. Reflecting a comprehensive view of classroom practice that is standards-based and inquiry-oriented, the ISIOP includes constructs and indicators of teacher practice (at right) theorized or demonstrated to be associated with student learning. The ISIOP organizes these indicators to provide, for a given lesson, a quantitative metric of the nature of the lesson activities, the teacher's classroom instruction, and the extent to which investigation-related experiences and science content are present across the lesson.

ISIOP CONSTRUCTS AND INDICATORS

Verbal Practices

- Questions to gauge or expand students' thinking
- Comments to provide signposts about the progression or order of the lesson
- Comments to provide feedback to students
- Comments to prompt students' thinking or reduce complexity

Lesson Events

- **Activities:** Verbal (Instruction, Discussion, Reading, Presenting, Writing); Physical (using models, demonstration, hands-on activity, field work)
- **Organization of Students:** Working as individuals, pairs, groups, or whole class
- **Disengagement of Students:** None, few, half, most, or all

Investigation-Related Experiences

- Student-Directed and Teacher-Directed Rubrics
- Questioning/Exploration
- Design
- Data Collection and Organization
- Analysis
- Conclusions and Communication

Classroom Instruction Leadership Practices

- Overall Teaching Style
- Support for Self-Directed Learning
- Lesson Organization
- Dealing with Distractions

Science Content

- Life Science
- Earth Science
- Physical Science
- Science and Technology

The NGSS framework, standards, and appendices present a vision of science education along three "dimensions." The Disciplinary Core Ideas (DCIs) are most like traditional science content and cover four central disciplines: Earth & Space Sciences (e.g., Biogeology, Earth and the Solar System), Life Sciences (e.g., Adaptation, Structure and Function), Physical Sciences (e.g., Forces and Motions, Chemical Reactions), and Engineering, Technology, & Applied Sciences (e.g., Developing Possible Solutions, Optimizing the Design Solution). The second dimension, Crosscutting Concepts (CCCs), includes six sets of ideas that recur in multiple core disciplines and persist across many or all grade bands. The third dimension, Scientific and Engineering Practices (SEPs), resembles many of the inquiry-based "skills" that have previously been emphasized in science curricula, but currently have a more central role in the overarching vision of the NGSS. Table 1 details the CCCs and SEPs.

Table 1. NGSS Crosscutting Concepts and Scientific & Engineering Practices

CCCs	SEPs
• Patterns • Cause and effect: Mechanism and explanation • Scale, proportion and quantity • Systems and system models • Energy and matter: Flows, cycles, and conservation • Structure and function • Stability and change	• Asking questions (for science) and defining problems (for engineering) • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Using mathematics and computational thinking • Constructing explanations (for science) and designing solutions (for engineering) • Engaging in argument from evidence • Obtaining, evaluating, and communicating information

To examine the alignment between the ISIOP and the NGSS, we used an iterative process of looking across the broad constructs for overlap, zooming in to individual indicators and standards, and then revisiting the broader ideas to consider the individual items within the overall picture of each document. We began our exploration by developing a matrix that outlined the broad elements, but contained all of the ISIOP items and all of the NGSS components. Through our work, it quickly became apparent that the ISIOP and the NGSS follow a similar vision: ISIOP content items align closely with the DCIs, and the ISIOP's Investigation-related Experiences (IE) align with the NGSS SEPs.

Although it was clear that there would be alignment between the ISIOP and the NGSS, we developed an extensive set of matrices to mark each connection between the ISIOP indicators and the NGSS items. We began by considering the larger constructs and categories, such as the ISIOP IE and the NGSS SEPs. We then created additional matrices that charted alignment of the ISIOP's specific items with individual NGSS standards, which in turn deepened our thinking about the alignment between the larger categories. We repeated this process for every ISIOP construct and item and the NGSS elements and standards, with a separate matrix for each of the major categories to enable us to illustrate the connections between the two documents. In our final step, we created summary tables to illustrate the broad connection. The Appendix presents our final summary matrices for ISIOP content items and the broad ISIOP IE categories.

Similarities and Differences Between the ISIOP and NGSS

ISIOP Content Checklist

Our review and analysis revealed that the content section of the ISIOP directly aligns with the NGSS DCIs. EDC developed the items in this content checklist to directly align with the NSES in order to enable researchers to document the extent to which teachers were addressing standards-aligned content. Therefore, alignment of the ISIOP content with the NGSS (see pages 13–16 in the Appendix for the matrices that display this alignment) in many ways also reflects the alignment between the NGSS DCIs and the NSES.

