Monitoring What Matters About Context and Instruction in Science Education: A NAEP Data Analysis Report

PREPARED FOR THE NATIONAL ASSESSMENT GOVERNING BOARD

By Alan Friedman and Alan Ginsburg

July 2013

Alan Friedman *is a museum and science communication consultant and former director of the New York Hall of Science. He is a member of the National Assessment Governing Board.* ***Alan Ginsburg*** *is an education consultant and analyst. He is former director of policy and program evaluation services for the U.S. Department of Education.*
The data analyses and interpretations in this report are those of the authors and do not necessarily represent the views of the National Assessment Governing Board.

Table of Contents

The authors wish to thank Lawrence Feinberg, Assistant Director for Reporting and Analysis of the National Assessment Governing Board, for his many analytic and editorial contributions to strengthen this report.

Executive Summary

This report explores background variables in the National Assessment of Educational Progress (NAEP) to examine key context and instructional factors behind science learning for eighth grade students. Science education is examined from five perspectives: student engagement in science, science teachers' credentials and professional development, availability and use of science resources, approaches to science instruction, and methods and uses of science assessment.

KEY FINDINGS

- *Contribution of student engagement in science to student achievement.*

    - Students who strongly exhibit attributes representing positive engagement in science—like science, do science after school, science is a favorite subject—tend to have significantly higher average NAEP science scores. For example, the 16 percent of the students who strongly agree that science is a favorite subject have a 25-point NAEP score advantage in grade 8 science over the 21 percent of students who strongly disagree that science is a favorite subject.

    - Students who agree strongly that they take science for extrinsic reasons—science is required or science is of benefit for the future—tend to have lower NAEP science scores. The 17 percent of students who strongly agree that they take science because it is required score 26 points lower in eighth grade science than the 18 percent who answer that they strongly disagree.

- *Decline in teachers of science with science majors.* Between 1996 and 2011, the percentage of grade 8 students taught by teachers who have science majors declined by about 10 percentage points both for teachers in earth/space science and in physics/chemistry. The percentages of students taught by a teacher with a biology or life science major held constant between 1996 and 2011.

- *Alternative certification routes for science teachers.*

    - In 2011, the percentage of grade 8 students' taught science by teachers who entered teaching through an alternative certification route was 5 percentage points higher than for reading.

    - Science teachers with alternate certification are about 20 percentage points more likely to have a science major compared with teachers of science who have traditional certifications. All of the difference occurs for teachers who major in biology or life science.

- Alternative certification is a major source of teachers for Black and Hispanic students. About 30 percent of grade 8 Black students had science teachers with alternate certified and 25 percent of Hispanic students compared with only 16 percent of White and Asian students.

- *Current science education emphasizes use of conventional science education resources.* Conventional education resources, such as a digital projector, science textbook, and DVD's, were the most widely used science resources by almost all teachers. By contrast, about 40 percent of students never used a computer to create a chart or graph for science or do a science simulation experiment. The least used resources were very specific computerized technologies, such as graphing calculators, tablet PC's and handheld computing devices.

- *Science instruction is structured heavily by state and district standards.* The schools clearly identify state and district standards as the key drivers in structuring their science education programs:

    - 86% of students were in schools that structured their program "a lot" according to state standards.
    - 71% of students were in schools that structured their program "a lot" according to district standards.

- *The percentage of students assigned to classrooms by ability has not changed much since 1996. Ability grouping is far less common than differentiated science instruction within classrooms.*

    - In 2011, 24 percent of students were in schools where assignments to science classes were by ability, about the same as 1996 when 21 percent of the students were in schools using ability-grouping assignments.

    - The most common practice for adjusting instruction to student performance is differentiated instruction within science classrooms, used by teachers of 75 percent of eighth grade students.

    -

RECOMMENDATIONS

Expanding current questionnaire topics:

- Recommendation 1: *NAGB should consider adding questions about the amount of time spent learning science, the nature of science activities in out-of-school or after-school settings, and the coordination of these activities with the regular classroom science program.*

- Recommendation 2. *NAGB should consider expanding background questions about teacher professional development to obtain information on its nature, duration and quality.*
-

Adding a new questionnaire topic:

- Recommendation 3: *NAGB should consider adding NAEP background questions to monitor how changes in science standards are affecting instruction, the challenges schools and teachers face in implementing new or changed standards, and whether they are receiving the needed technical assistance and professional development to bring about effective implementation of new standards.*
-

Technical background questionnaire issues:

- Recommendation 4. *NAGB should explore offsetting the additional time burden from adding additional science background questions through rotating questions in and out of the science assessments and matrix sampling so that a respondent answers only a sample of the background questions.*

- Recommendation 5. *NAGB should recommend to NCES the use of cognitive laboratories to clarify questions and responses in three areas of the science background variables: (1) understanding the generally more positive responses by schools than by teachers to questions about resource availability; (2) exploring the accuracy of school, teacher or student question responses when responses are qualitative and judgmental, such as "a little" or "a lot;" and (3) taking advantage of future science assessments that will be done on the computer to replace interval responses (e.g. 0-2 hours, 2-5 hours) with continuous sliders enabling respondents to drag an arrow to any point along a continuum.*

Extending the Usefulness of the Findings

- Recommendation 6. *NAGB should explore ways to support greater use of the current findings by policymakers and educators and to stimulate further analyses by academic researchers. NAGB should explore with NCES coordinated support for the further use of the NAEP science background variables.*

1. Introduction

This report analyzes the background variables collected during administration of the 2011 National Assessment of Education Progress (NAEP) science assessment. The NAEP background variables measure research-supported factors that contribute to student performance. Five sets of background factors are explored: student engagement, teachers of science, physical science resources, curriculum and instruction, and assessment and ability grouping. This exploratory analysis of the background variables in science is part of an effort by the National Assessment Governing Board (NAGB) to enhance the knowledge value derived from the NAEP assessments in science and other content areas.

The National Assessment for Educational Progress (NAEP) was established by Congress in order to provide information describing how well education is functioning in the United States. Starting with its first assessment in 1969 and operating since 1988 under policies set by the National Assessment Governing Board (NAGB), NAEP has proven to be a unique and valuable resource for the public and for everyone involved in the education enterprise.

Congress has given NAGB the final authority on all cognitive assessment and noncognitive background items used in NAEP. Among the noncognitive items Congress directed NAEP to include are race, ethnicity, socioeconomic status, disability, limited English proficiency, and gender. The assessment program has collected such data for more than four decades plus additional noncognitive information about teachers, students, schools, and classroom practices and resources when such information can shed light on academic performance.

While the personnel involved in NAEP are prohibited by statute from using the assessment "to establish, require, or influence the standards, assessments, curriculum, including lesson plans, textbooks, or classroom materials, or instructional practices of States or local educational agencies," NAEP reports and data can and are used extensively by academics and policy makers to inform their own decisions about important factors in educational achievement. For this reason, the decisions NAGB makes on what background variables to include in the assessment are critical in keeping NAEP useful to the education community.

What background and context items are included in NAEP and the science assessment reviewed in this report must change from time to time, as actual classroom practices and resources change. When NAEP began, there was no such thing as the Internet, there were no computers in K-12 classrooms, few afterschool classes in science, and under two dozen science-technology museums in the entire country. Today on-line science courses are the subject of intense interest; computers have become commonplace in schools and many science laboratories rely on "probeware" and other computer-assisted tools; there are thousands of afterschool science programs across the nation; and over 400 science-technology centers and museums are visited by a tens of millions of students, teachers, and families every year. To provide useful information on background variables and contexts like these, which can influence student achievement, NAGB has to pay attention to current practices and concerns in science, technology, and engineering education.

