Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials

The Council of State Science Supervisors (CSSS) developed the following rubric to assist a wide variety of audiences to develop an understanding of the desired characteristics of inquiry materials[1] and to describe the extent to which a given material contains the descriptors outlined in the rubric. A wide range of audiences should be able to use the rubric for a variety of purposes. Educational materials developers could make use of the information to produce more inquiry oriented teaching materials. Someone with limited knowledge of inquiry can use the list of descriptors as an educational aid to develop an understanding of the desired characteristics of inquiry materials. A teacher or curriculum specialist could use the descriptors, coupled with a limited knowledge of the levels, to make informal analyses of instructional materials for use in local classrooms. District or state level administrators can use the full instrument to select materials in a more official or policy-oriented capacity by selecting and providing professional development for a group of reviewers in the use of the rubric. It should be noted that the more reliability demanded of the rubric, the more training and experience the users should have.

The rubric is based on the following definition of inquiry adapted from the National Science Education Standards.

> Inquiry is the process scientists use to build an understanding of the natural world. Students can learn about the world using inquiry. Although students rarely discover knowledge that is new to humankind, current research indicates that students engaged in inquiry build knowledge new to themselves.
>
> Student inquiry is a multifaceted activity that involves making observations; posing questions; examining multiple sources of information to see what is already known; planning investigations; reviewing what is already known in light of the student's experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

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[1] Instructional material refers to almost any material that is intended for use in the instruction of students. The material may be a textbook, laboratory guide, website, or a short instructional module.

> As a result of participating in inquiries, students will increase their understanding of the science subject matter investigated (section A), gain an understanding of how scientists study the natural world (section B), develop the ability to conduct investigations (section C), and develop the habits of mind associated with (section D).

The overriding purpose of inquiry is stated in the first paragraph. Classroom inquiry is not only a desired outcome to be learned but also the process implemented to facilitate inquiry-based learning. It is broadly defined and an accepted means of studying the natural world described in the second paragraph. Some educators have viewed the purpose of inquiry in the classroom almost exclusively as students learning these processes. The definition used here views classroom inquiry as incomplete unless it also results in the four outcomes described in the third paragraph.

Those four outcomes provide the basis for the four sections of the rubric (sections A, B, C, D). Within each section there are a number of descriptors that materials should align with if they are going to adequately support students in the acquisition of the desired outcomes. The descriptor is stated in the first column followed by four levels or variations on the degree to which the material satisfies the descriptor.

Although the rubric is designed to describe a range of four possibilities for each descriptor, the interpretation of the levels varies somewhat from section to section. There are descriptors, such as those in Section A for subject matter, that are evaluative in nature. It clearly is important that the instructional material be aligned with the applicable standards, is accurate, and provides an adequate opportunity for students to learn the content.

In other cases, such as most of Sections B and C where students are engaged in developing the abilities and understanding of inquiry, the instructional material should be selected based on where the students are in their development of the skills and understanding of inquiry. Instruction and the materials used can and should vary the amount of structure built into the activity and the degree to which students ask their own questions, design an investigation, and develop their own explanations depending on their previous experience and understanding.

The development of scientific habits of mind from Section D results in a set of values and mental attitudes on the part of the student. These traits include curiosity, honesty, openness, and skepticism and are taken from the Project 2061 Benchmarks for Scientific Literacy. In this section the variations follow Bloom's taxonomy and progress from lower level thinking skills to higher level thinking skills such as metacognition. As in Sections B and C students should progress through the stages in their learning. The particular level that students are currently at will be determined by previous exposure to critical thinking, scientific inquiry, and developmental level. Inquiry instructional materials should be chosen to move students along the continuum to the highest level of thinking skills.

Often the inquiry in materials is described with terms such as “structured,” “guided,” and “open.” Although the rubric does not use this language, there may be a temptation to label the variations in some of the descriptors in this manner. These terms can be used to describe the extent to which students have control of the inquiry process and can be used as a means of describing the materials and associated instruction but they do not necessarily imply a negative connotation. The rubric is designed to aid the teacher, materials reviewer, and materials developers select or design instructional materials that best suit their students’ needs. The ultimate goal of inquiry-based science education will be to have students working with materials at level four on most descriptors but students usually cannot start with materials at this level; they need to progress over time to that end.

Once trained in the use of the rubric, educators can use this rubric to review instructional materials at any grade level. A person experienced in the use of the rubric and who understands the development of learners should be able to make judgments about the examples, questions, opportunities, and instructions, which are appropriate for the students in question. Based on these judgments they can decide where on each descriptor continuum the material belongs for it to fit their needs.