We also determined that each ISIOP content item directly aligns with one element of each DCI. For example, the ISIOP Life Sciences items clearly align with elements of the NGSS Life Science DCI, and the ISIOP Technology items clearly align with corresponding items of the NGSS Engineering, Technology, and Applications of Science DCI. However, in the areas of Life and Earth Science, because the NGSS built on the previous standards, by including and specifying additional elements, the ISIOP items do not reflect those elements. For example, the four elements of the Physical Science DCI are Matter and Its Interactions (PS1), Motion and Stability (PS2), Energy (PS3), and Waves and Their Applications in Technologies for Information Transfer (PS4). The last element was an addition to the content that had been included in the previous NSES. Therefore, since EDC developed the ISIOP based on prior standards, the physical science items align with the first three of these Physical Science DCI elements, but not the last one. Similarly, the NGSS contains greater specificity in the Life Science and Engineering DCIs; two of the NGSS Earth Science elements, ESS1A (The Universe and Its Stars) and ESS2E (Biogeology), do not have clear ISIOP counterparts.

In addition, the ISIOP items provide general indicators of the content that teachers address during a lesson, while the NGSS items are of a smaller grain size and articulate the exact content that students should learn. For example, the ISIOP contains three Earth Science items, each stated in broad terms that align with and encompass 10 of the NGSS Earth Science items. Similarly, while the ISIOP includes content items related to technology and engineering, these are more general than the three Engineering, Technology, and Applications of Science standards (ETS1) present in the NGSS standards.

ISIOP Investigation-related Experiences Rubric

The IE section of the ISIOP provides a checklist of possible scientific investigation opportunities divided into experiences that are directed by students (such as students determining variables for investigation and procedures) and those primarily directed and led by the teacher (such as teachers providing a step-by-step design for an investigation). Researchers can use the ISIOP IE items as indicators of teachers' pedagogical practice, namely the extent to which they promote and provide opportunities for students to lead and take responsibility for classroom experiences, which may lead to students' adoption of scientific practices.

Designed to align with the elements of the inquiry process, the IE section includes two rubrics to assess the extent to which these experiences are teacher- or student-directed. The items in the rubrics are divided into the following five broad categories of indicators, each of which is similar to SEPs described in the NGSS:

- Questioning/exploration
- Design
- Data collection and organization
- Analysis
- Conclusions and communication

In our analysis, we found that each of these broad categories of IE items aligns with at least one of the NGSS SEPs. However, some of the individual items within the IE section more closely align with the vision of the SEPs than other items. For example, while some of the ISIOP's IE items reference engineering practices, such as design, they more closely resemble scientific practices and do not explicitly align with engineering, whereas the NGSS SEPs make specific reference to engineering design when appropriate. More specifically, the IE items under the "Questioning" category closely resemble the SEP "Asking Questions and Defining Problems"; however, the IE does not include defining problems for engineering as explicitly as does the corresponding SEP.

In addition, our analysis of the IE and SEPs revealed a major difference between the two documents. While the ISIOP enables researchers to document student-led versus teacher-led experiences, the focus is on the teachers' pedagogy. However, the NGSS sets expectations for what students should know and be able to do. Neither document currently makes the link between what the students are expected to master (i.e., the SEPs) and the teachers' pedagogy. While both documents are based on prior research on effective science instruction and varied definitions of inquiry-oriented instruction, the alignment between the two relies on a direct relationship between the exact indicators of the ISIOP and the associated student outcomes specified within the NGSS. For example, teachers who provide more student-led experiences may encourage greater adoption of SEPs. Yet the nature of the relationship between providing these opportunities and students' adoption of scientific practices remains to be determined.

ISIOP Verbal Practices, Classroom Activities, and Instructional Leadership Practices

As noted above, while the NGSS lays out expectations for what students should master, the ISIOP tool focuses on documenting teacher practices. ISIOP items, such as those that are comprised in the Teacher Verbal Practices and the Classroom Instructional Leadership Practices rubric, provide indicators of effective teacher practices and the classroom context, which could potentially affect the student outcomes articulated in the NGSS. Yet the intent of these items is to describe the classroom and teacher as they align with inquiry-based pedagogy. Therefore, through our analysis of these two documents, we found that the Verbal Practices, Classroom Activities, and Instructional Leadership Practices sections of the ISIOP are related to the NGSS—that they describe the pedagogy underlying these opportunities—but do not align with specific NGSS learning outcomes as explicitly as the ISIOP's content and IE sections. However, EDC developed these ISIOP items based on reviews of the literature on inquiry-based and effective teacher practices that impact student outcomes aligned with the vision of the NGSS. Thus, while the ISIOP focuses on instructional practices and the NGSS emphasizes student performance, research on the relationship between instructional practices and student performance has shown that teacher practices around discourse and dialogue, as well as specific types of activities, have a positive effect on student learning outcomes. Below, we provide a brief overview of this research.