In the preparation of this paper, we asked several leaders in STEM education what kinds of information they would find valuable from NAEP's background questions, and we examined various discussion forums for a sample of "hot" topics among STEM educators. Among the common "hot" issues we found under active discussion were:

- How much time is spent in teaching science using the various strategies such as lecture, laboratory, and discussion?
- What factors motivate students to learn science?
- How do teachers deal with student misconceptions and wrong answers about science?
- Do out-of-school time activities, such as science clubs and museum visits, impact classroom performance?
- Are school laboratories used for *exploring* or for *confirming*?
- To what extent are student laboratories using virtual science experiments, or using data and instruments available on-line?
- What kinds of teacher professional development are commonly available, such as on-line, blended, active, or passive, and does the kind or duration chosen correlate with student performance?
- Which topics in STEM are of the greatest interest to students, and how does their performance relate to their interests?
- How extensive is participation in "citizen science" projects, and do they contribute to science learning?
- Are school systems prepared to respond to reforms underway in science education to focus teaching and learning on the big cross-cutting topics and issues in science and teach these with greater depth and understanding?

Another list of requested K-12 STEM education indicators, summarized in Exhibit 1-1, was published in the National Research Council (NRC) report *Monitoring Progress Toward Successful K-12 STEM Education* (National Research Council, 2013). There is substantial overlap with the informal survey we took before we had read the NRC's report. One key difference is that while affective domain traits such as motivation and interest appear in our informal survey, they do not appear in the NRC's summary table of desired indicators, below. The NRC's report discusses the importance of interest, attitudes, and other affective domain indicators, but this realm did not make it into the list of 14 key indicators in the table reproduced above. The NRC says that affective domain indicators and other topics are important but require separate studies (NRC, 2013, p. 33). The NAEP background questions do provide some evidence for these parameters, as we will discuss.

Exhibit 1-1: Indicators from NRC 2013, p. 2

Recommendations from *Successful K-12 STEM Education* (NRC, 2011)	Indicators
Districts Should Consider All Three Models of STEM-Focused Schools	1. Number of, and enrollment in, different types of STEM schools and programs in each district.
Districts Should Devote Adequate Instructional Time and Resources to Science in Grades K-5	2. **Time allocated to teach science in grades K-5.**
	3. Science-related learning opportunities in elementary schools.
Districts Should Ensure That Their STEM Curricula Are Focused on the Most Important Topics in Each Discipline, Are Rigorous, and Are Articulated as a Sequence of Topics and Performances	4. **Adoption of instructional materials in grades K-12 that embody the *Common Core State Standards for Mathematics* and *A Framework for K-12 Science Education.****
	5. **Classroom coverage of content and practices in the *Common Core State Standards* and *A Framework for K-12 Science Education.***
Districts Need to Enhance the Capacity of K-12 Teachers	6. **Teachers' science and mathematics content knowledge for teaching.**
	7. Teachers' participation in STEM-specific professional development activities.
Districts Should Provide Instructional Leaders with Professional Development That Helps Them to Create the School Conditions That Appear to Support Student Achievement	8. Instructional leaders' participation in professional development on creating conditions that support STEM learning.
Policy Makers at the National, State, and Local Levels Should Elevate Science to the Same Level of Importance as Reading and Mathematics	9. **Inclusion of science in federal and state accountability systems.**
	10. Inclusion of science in major federal K-12 education initiatives.
	11. State and district staff dedicated to supporting science instruction.
States and National Organizations Should Develop Effective Systems of Assessment That Are Aligned with A Framework for K-12 Science Education *and That Emphasize Science Practices Rather Than Mere Factual Recall*	12. States' use of assessments that measure the core concepts and practices of science and mathematics disciplines.
National and State Policy Makers Should Invest in a Coherent, Focused, and Sustained Set of Supports for STEM Teachers	13. State and federal expenditures dedicated to improving the K-12 STEM teaching workforce.
Federal Agencies Should Support Research That Disentangles the Effects of School Practice from Student Selection, Recognizes the Importance of Contextual Variables, and Allows for Longitudinal Assessments of Student Outcomes	14. **Federal funding for the research identified in *Successful K-12 STEM Education.***

While a number of the issues raised by our informal survey and by the NRC report could be informed using current NAEP context and instruction item responses, as we will demonstrate below, the current NAEP background questionnaires have two important limitations. One, the current questions fail to address some important science education topics. These include providing almost no information about the amount and kind of exposure to out-of-school science learning, or the quality and relevance of professional development activities. Items are missing which could shed light on some of the greatest challenges schools and teachers are facing in improving science education, including concerns about having to teach too many science topics annually, lack of knowhow in integrating virtual experiments into instruction, and meeting the needs of students who differ greatly in science performance.

Two, many of these questions cannot be answered by NAEP alone, especially since NAEP data provide correlation indicators but not causality research. Nevertheless, NAEP can currently provide invaluable guidance for researchers and policy-makers in pointing to significant correlations, and can provide information about which educational variables are sufficiently common or sufficiently correlated with performance to encourage further research.

This report explores the current science background questions, the science issues and topics they do address, and offers recommendations for improving the background questions in science in the following sections of the report: section 2 describes the methodology of the analysis; sections 3-7 provide findings from the currently available NAEP background data on student engagement, science teachers, science resources, science instruction, and science assessment; and section 8 consists of recommendations to NAGB to improve the collection of the NAEP background variables in science education.

2. Methodology

Analytic Framework for Science Education Background Questions

NAGB questionnaire development process. NAGB follows a systematic process for developing its Science Background Questionnaires. General guidance for this process comes from a framework document published in 2002 (NAGB, 2002).

A 2009 Science Background Question Issues Paper (NAGB, n.d.) identified potential issues for the Science Background Questionnaires to address. The five issue areas identified are: 1. Availability and Use of Instructional Resources; 2. Organization of Science Instruction; 3. Teacher Preparation; 4. Role of Technology in Instruction; and 5. Student Engagement with Science. This listing and the specific issues in each area represented a broad identification of potential questions with a supporting research rationale. However, for such reasons as limited questionnaire time, some identified issues, such as learning activities outside of school, were omitted in the final questionnaire.

A systematic process was then followed for generating science-specific background variables (WestEd & CCSSO, 2006):

- Informed by the Background Questions Issues Paper, a Planning Committee brainstormed a list of possible variables.
- Next, a sub-group of Steering Committee members reviewed and culled the list and suggested additional items.
- NCES staff members then refined items from this list and sent a draft of this paper out for review to members of the Planning Committee and Steering Committee, who had expressed interest in being reviewers.
- After receiving feedback from these individuals, staff made appropriate changes and sent the document to NAGB for a preliminary review.
- After making edits suggested by NAGB, the document was sent to the entire Planning Committee and Steering Committee for review.
- After incorporating members' feedback, the document was then sent back to NAGB for presentation to the NAGB Assessment Development Committee and the full board.

The final questionnaires (http://nces.ed.gov/nationsreportcard/bgquest.aspx) for the 2009 and 2011 assessment are organized by respondent categories of students, teachers, and schools:

- "Student questionnaires include items on: ethnicity/race; resources (magazines, books, computers) available in the home; the student's attendance; language spoken in the home; education level of the parents (8th and 12th grade questionnaires only); and the student's program of study (12th grade questionnaire only)."

- "Teacher questionnaires include items on: race/ethnicity; years teaching; certification; number of courses in a subject area; professional development activities; leadership activities; and school improvement activities. Teacher questionnaires are completed by teachers in grades 4 and 8. NAEP typically does not collect grade 12 teacher information because of the difficulty of drawing a valid sample including the inability to relate student and teacher responses."