This rubric has been developed as a descriptive tool but may be used in an evaluative form. The variations in opportunity to learn typically increase in the level of difficulty in moving from left to right across the descriptor rows. Not all instructional materials need to be or should be at the highest level. Keep in mind that this level is the ultimate goal of inquiry-based science instruction. Where any given student is in the continuum of inquiry learning depends on many factors. Classroom teachers are the final decision makers as to the appropriateness of any given instructional material for their students’ abilities. Please note that the descriptors and variations are continuations of the stems found at the tops of the columns within the table.

As a result of participating in inquiries, students will…

A. Increase their understanding of the science subject matter investigated

Developing a thorough understanding of subject matter content, as identified in national, state, or local standards, is a major goal of science teaching and learning. When considering materials, the first judgment that needs to be made is whether the content of the material matches the standards. **If the content of the material does not match standards, then it should not be used. There is no need to proceed further with the analysis.** There is far too little time for teaching, and efforts must focus on helping all students achieve identified learning goals. Well-aligned materials, with accurate scientific content, will help students achieve those goals. Inquiry is both content and a means to achieve content. Materials that use inquiry as the centerpiece of science teaching and learning provide opportunities for students to construct their own subject matter understanding while developing abilities to do science. This understanding takes time and involves authentic experiences in developing questions, gathering and analyzing data, developing explanations based on evidence, and communicating results.

A1. Content				
Descriptor	**Variations in opportunity to learn**			
Material …				
A1a. …provides content aligned with national, state or local standards (p. 174 Inquiry Add).	…does not match standards, i.e. displays no evidence of any alignment. ***Stop here- no further evaluation.**	…matches on the topic of the standard or benchmark but not the specific outcome described.	…matches the topic of the standard of the standard or benchmark and addresses a part of or more than the specific outcome described.	…matches the specific outcome of the standard or benchmark.
A1b. ..provides opportunity to develop enduring understanding of subject matter content. (NSES p.113; 174 Inquiry Add p. 135,).	…covers too many concepts and abilities (too much breadth and not enough depth). Time is insufficient to develop understanding of any of the concepts and abilities.	…focuses on several important concepts and abilities, several which are peripheral to the inquiry. More time may be needed to develop enduring understanding.	…focuses on the few important concepts and abilities that are central to the inquiry although a few peripheral ideas are present. More time may be needed to develop enduring understanding.	…focuses on the few important concepts and abilities that are central to the inquiry. Material provides time to develop enduring understanding.

A1c. …contains accurate content (Inquiry Add p. 174).	…has content which, as presented, contains major inaccuracies.	…has content which, as presented, contains minor inaccuracies that are evident in statements and/or representations..	…has content which, as presented, is scientifically accurate but may contain the potential for misconceptions to occur from implied statements or representations.	…has content which, as presented, is scientifically accurate (i.e. There is no erroneous content or potential for misconceptions to occur from implied statements or representations).

This section correlates to: NSES: pgs 6, 22, 103-113, 115-204
NSES Inquiry Addendum: pgs 41, 59, 60, 70
Benchmarks: pgs 3-21, 264-266, 268-270, 272-275, 277-279

B. Gain an understanding of how scientists study the natural world

The use of biographies, case studies and historical scientific materials can be very useful to students in their understanding of how scientists study the natural world. The participation in actual scientific inquiry at the appropriate level for the students allows them to compare their inquiry experiences to that of scientists. This set of descriptors is based on looking at the work of scientists and only meant as a comparative point to the work that the students do. There is a difference in the work carried out by students when compared to that of scientists' work but this difference should only be in the degree of sophistication of the work.

B1. Understanding of how scientists work				
Descriptor	**Variations in opportunity to learn**			
Material provides…				
B1a. …an opportunity to learn how different kinds of questions based on prior scientific knowledge suggests different kinds of investigations	…no mention of how questions are developed.	…a discussion of how questions are developed but no examples are provided.	…a discussion of how questions are developed and examples of different kinds of questions but no connections are made to the student's own work.	…an opportunity to learn how scientists use what is already known to develop different types of questions and investigations. This is accomplished by providing real world examples and the explanations of how the examples relate to the student's own work.
B1b. …an opportunity to learn that scientists conduct investigation for a variety of reasons. NSES p176	…no mention of why investigations are conducted.	…a discussion of why investigations are conducted but no examples are provided.	…a discussion of why investigations are conducted and examples are provided but no connections are made to the student's own work..	…real world examples showing one or more different reasons [such as discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigation]for the investigation(s) and connecting the examples to the student's own work.