The Teacher Verbal Practices section of the ISIOP provides a place to record instances where teachers ask questions, make connections, rephrase student responses, and think aloud—to name a few instructional strategies that studies have shown enhance students' science learning. Previous research using the ISIOP has revealed possible associations between teachers' questioning strategies and student outcomes (DeLisi, McNeill, & Minner, 2011). Other researchers, such as Resnick, Michaels, and O'Connor (2010), have examined the effects of such instructional strategies, noting that "sense making and scaffolded discussion, calling for particular forms of talk, are seen as the primary mechanisms for promoting deep understanding of complex concepts and robust reasoning" (p. 173).

Similarly, Mercer's (2008) research highlights the importance of the teacher's role and underscores how teachers' use of questioning strategies can contribute to students' reasoning and communication skills. Mercer, Dawes, Wegerif, and Sams (2004) studied the effects of exploratory talk, which parallels the ISIOP's approach to documenting teachers' higher-order questions and the opportunities for student- and teacher-led discussions. In this approach, students learn "rules" of group work where everyone contributes to discussions, respects each other's ideas, can challenge ideas or offer alternatives, and must reach a consensus before taking action. This study allowed children to "work together more effectively, improve their language and reasoning skills and reach higher levels of attainment in their study of science" (Mercer et al., 2004, p. 26) each of which could contribute to NGSS-related outcomes.

Gillies (2014) summarized research on classroom-based talk, identifying the many instructional strategies around discourse that have an impact on student learning. He points to research by Adey and Shayer (2011), Gillies and Boyle (2006), Mercer and Littleton (2007), Resnick (1987, 2010), Trickey and Topping (2004, 2006), and others that highlights the importance of various dialogic interactions in promoting students' reasoning skills, problem-solving skills, and overall performance and abilities to transfer learning to other subjects. Those strategies, which research shows elicit greater understanding from students, align directly with the ISIOP Teacher Verbal Practices, which include Gauge/Expand, Signposts, Feedback, and Prompt Thinking/Reduce Complexity. These items focus on a variety of teacher practices that elicit students' thinking by asking questions that require students to recall steps or theories, apply learning to new situations, or evaluate the use of evidence in argument; making connections between previous material learned and current work and foreshadowing what will come later; providing feedback by repeating what students say or correcting misconceptions; and calling upon teachers to demonstrate their own thinking and encourage students to find the answers themselves.

Implications

Three overall findings result from this work. First, our exploration of the items and vision of the ISIOP and the NGSS reveals that the ISIOP can provide valuable information about the extent to which teachers engage students in aspects of the NGSS, such as SEPs, which were not part of previous standards and are not explicit dimensions of other science classroom observation tools. Documenting the degree of student engagement will be important, particularly as scholars, policymakers, and researchers consider avenues for assessing the NGSS and as new understandings of NGSS implementation emerge. Second, our analysis reveals important insights about the differences between the ISIOP and the NGSS. The ISIOP is a tool designed to document teacher practices, while the NGSS lays out expectations for what students should master. Often these are closely related, but our alignment efforts required returning to the literature to determine current thought around what teachers can do to influence particular student outcomes. Third, teacher instruction is a complex endeavor, and the field's understanding of the elements that optimally produce particular student outcomes is still evolving. Therefore, it is worth emphasizing that teachers' use of particular practices may not always lead to students' mastery of particular standards.

Our work also highlights the potential for the ISIOP to provide a powerful framework or assessment tool for supporting district implementation of the NGSS. However, further research is needed to more explicitly connect ISIOP indicators to the student outcomes outlined by the NGSS. For example, while authentic inquiry experiences, such as those articulated by the student-led IE checklist, have been shown to be related to student outcomes, the specific items within this checklist have not been correlated with students' adoption of SEPs. Additional work will be required to create assessments of students' adoption of these practices, and then examine whether teachers who provide those experiences are more likely to have students who adopt these practices. This is crucial, as it will lay the groundwork for a deeper understanding of what teachers will need to do to support students' growth toward meeting the expectations of the NGSS.

Our analysis also illuminates the need to refine the ISIOP's indicators to more explicitly align with the NGSS and to provide NGSS-aligned supports for practitioners. For example, there are specific NGSS standards, such as some of the new DCIs and CCCs and an increased emphasis on engineering, which are not reflected within the ISIOP indicators. In addition, work is needed to not only provide a measure of teachers' instructional practice for researchers, but to support teachers, schools, and districts as they gather data on the educational opportunities that teachers provide in their classrooms. The work to develop, validate, and align the ISIOP to the NGSS lays the groundwork for additional avenues that could enable teachers to understand and develop their practice and document the ways in which they are meeting the expectations of the NGSS.