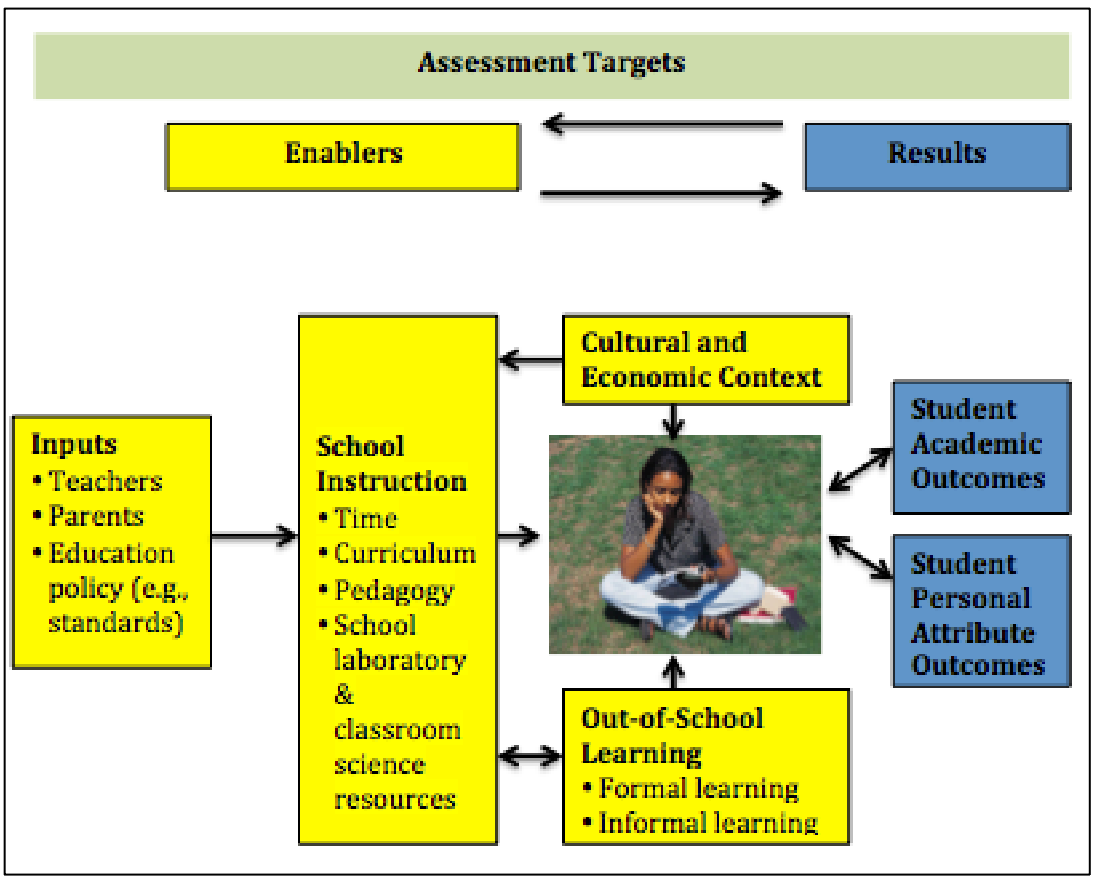
- "School questionnaires included items on: general characteristics of the school such as grades taught; number of hours of instruction; enrollment; percentage of limited English proficient students; participation in the

National School Lunch Program; percent of students receiving free lunch; and percent of students receiving special services."

While an organization of questions by respondent is useful for assessment administration, this report is focused on exploring the NAEP background variables organized around critical factors in the delivery of science education. These factors may cut across questionnaires. To guide the exploration of the science background variables, an analytic framework describing the key factors in the delivery of science education was developed (Exhibit 1-1). This framework identifies the potential factors influencing science education and their relationships.

- On the left side of the framework are *inputs* supporting instruction including teachers, parents, and education policies. As noted in the introduction, with respect to education policy, national education organizations in concert with many states are reviewing their K-12 science education standards and this has enormous potential for changing science instruction.

Exhibit 2-1: Science education analytic framework (K-12)



- Inputs feed into *formal student instruction at school*. This includes four factors of instructional time, curriculum, pedagogy and school science laboratories and classroom science resources

- *Out-of-school learning* can reinforce school science instruction and student learning and can produce both cognitive and affective domain learning in parallel or independently of what happens in school (*Learning Science in Informal Environments,* NRC, 2009). Out-of-school learning can be delivered through a formal afterschool program or informal exposure to science at a museum, the web or other non-formal learning settings. Schools and providers of informal science learning may work in partnership for their activities to reinforce instruction.

Outcomes may be both non-cognitive and cognitive outcomes.

- Non-cognitive outcomes are associated with affecting student engagement. They include student attitudes and behaviors such as liking science or wanting to take science to improve future opportunities.

- Cognitive science outcomes are measured by the knowledge and skills assessed by NAEP. Cognitive outcomes would be expected to be influenced by non-cognitive outcomes as students who are motivated to learn science may put more effort and concentration in science. Also, cognitive outcomes may also influence non-cognitive outcomes, as students may like a subject in which they perform well.

This science education analytic framework is used to organize the exploration of the data produced by the NAEP science background questionnaires.

Data Characteristics and Issues

Data considerations for this report include the years for which science background variables will be examined, the selection of individual background variables, measurement issues, analytic capability of the NAEP data explorer, and a cautionary note in making causal interpretations based solely on the NAEP data.

Years covered. The NAEP science assessment began in 1996 and was administered in 2000, 2005, 2009 and 2011. It is significant for the present analysis that the NAEP science assessment frameworks were redone in a major way beginning with 2009, in response to major changes in science education curriculum and practices. Because the science assessment outcomes are not comparable for prior to 2009, this analysis will focus primarily on the most recent 2011 assessment.

For a few variables where trend data are of interest, the science background data are shown for both the earliest 1996 and the 2011 periods. An example is the trend in the proportion of teachers of science by whether they have a degree in science.

Background variable omissions. The background variables cover many areas of the framework, but there are several notable omissions.

- No information is available for some items. In particular, the out-of-school learning variables are almost non-existent for science education. Thus, no questions are asked about time spent on science homework nor for time spent on science formal or informal learning outside the classroom. Nor is there any data on visits to science museums or on school partnerships with science museums. The only information on out-of-school science learning is a single question on doing science activities out-of-school, without any explicit direct information about frequency or amount, as follows:

  "Please indicate how much you disagree or agree with the following statements about science: I do science-related activities that are not for schoolwork." Responses: Strongly disagree, Disagree, Agree, Strongly agree.

- Information about professional development is available about topics taken. However, it would be informative to know the amount of time spent in professional development, what teachers thought of its quality, whether they changed their practice in response to the professional development and whether it addressed their science challenges. Given the changes in science standards expected to occur in many states, and the central role of professional development to support curriculum changes, NAEP could potentially provide important information about professional development time and quality.

Measurement error. Information from survey questionnaires is subject to measurement error of different types. Three examples of potential measurement errors are:

- Different respondent groups offer inconsistent answers to the same or similar factual background questions. As a case in point, the data analyses will show that schools are much more likely than teachers to indicate that they have adequate supplies of science resources.

- Judgmental measures. Many of the NAEP background variables are questions involving personal judgments. An example, from the student questionnaire:

  "Please indicate how much you disagree or agree with the following statements about science: I like science." Responses: Strongly disagree, Disagree, Agree, Strongly agree.

  As the analyses below indicate, students' responses to this question are associated with students' science scores. It would be helpful in understanding the importance of motivation and liking science to understand more about what students meant when they interpreted the question and the response of Strongly disagree, Disagree, Agree, Strongly agree.

- Some questions may not be clear. Student grade questionnaire: "I take science only because I have to."

  It is not clear who doesn't have to take science at grade 8, so the students' interpretation of the question may not be clear.

It is recommended that questions where there are uncertain interpretations of response be submitted for *review by the NCES cognitive laboratories.* This is process where a sample of students is probed in-depth for their question interpretation and the process could help strengthen question accuracy.