B1c. …an opportunity to learn that scientists use a variety of tools, technology, and methods to extend the senses	…no mention of how the senses are extended.	…a discussion of how the senses are extended but no examples are provided.	…a discussion of how the senses are extended and examples are provided but no connections are made to the student's own work..	…real world examples of how the senses are extended to gather evidence, guide inquiry, and analyze data and how the examples are connected to the student's own work. Material demonstrates that the accuracy and precision of the data depend upon the quality and choice of the tools
B1d. …an opportunity to learn that mathematics is essential in scientific inquiry.	…no mention of the use of mathematics in inquiry.	…a discussion of the use of mathematics in inquiry but no examples are provided.	…a discussion of the use of mathematics in inquiry, examples are provided but no connections are made to the student's own work.	…real world examples of the use of mathematics in inquiry for data collection and analysis and the development and communication of explanations which are connected to examples of the student's own work
B1e. …an opportunity to learn that scientists use evidence, logic, and current scientific knowledge to propose explanations.	…no mention of how scientists propose explanations.	…a discussion of how scientists propose explanations but no examples are provided.	…a discussion of how scientists propose explanations; examples are provided but no connections are made to the student's own work..	…real world examples that proposed explanations are based on logical inference, analysis, and synthesis of evidence combined with prior scientific knowledge; and how the examples are connected to the student's own work.
B1f. ...an opportunity to learn that scientists collaborate and communicate with each other in a variety of ways to reach well-accepted explanations	…no mention of how scientists collaborate and communicate.	…a discussion of how scientists collaborate and communicate but no examples are provided.	…a discussion of how scientists collaborate and communicate; examples are provided but no connections are made to the student's own work..	…real world examples of the importance of collaboration, clarity, accuracy, logic, criticism, and skepticism in communication as a means of reaching well-accepted explanations; and how the examples are connected to the student's own work.

This section correlates to: NSES Inquiry Addendum: pg. 20
Benchmarks: pgs. 3-21, 37, 41-58, 129, 281-300

C. Develop the ability to conduct investigations

Teachers should choose materials/sites with the variation that match their students' abilities and interests, and corresponds to the objectives/outcomes or standards of the planned instruction. Precise definitions of the variations depend upon the students for which the materials are being chosen. Materials meant for long- term use during the school year should show a progression to more advanced variations of inquiry.

C1. Posing scientifically oriented questions				
Descriptor	**Variations in opportunity to learn**			
Material …				
C1a. …provides an opportunity to ask questions that can be answered through scientific investigations.	…allows students to answer provided questions.	…allows an opportunity to clarify provided questions.	…allows an opportunity to select among provided questions and pose new questions for investigation.	…allows an opportunity to pose new questions for investigation relevant to their interests.

C2. Designing and conducting investigations				
Descriptor	**Variations in opportunity to learn**			
Material…				
C2a. … engages learners in planning investigations to gather evidence in response to questions.	…provides the complete plan for the investigation.	…provides guidelines for learners to plan a full investigation based on their determination of necessary evidence and appropriate methodologies.	…encourages learners to plan a full investigation based on their determination of necessary evidence and appropriate methodologies.	…requires learners to independently plan a full investigation based on their determination of necessary evidence and appropriate methodologies.
C2b. … engages learners in conducting the investigation.	…provides the procedure for the investigations.	…provides the questions, directs the student on the procedure and what data to collect.	…provides the questions and engages students in determining what constitutes correct procedure and appropriate data and in conducting the investigation to collect the data.	…requires the student to self-direct the full investigation based on their determination of necessary evidence and appropriate methodologies.
C2c. … engages learners in the use of analytical skills.	…does not allow for student use of analytical skills.	…provides exact guidelines for students to use analytical skills, mathematics, and technology to gather, analyze and produce a data analysis.	… encourages students to use analytical skills, mathematics, and technology to gather, analyze and produce a data analysis.	…requires students to independently use analytical skills, mathematics, and technology to gather, analyze and produce a data analysis.

C3. Proposing answers				
Descriptor	**Variations in opportunity to learn**			
Material…				
C3a. … engages learners **in** proposing answers and explanations to questions	…provides no opportunity for students to propose answers and explanations to questions	…provides certain data and asks students to analyze it.	…encourages student to collect and analyze certain data.	…requires students to use evidence from data they gather to propose answers and explanations.