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Appendix

1. ISIOP Investigation Experiences and the NGSS Science and Engineering Practices

		ISIOP Investigation-related Experiences				
		Questioning/ Exploration	**Design**	**Data Collection and Organization**	**Analysis**	**Conclusions/ Communication/ Evaluation**
NGSS Science & Engineering Practices	Asking questions (for science) and defining problems (for engineering)	X				
	Developing and using models		X	X		X
	Planning and carrying out investigations		X	X		
	Analyzing and interpreting data				X	
	Using mathematics and computations thinking			X	X	
	Construction explanations (for science) and designing solutions (for engineering)					X
	Engaging in argument from evidence					X
	Obtaining, evaluating, and communicating information					X

2. ISIOP and the NGSS Physical Science Content

			ISIOP Content—Physical Science		
			Properties & changes of properties in matter, properties of substances	Motions & forces (e.g., motion can be described by position, direction, & speed)	Transfer of energy (e.g., heat, light, electrical, sound, chemical, atomic, mechanical)
NGSS—Physical Science DCIs	Matter & Its Interactions	PS1A: Structure & Properties of Matter	X		
		PS1B: Chemical Reactions	X		X
		PS1C: Nuclear Processes	X		X
	Motion & Stability	PS2A: Forces & Motion		X	
		PS2B: Types of Interactions		X	
	Energy	PS3A: Definitions of Energy			X
		PS3B: Conservation of Energy & Energy Transfer			X
		PS3C: Relationship Between Energy & Forces			X
		PS3D: Energy in Chemical Processes & Everyday Life			X
	Waves & Their Applications in Technologies for Information Transfer	PS4A: Wave Properties			
		PS4B: Electromagnetic Radiation			
		PS4C: Information Technologies & Instrumentation			

3. ISIOP and the NGSS Life Science Content

			ISIOP Content—Life Science				
			Structure & function in living systems (e.g., the cells, organs, & human systems)	Reproduction & heredity (e.g., types of reproduction, genes, & chromosomes role)	Regulation & behavior (e.g., biological relationship of internal processes to changing environmental stimuli)	Populations & ecosystems (e.g., definitions & basic functioning of ecosystems)	Diversity & adaptations of organisms (e.g., role of biological evolution)
NGSS—Life Science DCIs	**From Molecules to Organisms**	LS1A: Structure & Function	X				
		LS1B: Growth & Development of Organisms		X			
		LS1C: Organization for Matter & Energy Flow in Organisms			X		
		LS1D: Information Processing			X		
	Ecosystems, Interactions, Energy, & Dynamics	LS2A: Interdependent Relationships in Ecosystems				X	
		LS2B: Cycles of Matter & Energy Transfer in Ecosystems				X	
		LS2C: Ecosystems Dynamics, Functioning, & Resilience					X
		LS2D: Social Interactions & Group Behavior					X
	Heredity	LS3A: Inheritance of Traits		X			
		LS3B: Variation of Traits		X			
	Biological Evolution	LS4A: Evidence of Common Ancestry & Diversity					X
		LS4B: Natural Selection					X
		LS4C: Adaptation					X
		LS4D: Biodiversity & Humans					X

4. ISIOP and the NGSS Earth Science Content

			ISIOP Content—Earth & Space Science		
			Structure & processes of the earth system (e.g., plate motion, rock & water cycles, atmosphere, weather patterns)	Earth's history (e.g., same processes produced different conditions on Earth over time, fossil record)	Earth in the solar system (e.g., gravity's role, seasonality, sun's influence on earth systems)
NGSS—Earth & Space Science DCIs	**Earth's Place in the Universe**	ESS1A: The Universe & Its Stars			
		ESS1B: Earth & the Solar System			X
		ESS1C: The History of Planet Earth		X	
	Earth's Systems	ESS2A: Earth Materials & Systems	X		X
		ESS2B: Plate Tectonics & Large-Scale Systems	X		X
		ESS2C: The Role of Water in Earth's Surface Processes	X		X
		ESS2D: Weather & Climate	X		X
		ESS2E: Biogeology			
	Earth's & Human Activity	ESS3A: Natural Resources	X	X	
		ESS3B: Natural Hazards	X	X	X
		ESS3C: Human Impacts on Earth Systems		X	
		ESS3D: Global Climate Change	X	X	

5. ISIOP and the NGSS Applications of Science Content

			ISIOP Content—Science & Technology	
			Technological design cycle (e.g., identify problem, design solution, implement design, evaluate, communicate the process)	Understanding about science & technology (e.g., not the same as scientific inquiry; technological solutions have trade-offs)
NGSS—Engineering, Technology, & Applications of Science DCIs	**Engineering Design**	ETS1A: Defining and Delimiting an Engineering Problem	X	X
		ETS1B: Developing Possible Solutions	X	X
		ETS1C: Optimizing the Design Solution	X	X

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