Data Explorer Strengths and Limitations. The NAEP data set with its matrix sampling is a very large and extremely complex database to analyze statistically. The NCES online *NAEP Data Explorer* enormously simplifies complex computational analyses of responses. The *Data Explorer* is in many respects an exceptional analytical tool providing access to all NAEP background variables since the mid-nineties by subject. Nevertheless, while the Data Explorer also permits some cross-variable categorization, the Data Explorer does have its limitations in that at the time of this study it was not capable of performing multivariate statistical analyses that would permit stronger statements about the contribution of an individual variable to an education outcome. For example, multivariate analyses would permit stronger statements about how much student engagement in science differs by students' race/ethnicity after controlling for differences in students family income and gender, as compared with analyses of a simple correlation alone. According to NCES Commissioner Jack Buckley in remarks before NAGB (May 2013), NCES is committed to adding a multivariate capability in the near future to enhance the capabilities of the NAEP Data Explorer.

Causal interpretations. The NAEP samples are repeated regularly at the same grade over different students. This repeated cross-section sampling does not, however, produce a measure of the change in outcomes for the same students over time. Without change data over the same respondents, causal interpretations with the NAEP data must be cautioned.

The approach of this report to making causal statements is to draw on the findings about the causality of a variable in relation to science outcomes from well-designed experimental or quasi-experimental studies. Once causality is shown with some degree of validity from non-NAEP independent sources, then these results can be used to justify examining the variable-outcome relationship from the NAEP assessment data. The NAEP data adds information by shedding light on the strength of the association under different conditions.

Organization of the Background Variable Analyses of Science Education

Consistent with the above framework (Exhibit 2-1), the background analyses explore for *grade 8 the following five science education related areas*:

- Student Engagement Toward Science
- Teachers of Science
- School Science Resources
- Science Instruction (Curriculum And Pedagogy)
- Science Assessment and Performance-Based Student Groupings

Note that the framework factor related to the science education a student receives out-of-school is not directly broken out because of the limited information on out-of-school learning from the NAEP student questionnaire. The only question available is one that asks students: "I do science-related activities that are not for schoolwork." There are no measures of the actual amount of time spent in out-of-school learning nor of the nature of the out-of-school learning.

Each analysis of a science area follows a three-part discussion:

- Brief highlights of the research and policy to identify variables that are important to measure within a science area.
- Descriptions of the NAEP background questions available to describe a science area.
- Analyses of the available background question data for that science area.

3. Student Engagement: Interest, Attitudes, Behavior and Identity

Research on Student Engagement

Student engagement embraces a broad category of student characteristics including interest and attitudes toward science, behaviors such as reading about or doing science voluntarily, and identifying oneself personally with science (McCallie, et.al., 2009 offers a variety of definitions and mechanisms for "engagement"). The underlying theory of action behind the student engagement factor is straightforward. If you like a subject and have confidence in your ability in a subject you will concentrate more, work harder and do better in learning that subject.

The direction of causation is also two ways. Do you come to like a subject *because* you do well and have higher achievement, or do you do well in a subject *because* you already liked it? These two possibilities are likely cyclic and mutually reinforcing. This section examines the research evidence about whether this theorized relationship between students' science attitudes and behaviors and their science test scores exist.

In fact, findings from international mathematics and science assessments have been cited to challenge the common sense idea that students who have positive engagement especially attitudes toward a subject are more likely to be motivated to learn and consequently will do better in a subject. Specifically, researchers point out that some high performing countries, such as Japan and Korea, have students who on average like mathematics and science less than do students in many lower performing countries. Based on this cross-country evidence, Loveless (2006) in a Brookings report concludes: "National indices of student happiness are inversely related to achievement in mathematics (p. 2-1)….. The evidence does suggest that the American infatuation with the happiness factor may be misplaced" (p.2-6)

Often lost in the discussion is that the very same international evidence also shows that *within* each of these countries, students with more positive attitudes towards mathematics and science consistently outperform students with less positive attitudes (Buckley, 2009). A case in point is the conclusion of the authors of the most recent 2011 results from the TIMSS grades 4 and 8 science assessment:

> "Each successive TIMSS assessment has shown a strong positive relationship within countries between student attitudes toward science and their science achievement. The relationship is bidirectional, with attitudes and achievement mutually influencing each other."(TIMSS, 2012, p.17)

The few rigorous longitudinal studies relating student attitudes to achievement in the STEM area also support the conclusion that student attitudes affect learning in important ways. Two examples are:

- Longitudinal "research examined how motivation (perceived control, intrinsic motivation, and extrinsic motivation), cognitive learning strategies … and intelligence jointly predict long-term growth in students' mathematics achievement for 3500 German students over 5 years from grades 5 -10. Using longitudinal data from six annual waves, latent growth curve modeling was employed to analyze growth in achievement. Results showed that the initial level of achievement was strongly related to intelligence, with motivation and cognitive strategies explaining additional variance. In contrast, intelligence had no relation with the growth of achievement over years, whereas motivation and learning strategies were predictors of growth." (Murayama, et.al., 2012)

- Student engagement can be defined as the level of participation and intrinsic interest that a student shows in school…Extensive evidence exists that engagement and motivation are critical elements in student success and learning. Researchers agree that engaged students learn more, retain more, and enjoy learning activities more than students who are not engaged. Studies have shown a direct link between levels of engagement and achievement in reading and mathematics. (Akey, 2006).

Two studies commissioned by the Wellcome Trust examined the role of informal STEM education in UK and beyond. These studies included an extensive literature survey and review of 553 published works. The Trust concluded that "Researchers have conclusively shown the positive impact on student attainment of learning experiences during the summer gap and the PISA 2006 study shows that school extracurricular activities relate to better performance, enjoyment and more positive attitudes to science" (Wellcome Trust, 2012).

All of these studies are consistent with the National Research Council's report on learning science in informal environments (2009), which added two strands of affective domain parameters to the four strands of cognitive domain indicators the NRC had identified earlier as essential components of science learning:

Six strands for impact for Informal Science Education
1. Develop interest in STEM
2. Understand STEM knowledge
3. Engage in STEM reasoning
4. Reflect on STEM
5. Engage in the practice of STEM
6. Identify with the STEM enterprise

The first and sixth strands are affective domain characteristics which are accepted major goals for informal science education, but are normally not explicit goals or parameters assessed in formal education. This makes it especially valuable if NAEP background questions can shed light on how these affective domain qualities, such as interest, attitude, engagement, and identity, are reflected in the student population, and what school and non-school factors are associated with improvements in these qualities.

The NAEP background questions about student attitudes and behavior provide empirical evidence about the baseline and changing affective domain characteristics of U.S. students, and the strength of the association of these characteristics with science achievement within the U.S.

NAEP Background Questions About Students' Engagement Toward Science

In describing students' non-cognitive attributes, NAEP identifies eight questions reflecting students' engagement focused on attitudes and behaviors toward science (Exhibit 3-1).

Exhibit 3-1. Non-cognitive questions about students' science engagement: attitudes and behaviors

Eight non-cognitive questions

- Difficulty of this science test details
- Effort on this science test details
- How much student likes science details
- How often student does science activities that are not for schoolwork details
- Importance of success on this science test details
- Science is a favorite subject details
- Take science because it will help in future details
- Take science because required details

The student response categories to these questions are: "Strongly disagree, Disagree, Agree, Strongly agree"

Three of the questions are about the difficulty, effort and importance a student attaches to the NAEP science test. These questions are useful for understanding the design and interpretation of the cognitive science assessment, but are not germane for this report on how the student background variables influence science education and its effectiveness. Therefore this analysis focuses on the remaining five questions.

Two of the five student attitude and behavior questions explore how much a student enjoys science as a subject:

- How much student likes science.
- Science is a favorite subject.

A related student question is about discretionary science behavior

- How often student does science activities that are not for schoolwork.

This last question is also the only measure of out-of-school science learning. Unfortunately, the response categories do not directly ask about the frequency in time of doing out-of-school science activities.