C4. Comparing explanations with current scientific knowledge				
Descriptor	**Variations in opportunity to learn**			
Material…				
C4a. …engages learners in the consideration of alternative explanations.	…does not mention alternative explanations.	…provides students with an opportunity to produce one conclusion and one explanation.	…encourages students to consider and state alternative explanations.	…requires students to consider, state, investigate, and evaluate alternative explanations.
C4b. ...engages learners in linking explanations with scientific knowledge	… does not mention linking explanations with scientific knowledge.	…provides guidelines for students to examine historical and current scientific knowledge and form links to explanations.	…encourages students to examine historical and current scientific knowledge and form links to explanations.	…requires students to independently examine historical and current scientific knowledge and form links to explanations.

C5. Communicating and justifying results				
Descriptor	**Variations in opportunity to learn**			
Material engages learners in…	Material provides an opportunity for students to…			
C5a. …communication of scientific procedures and explanations.	Material does not mention communicating inquiry.	…follow prescribed communication procedures.	…communicate some aspects of the inquiry.	…clearly communicate all aspects of the inquiry including the question, procedures, evidence, proposed explanations, and the review of alternative explanations.
C5b. …appropriately respond to critical comments	Material does not mention justification of explanations.	…follow broad guidelines to clarify the justification.	…be coached in the development of the justification.	…self direct and form reasonable and logical arguments; and communicate a response to the criticism.
C5c. …raising additional questions.	Material provides no opportunity for additional questions to be generated.	…raise additional broad questions to be answered while doing the activity	…generate additional specific questions that help clarify the activity.	… generate and redefine inquiry based on new evidence gained while engaged in the activity.

This section correlates to: NSES Inquiry Addendum pgs. 1-3, 7, 8, 18-20, 25-29, 35, 82, 161-167
NSES: 121-123, 143-145, 173-175
Benchmarks: 6-8, 11-13, 16, 19, 33, 285, 300

D. Develop the habits of mind associated with science

Habits of mind can be a difficult topic to teach but they should develop in an enduring form if they are presented in all elements of science teaching and modeled through classroom practice. As students experience the role of investigations and develop their inquiry skill they can be encouraged to practice habits of mind associated with science. When they study the way scientists do their work to better understand the role of inquiry in science they become aware of how scientists demonstrate the values and habits of mind associated with science. These values are interdependent and not mutually exclusive with the development of the other outcomes of inquiry.

D1. Develop the habits of mind associated with science				
Descriptor	**Variations in opportunity to learn**			
Material…				
D1a. …promotes the questioning of assumptions (skepticism)	…does not address the need to evaluate or consider the underlying assumptions of an investigation.	…promotes skepticism through explanations or examples.	…promotes skepticism through prompting learners to consider the assumptions inherent in a scientific investigation or to consider the consequences of the lack of skepticism in scientific investigations.	…promotes skepticism by prompting learners to reflect in oral or written form on the thinking involved in the assumptions underlying their own investigations and conclusions and to defend their thinking process.
D1b. …presents science as open and subject to modification based on communication of new knowledge and methods (openness)	…contains no references to the idea of challenging previous scientific knowledge.	…prompts learners to examine previously established scientific ideas, and provides explanations or examples that illustrate how new information can modify accepted scientific knowledge.	…promotes respect for the modification of scientific knowledge by engaging the learner in analyzing the basis for conclusions in other investigations or to consider the consequences of the lack of modification in scientific knowledge.	…promotes respect for the modification of scientific knowledge prompting learners to reflect in oral or written form on the thinking involved in their own basis for conclusions and to defend their thinking process.

D1c. …promotes longing to know and understand (curiosity)	…does not mention or prompt learners to explore the possibility of future investigations stemming from the current inquiry or observations.	…promotes curiosity by providing explanations and/or examples of how questions for further investigations can spring from a completed inquiry or interesting observations.	…promotes respect for curiosity by engaging the learner in analyzing investigations for further questions or to consider the consequences of the lack of curiosity in science.	…promotes respect for curiosity prompting learners to reflect in oral or written form on the thinking involved in their own development of ideas for investigations and to defend their thinking process.
D1d. …promotes respect for data (honesty)	…does not promote respect for data.	…explains and/or provides examples detailing the use of honest and dishonest data from scientific investigations.	…promotes respect for data by engaging the learner in analyzing the validity of data in other investigations or in considering the consequences of the disregard for honest data in science.	…engages learners in examining respect for data by prompting students to reflect in oral or written form on why it's important to report and record observations accurately (vs. reporting what they think it should be, etc.) and to articulate the bias and limitations of their data.