The responses to these questions shown at the bottom of Exhibit 3-1 indicate how strongly students agree with the above three questions. Agreement is a sign that students' like and enjoy science and hence are apt to be engaged positively with science.

The two additional questions at the bottom of the list (Exhibit 3-1) deal with two primary reasons students take science.

- Take science because it will help in the future.
- Take science because required.

Yes answers to these questions suggest that the motivation to take science is not necessarily because of an intrinsic like for science, but because of some external requirement or reward. The following data analyses will compare the responses to the first three questions that reflect liking science with the last two questions that reflect taking science for reasons other than personal satisfaction with the subject.

NAEP Background Variable Data on Student Engagement in Science

The analyses first look at the pattern of association nationally of student responses to the five attitude and behavioral questions with student science assessment scores. *These data are correlation data that show the strength of the association in the U.S. across students in grade 8 science, but by themselves do not prove causation. The research evidence supporting causation was discussed above.* Following the analyses for all students, the analyses then breakout the distribution of student attitudes and behaviors toward science by gender, low-income and racial-ethnic student sub-groups.

Student engagement toward science and science assessment scores

Questions 1-3 in Exhibit 3-2 reflect students' positive attitudes/engagement toward science. Strongly disagree means the students do not hold positive attitudes/behaviors toward science. Strongly agree is a sign of positive attitudes/behaviors. The student responses show:

- For each of questions 1-3, there is a strong positive improvement in students' NAEP science assessment scores, as student responses move from strongly disagree to strongly agree.

Exhibit 3-2. Average NAEP science assessment scores by student responses to questions about engagement in science for grade 8, 2011

NAEP science scores by grade 8 students' attitudes and engagement in science: 2011

Question	Strongly disagree	Disagree	Agree	Strongly agree	Strongly agree minus Strongly disagree
	Average scale score	Average scale score	Average scale score	Average scale score	Average scale score
1. Tthe student likes science	136	144	155	166	30
2. Student does science activities that are not for schoolwork	146	153	157	162	16
3. Science is a favorite subject	141	149	158	166	25
4. Take science because it will help in future	154	161	150	143	-11
5. Take science because required	164	160	146	138	-26

NCES, NAEP Data Explorer

- The differences in the science achievement scores range from 30 points for students liking science activities to 16 points for students doing science activities. In judging differences in student assessment scores, the 30-point differential is about the same as the difference between the cut-scores for the Basic and Proficient achievement levels. The 16-point differential is about half the difference between the two performance standards.

Questions 4 & 5 explore the reasons for taking science. They ask students about whether they are taking science because it will help them in the future or because it is required. Implicitly, a strong positive answer suggests that students who hold these reasons for taking science take science for external reasons and do not take science primarily because they are engaged in and like science. The pattern of science scores for questions 4 and 5 is different than for questions 1-3.

- For both questions, a strong positive answer that students took science for reasons other than they liked science produced an average lower grade 8 science score.

- The range in score decline between strongly disagree and strongly agree was 11 points (about 30 percent the Basic and Proficient cut-score difference) for students who took science because it would help in the future. It was 26 points (over 85 percent of the Basic and Proficient cut-score difference) for students who took science primarily because it was required.

Exhibit 3-3. Average NAEP science assessment scores by student responses to questions about engagement in science for grade 8, 2011, controlling for income status

NAEP science scores by grade 8 students' attitudes and engagement in science controlling for students' family low-income status: 2011						
Question	Low-Income Status	Strongly disagree	Disagree	Agree	Strongly agree	Strongly agree minus Strongly disagree
		Average scale score	Average scale score	Average scale score	Average scale score	Average scale score
1. The student likes science	Eligible	125	131	140	149	24
	Not eligible	147	156	166	176	29
2. Student does science activities that are not for schoolwork	Eligible	134	138	141	140	6
	Not eligible	157	164	170	178	21
3. Science is a favorite subject	Eligible	128	135	143	149	21
	Not eligible	153	160	168	176	23
4. Take science because it will help in future	Eligible	140	146	136	130	-10
	Not eligible	165	170	162	158	-7
5. Take science because required	Eligible	147	145	133	128	-19
	Not eligible	175	170	158	150	-25
NCES, NAEP Data Explorer						

Exhibit 3-3 shows the same pattern of correlations controlling for family-income status, as measured by the stand-in variable of eligibility for free or low-priced lunch, except for one of the engagement measures.

There are no differences in the direction of the correlations (positive for questions 1, 2, and 3, negative for questions 4 and 5), but the correlation is much weaker among low-income students on question 2. We speculate that this may be because some highly engaging activities (such as amateur astronomy, video-making, or bird watching) require equipment and/or travel, which may be less available to low-income students. Further investigation is required to determine why this particular engagement variable differs from the others so much with respect to income level.

Exhibit 3-4. Percentage of grade 8 students by engagement toward science, 2012

Question	Strongly disagree	Disagree	Agree	Strongly agree	Agree or strongly agree
	Percentage	Percentage	Percentage	Percentage	
1. The student likes science	12	19	50	19	69
2. Student does science activities that are not for schoolwork	25	46	25	4	29
3. Science is a favorite subject	21	32	31	16	47
4. Take science because it will help in future	12	32	39	18	57
5. Take science because required	18	34	30	17	47
NAEP Data Explorer					

Given the associations between these student attitude and behavioral questions about engagement in science, Exhibit 3-4 shows that the percentage distribution of student responses nationally to these questions. There is considerable variability in the percentage of students who agree or strongly agree when asked about positive science attitudes and behaviors, with a range for agree or strongly agree of:

- 69 percent agree or strongly agree that they like science.
- 29 percent agree or strongly agree that they do science activities that are not for school work.

The following sections examine how student engagement, as measured by responses to these five questions, differs by the gender, low-income or race-ethnicity of a student.

Gender. By gender, grade 8 students' scores on the NAEP science assessment exhibit a modest score advantage of 5 points favoring males. Five points represent slight more than 15 percent of the much larger Basic-Proficient science cut-score difference.

Exhibit 3-5. Percentage of grade 8 students by gender and students' engagement for science: 2011

Question	Gender	Strongly disagree	Disagree	Agree	Strongly agree	Agree or strongly agree
		Percentage	Percentage	Percentage	Percentage	Percentage
1. The student likes science?	Male	11	16	51	22	73
	Female	12	23	49	16	65
2. Student does science activities that are not for schoolwork	Male	26	42	27	5	32
	Female	25	50	23	3	26
3. Science is a favorite subject	Male	18	28	34	19	53
	Female	23	35	28	14	42
4. Take science because it will help in future	Male	14	33	36	16	52
	Female	10	30	41	19	60
5. Take science because required	Male	21	35	27	17	44
	Female	15	34	33	18	51
Source: NCES NAEP Data Explore, February 2013						

Exhibit 3-5 explores students' engagement in science by gender for the five questions about student engagement. The pattern of responses shows that:

- A greater percentage (between 6 and 11 percentage points) of males than females agree or strongly agree on the first three questions in which positive responses are associated with higher NAEP student achievement scores.
- A greater percentage (between 7 and 8 percentage points) of females agree or strongly agree on the bottom two questions in which positive responses are associated with lower achievement.

Thus, for both groups of questions, males hold attitudes and behaviors more favorably associated with higher achievement than do females.

Low-income Students. Students from low-income families identified as those who receive free or reduced price lunch, do not do as well on the grade 8 NAEP science assessments as students who are from non-low-income families, as identified by not receiving free or reduced-price lunch. On average, low-income students' grade 8 2011 science scores are 27 points below those of non low-income students.

Exhibit 3-6. Percentage of grade 8 students by school-lunch eligibility and students' engagement in science

Question	School lunch eligibility	Strongly disagree	Disagree	Agree	Strongly agree	Agree or strongly agree
		Percentage	Percentage	Percentage	Percentage	
1. The student likes science	Eligible	14	20	49	17	66
	Not eligible	10	18	51	20	71
2. Student does science activities that are not for schoolwork	Eligible	27	44	25	4	29
	Not eligible	24	47	25	4	29
3. Science is a favorite subject	Eligible	23	33	29	15	44
	Not eligible	19	31	33	17	50
4. Take science because it will help in future	Eligible	12	27	40	21	61
	Not eligible	12	35	38	15	53
5. Take science because required	Eligible	16	31	32	21	53
	Not eligible	20	37	28	15	43

Source: NCES NAEP Data Explore, February 2013

Consistent with their lower science assessment scores, students from low-income families (school-lunch eligible) are less likely to hold attitudes and behaviors that are correlated with higher science achievement (Exhibit 3-6).

- Low-income students are 5-6 percentage points less likely to agree or strongly agree that they like science or that science is a favorite subject. There are no differences in doing science activities that are not for schoolwork.

- Low-income students are more likely to agree or strongly agree (between 8 to 10 percentage points) that they take science because it will help in the future or because it is required. Again, a positive response is associated with lower assessment scores, perhaps because implicit to these answers is that they do not take science primarily because they are engaged in the subject.

Race/Ethnicity of Students. On the NAEP grade 8 2011 science assessment, White and Asian science scores are substantially higher than the scores for Black, Hispanic or American Indian students. To illustrate, White student scores are 34 points higher than Black students, 26 points higher than Hispanic students, and 22 points higher than science scores for American Indian students. As with Whites, Asian student science scores are similarly higher than for other minorities.

Exhibit 3-7. Percentage of grade 8 students by race/ethnicity and students' engagement for science: 2011

Question	Race/Ethnicity	Strongly disagree	Disagree	Agree	Strongly agree	Agree or strongly agree
		Percentage	Percentage	Percentage	Percentage	Percentage
1. Tthe student likes science	White	10	19	50	20	70
	Black	16	20	46	19	65
	Hispanic	13	21	50	16	66
	Asian/Pacific Islander	8	17	56	19	75
	American Indian/Alaska Native	14	19	52	15	67
2. Student does science activities that are not for schoolwork	White	25	46	25	4	29
	Black	29	42	25	4	29
	Hispanic	26	47	24	4	28
	Asian/Pacific Islander	21	46	28	5	33
	American Indian/Alaska Native	26	46	23	5	28
3.Science is a favorite subject	White	19	31	33	17	50
	Black	26	30	26	17	43
	Hispanic	21	35	30	14	44
	Asian/Pacific Islander	14	34	35	17	52
	American Indian/Alaska Native	22	31	34	13	47
4. Take science because it will help in future	White	13	36	37	13	50
	Black	12	22	37	29	66
	Hispanic	11	27	42	20	62
	Asian/Pacific Islander	9	26	42	22	64
	American Indian/Alaska Native	10	27	44	18	62
5. Take science because required	White	20	37	28	16	44
	Black	17	28	30	25	55
	Hispanic	15	33	35	18	53
	Asian/Pacific Islander	19	37	30	14	44
	American Indian/Alaska	14	29	37	19	56
Source: NCES NAEP Data Explore, February 2013						

As with gender and low-income, with respect to student attitudes and behaviors toward science by race/ethnicity (Exhibit 3-7), the overall pattern of student engagement is again generally consistent with the pattern of relative science scores across racial/ethnic groups. The largest differences in student attitudes and behaviors related to engagement are with respect to Asian students.

- Compared with Asian American students, Black, Hispanic and American Indian students are about 8-10 percentage points less likely to agree or strongly agree that they like science; and 5-9 percentage points less likely to indicate that science is a favorite subject. The differential in doing science activities that are not for schoolwork are only 4-5 percentage points higher for Asian students. The patterns for White students are similar but the differences are not as large as with Asian students for questions about liking science or science is a favorite subject. here is essentially no difference for the question about the student does science activities not for schoolwork.

- Black, Hispanic and American Indian students are about 10 percentage points more likely to agree or strongly agree that they take science because it is required than Asian students. However, Asian students, but not White students, are about as likely as Black, Hispanic or American Indian students to take science because it will help them in the future. In the case of Asian Americans, they are more likely to agree or strongly agree with taking science for future benefit.

In summary, overall there are definite patterns of differences in student attitudes and behaviors among students taking grade 8 science nationally and by student subgroups of gender, low-income and race-ethnicity. In most cases, the pattern of responses to these questions about science attitudes and behaviors are correlated in the expected direction with student achievement.

4. Teachers of Science

The National Research Council's review of teacher preparation concludes "that both strong content knowledge and familiarity with how students learn a particular subject are important for reading, math, and science teachers" (National Research Council, 2010). This section examines NAEP background variables describing teachers of grade 8 science with respect to three characteristics related to teacher preparation and training:

- *What is the proportion of teachers of science who have an undergraduate or graduate major by science area?* Having a degree in science provides evidence of a teacher's content knowledge in science, although the relevance of a teacher's knowledge may depend on the recency of a teacher's degree and the specific area of science the teacher is now assigned to teach.

- *What is the proportion of teachers of science who have taken alternative routes to certification?* Alternative certification is a route more commonly relied upon in K-12 fields of teaching where there are potential shortages of qualified teachers to fill vacancies. The NAEP data provide estimates of alternative certification by science major. They also indicate whether teachers from alternative certification routes are less experienced in teaching science, addressing a concern that students who enter teaching through alternative certification paths may be less likely to stay in teaching.

- *What is the amount and type of teacher professional development in science?* Professional development is a major source of teacher improvement, a means to stay current in science topics, and to develop skills in the emerging use of instructional technology in science education.

The analyses primarily focus on the grade 8 questionnaires for 2011. However, we do compare science degrees of grade 8 teachers of science between 1996 and 2011 to determine if there has been progress in exposing students to teachers with content mastery as measured by a science degree.

A. Teachers with Science Degrees

Research. The National Research Council's *Taking Science to School* (2007) notes the limited number of sound research studies investigating the relationship between teachers' postsecondary study of science with their students' achievement scores. However, the NRC finds that the available evidence does support the importance of science teachers' content knowledge as positively affecting the STEM achievement of their students. Two of the citations with strongest evidence are:

- "a 1983 meta-analysis (Druva and Anderson, 1983) found a positive relationship between student achievement and the number of science courses their teachers had taken. "

- "Monk (1994) presents data from a longitudinal survey that addressed teacher degrees in relation to both science and mathematics instruction and also identified positive effects."

In the related STEM area of mathematics, the International Education study (TEDS-M) of elementary and middle-school U.S. teachers of mathematics found that those teachers with a major in mathematics had substantially greater content knowledge that was more comparable to the knowledge of teachers of mathematics in countries with high-performing students (Schmidt, et.al,. 2007).

Professional consensus is also clear about teachers of science needing to have strong content knowledge base in science. The National Science Teachers Association (2011) recommends both strong knowledge of science content and knowledge of how students learn. Also, the Council of Chief State School Officers (2012, p15) in developing their new vision for teacher education stresses, "As part of the evidence of a candidate's ability to perform, states will need evidence of a candidate's content knowledge."

Exhibit 4-1. NAEP background questions on science degrees held by teachers of science, 2011

☐ Graduate major or minor in biology or other life science details	☐ Undergraduate major or minor biology or other life science details
☐ Graduate major or minor in earth or space science details	☐ Undergraduate major or minor earth or space science details
☐ Graduate major or minor in elementary or secondary education details	☐ Undergraduate major or minor elementary or secondary education details
☐ Graduate major or minor in engineering or engineering education details	☐ Undergraduate major or minor engineering or engineering education details
☐ Graduate major or minor in English-language learning details	☐ Undergraduate major or minor English-language learning details
☐ Graduate major or minor in math or math education details	☐ Undergraduate major or minor math or math education details
☐ Graduate major or minor in physics or chemistry details	☐ Undergraduate major or minor physics, chemistry or other physical science details
☐ Graduate major or minor in science education details	☐ Undergraduate major or minor science education details
☐ Graduate major or minor in special education details	☐ Undergraduate major or minor special education details

Data Explorer, 2013

NAEP Questions about Science Teachers' Science Degrees. Exhibit 4-1 displays the NAEP Background questions, which ask teachers of science about their undergraduate and graduate degrees. The focus of this background variable report is on the six questions that ask about having an undergraduate or graduate major or minor related to science. These cover the three science fields of biology or other life science, earth or space science, and physics or chemistry.

One important limitation of the analyses of teachers' science degrees generated by the NAEP Data Explorer is that it treats each undergraduate or graduate degree in a field as if it came from a separate individual. Undoubtedly, some teachers who received an undergraduate degree in a science field also went on to obtain a graduate degree, thus creating the potential for double counting. Consequently, the numbers in the tables represent an upper limit on the number of grade 8 teachers of science with an undergraduate or graduate degree in one of the three science fields.

Analyses of Teachers With Science Degrees. Exhibit 4-2 compares the percentages between 1996 and 2011 of grade 8 students taught by teachers of science who have an undergraduate or graduate major in one of three science areas: biology or other life science, earth or space science, or physics or chemistry.

Exhibit 4-2

Jurisdiction	Percent of grade 8 students taught by science teachers who have an undergraduate or graduate science major, by science field, 1996 and 2011					
	Biology or Other Life Science		Earth or Space Science		Physics or Chemistry	
	Undergraduate	Graduate	Undergraduate	Graduate	Undergraduate	Graduate
2011	36	10	9	4	9	3
1996	38	10	18	8	18	6

Source: NCES, NAEP Data Explorer

<u>All students</u>. Between 1996 and 2011, the percentage of grade 8 students taught by teachers of science who have a science major declined by about 50 percent for teachers in earth/space science or physics/chemistry. The percentages of students taught by a teacher with a biology or life science major held constant between 1996 and 2011. In both time periods, the highest percentages of teachers with a science major were in biology or other life sciences (Exhibit 4-2).

<u>Race/ethnicity (Exhibit 4-3)</u>. In 2011, students within different subgroups of race/ethnicity generally had roughly similar percentages of teachers with science majors. However, in 1996 a significantly lower percentage of Black students compared with Whites had access to teachers with a science major, while Asian and Hispanic students had greater access compared with White students. However, the greater equality in 2011 compared with 1996 was achieved by reductions for groups with greater access to science teachers in 1996 rather than by increases in the percentages of the groups with lower access.

- In 2011, all racial/ethnic groups were within 10 percentage points of White students in access to teachers with a science major. Black and American Indian students had somewhat lower access and Asians somewhat greater access with Hispanics similar to White students.

- This contrasts with 1996, in which Black students had less access to teachers with a science major than whites by 21 percentage points, Asians 20 percentage points greater access, American Indians 14 percentage point greater access, and Hispanics 9 percentage points greater access. However the improved Black equality in 2011 occurred through reducing the 2011 percentages of teachers with a science major for those groups with higher percentages of such teachers in 1996 rather than by increasing 2011 Black access to teachers with a science major.

Exhibit 4-3

Jurisdiction	Percent of grade 8 students by race/ethnicity, taught by science teachers who have an undergraduate or graduate science major, by science field, 1996 and 2011					
	Biology or Other Life Science		Earth or Space Science		Physics or Chemistry	
	Undergraduate	Graduate	Undergraduate	Graduate	Undergraduate	Graduate
2011						
White	36	9	10	5	9	3
Black	36	11	5	3	8	3
Hispanic	38	10	7	3	11	4
Asian/Pacific Islander	41	11	10	4	12	2
American Indian/Alaska Native	32	10	7	4	8	3
1996						
White	38	9	20	8	19	7
Black	33	10	12	9	11	5
Hispanic	44	13	18	8	20	7
Asian/Pacific Islander	54	13	15	9	22	9
American Indian/Alaska Native	56	27	11	2	19	0

Source: NCES, NAEP Data Explorer

Gender (Exhibit 4-4). There were no systematic differences between the percentages of grade 8 male and female students who were taught science by a teacher who majored in science, by field in either 1996 nor 2011.

Exhibit 4-4

Jurisdiction	Percent of grade 8 students by gender, taught by science teachers who have an undergraduate or graduate science major, by science field, 1996 and 2011					
	Biology or Other Life Science		Earth or Space Science		Physics or Chemistry	
	Undergraduate	Graduate	Undergraduate	Graduate	Undergraduate	Graduate
2011						
Male	36	9	9	4	10	3
Female	37	10	9	4	9	3
1996						
Male	39	10	18	8	18	5
Female	38	10	18	9	17	8

Source: NCES, NAEP Data Explorer

Low-income (Exhibit 4-5). There were no major differences between the percentages of grade 8 low-income and non low-income students who were taught science by a teacher who majored in science, by field, in either 1996 nor 2011.

Exhibit 4-5

Jurisdiction	Percent of grade 8 students by low-income, taught by science teachers who have an undergraduate or graduate science major, by science field, 1996 and 2011					
	Biology or Other Life Science		Earth or Space Science		Physics or Chemistry	
	Undergraduate	Graduate	Undergraduate	Graduate	Undergraduate	Graduate
2011						
Eligible	36	10	7	4	9	3
Ineligible	37	10	10	5	9	3
1996						
Eligible	36	10	18	7	18	5
Ineligible	39	11	18	9	16	7

Source: NCES, NAEP Data Explorer

B. Alternative Certification of Teachers of Science

Research and Background. There are several reasons why schools may hire teachers who have taken alternative routes to become a teacher. One is to fill positions for which available candidates are in short supply. Another reason is to increase the quality of teachers by drawing upon a broader group of graduates interested in teaching than only those who have matriculated through education school. Both trends are a widespread concern in science.

One well-known example of an alternative certification program is Teach for America, a program that is designed to draw into teaching graduating students from the upper academic tier of colleges and universities. These are students who are less likely to enter teaching through traditional education school preparation.

The evaluation evidence on the test scores of students of teachers entering through alternative certification routes is that their students' scores are about the same as regular teachers. (Constantine, et.al., 2004). There is concern, however, that these teachers are less likely to stay in education (Fowler, 2003). Higher turnover would raise the likelihood of students having a less experienced teacher, a concern as research consistently shows that students of beginning teachers (first three years) have lower performance.

Questions and Analytic Approach. NAEP in 2011 asks a single question of grade 8 teachers of science,

"Did you enter teaching through an alternative certification program"
Teacher-reported responses are: Yes, No.

The analyses address the following questions:

- How does the percentage of students taught by grade 8 teachers of science with alternative certification routes compare with the percentage taught by grade 8 teachers in non-STEM subjects? This analysis compares teachers of reading with teachers of science.

- Given the potential greater difficulty in finding teachers of science for schools serving low-income or minority students, are schools with higher proportions of low-income or minority students more likely to hire teachers who have gone through alternative routes to teaching?

- Is there evidence that science teachers of students from low-income or minority families have less experience and if so could this be related to higher rates of science teachers with an alternative certificate?

Exhibit 4-6

Percent of Grade 8 students taught science and reading by teachers entering teaching through alternative certification: all students, race/etnicity & low-income, 2011

Student Group	Science Teachers	Reading Teachers
	Percent	Percent
National	**20**	**15**
Race/ethnicity		
• White	16	11
• Black	30	22
• Hispanic	25	21
• Asian/Pacific Islander	16	13
• American Indian/Alaska Native	14	12
Low-income (school lunch eligible)		
• Eligible	24	18
• Ineligble	18	12

Source: NAEP Data Explorer, 2013

Data Analyses and Findings. Exhibit 4-6 shows the percentage of grade 8 students taught by teachers who entered teaching through an alternative certification route in science compared with reading. *Overall, the percentage of grade 8 students' taught science by teachers who entered teaching through an alternative certification route was higher than for reading. Black students and to some extent Hispanic students were more likely to be taught by teachers who entered through alternative certification than White or Asian students. Similarly students from low-income families are more likely to be taught science by a teacher entering through alternative certification than for non-low-income students.*

- Nationally, 20 percent of grade 8 students had teachers of science who entered through alternative certification, 5 percentage points higher than for students taught by teachers of reading.

- By race/ethnicity, 30 percent of grade 8 Black students and 25 percent of Hispanic students had science teachers who were alternatively certified compared with only 16 percent for White or Asian students. Interestingly, teachers of American Indian students are no more likely to go through alternative certification routes. Use of alternative certification in reading is also greater for teachers of Black or Hispanic students, but the rates are not nearly as high as for teachers of science.

- Grade 8 students from low-income families were 6 percentage points more likely to have science teachers who entered through alternative certification than for non low-income students.

Exhibit 4-7

Percentage of alternative certification and non alternative certification teachers who majored in science as under graduates or graduates by field, 2011

	Bilogy & Other ife Science		Earth or Space Sciece		Physics or Chemistry	
	Under graduate	Graduate	Under graduate	Graduate	Under graduate	Graduate
	Percent	Percent	Percent	Percent	Percent	Percent
Alterntive Certification	51	12	7	4	11	4
No Alternative Certification	33	9	9	4	9	3

Source: NAEP Data Explorer

The NAEP data also yield information about whether schools are more likely to hire teachers who have a major or minor in science by hiring alternative certification teachers for grade 8 science. *Exhibit 4-7 shows that alternative certification teachers are more likely to have a majored in science, but only with respect to biology and life sciences.*

- Considering grade 8 entrants through alternative certification routes, 51 percent of the teachers had an undergraduate major in biology or other life science, which is 18 percentage points higher than the 33 percent who entered teaching through other than alternative certification.

- The incidence of science majors for earth/space science or physics/chemistry is similar between alternative certification and non-alternative certification teachers.

In terms of *years of experience teaching science, 26 percent of the grade 8 students had teachers who have taught science four or fewer years* (Exhibit 4-8).

Exhibit 4-8

Teachers of grade 8 science by years of experience for all students, students taught by alternative certification teachers, students by race/ethnicity and low-income: 2011

All students	0-4 years	5-9 years	10-19 years	20+ years
	Percentage	Percentage	Percentage	Percentage
All students	**26**	**26**	**32**	**17**
Alternative Certification				
Yes	39	33	24	4
No	22	24	34	20
Race/Ethnicity				
White	22	25	33	19
Black	31	27	28	14
Hispanic	32	27	28	13
Asian/Pacific Islander	22	24	37	16
American Indian/Alaska Native	32	24	28	16
Low-income (School-lunch Eligibile)				
Eligible	29	27	29	15
Not eligible	22	25	34	19

Source: NAEP Data Explorer

- Teachers with the least science teaching experience are more likely to have entered teaching through alternative certification paths.

- Among students taught science by an alternatively certified teacher, 39 percent of the students were taught science by an alternatively certified teacher with 4 or fewer years of experience. This compared with only 22 percent of students taught science by a teacher with 4 or fewer years of experience when that teacher entered teaching through a traditional route. These numbers suggest merit in a frequent criticism of alternative certification programs, such as Teach for America, in that teachers are less likely to stay in the system. However, because alternatively certified teachers may also tend to be disproportionately new hires, these numbers need to continue to be tracked over time.

- The least experienced teachers of science are also more likely to teach Black, Hispanic or low-income students. Blacks, Hispanic and American Indian students have 31 or 32 percent of their teachers falling in the 0 to 4 years range, about 10 percentage points more than for White or Asian students.
- Low-income students are about 7 percentage points more likely to have teachers in the 0-4 years experience range than non low-income students.

As noted above, students who are Black or Hispanic or low-income are more likely to be taught by an alternatively certified teacher, which may explain why these students are being taught, on average, by a less experienced teacher.

C. Teachers of Science Professional Experiences

Research and Background. Research on professional development consistently finds that elementary and secondary teachers of all subjects are exposed to less than optimal professional development practices. Professional development is typically delivered through one-time external workshops that often lack integration with a teacher's regular classroom preparation and teaching. Consequently, research finds professional development as typically delivered often had little impact on changing teacher practice. (Sawchuck, Nov 10, 2010)

The Federal *No Child Left Behind Act of 2001* recognized that the problems with professional development were primarily funding pullout and short term teacher workshops. The act responded to this concern by defining professional development eligible for funding to include: activities that "are not one-day or short-term workshops or conferences. " However, data from federal evaluations of federally supported activities still continue to show that short-term workshops are the dominant form of teacher professional undertakings" (PPSS, 2009)

The *National Academy of Sciences* National Science Education Standards (http://www.nas.edu/rise/backg4.htm) are helpful in describing appropriate professional development that is ongoing and integrated:

> "Professional development for teachers should be analogous to professional development for other professionals. Becoming an effective science teacher is a continuous process that stretches from pre-service experiences in undergraduate years to the end of a professional career. Science has a rapidly changing knowledge base and expanding relevance to societal issues, and teachers will need ongoing opportunities to build their understanding and ability. Teachers also must have opportunities to develop understanding of

> how students with diverse interest, abilities, and experiences make sense of scientific ideas and what a teacher does to support and guide all students. And teachers require the opportunity to study and engage in research on science teaching and learning, and to share with colleagues what they have learned. "(NAS p. 55)

The next section examines how the NAEP questionnaires inform about professional development in light of research about the type of professional opportunities teachers of science need.

NAEP Background Questions and Analyses About Teacher Professional Development. Unfortunately, the NAEP questions of teachers of science are limited, asking only about the emphasis on professional development topics. *Missing entirely are questions about the amount of time for professional learning, the time available to develop lessons and improve, the integration of staff development into school activities, teachers perception of the value of their professional development and whether they changed their practice in response to their professional development activities.*

The questions of professional learning follow a similar format in their focus on professional development content and ask:

"Consider all of the professional development activities you participated in during the last two years. To what extent did you learn about:

- Instructional methods for teaching science
- Instructional methods for teaching technological design
- Learned about content standards in science
- Learned about curricular materials in science
- Learned about effective use of ICT in science
- Learned about effective use of lab activities in science
- learned about how students learn science
- Learned about methods for assessing in science
- Learned about preparing students for district or state assessments
- Learned about scientific inquiry and technological design
- learned about teaching science to students from diverse backgrounds"

The NAEP background questions typically cover answers of "not at all," "small extent," "moderate extent," and "large extent." No information is available on the actual amount of time teachers spent.

Analyses and Findings about science professional development. The analyses show that grade 8 professional development for teachers of science emphasizes the core instructional topics (Exhibit 4-9). The topics with the highest percentage of teachers indicating they learn about to a moderate or a great extent are:

- Content standards in science: 72% to a moderate or a great extent.
- Instructional methods for teaching science: 63% to a moderate or a great extent.
- Scientific inquiry and technological design: 62% to a moderate or a great extent.

The topics receiving least emphasis in terms of professional learning were in the technology area:

- Instructional methods for teaching technological design: 29% to a moderate or a great extent.
- Effective use of ICT in science: 30% to a moderate or a great extent.

The relatively low-emphasis given to developing professional skills in using technology may be a concern for limiting improvement because technology, especially in science instruction, offers the potential to radically change the delivery of science education through such means as computerized science simulations.

Example 4-9

Grade 8 teacher responses to questions asked about their professional development activities over the last two years, 2011

	Not at all	Small extent	Moderate extent	Large extent	Agree to a moderate or large extent
Question	Percentage	Percentage	Percentage	Percentage	Percentage
Learned about instructional methods for teaching science	11	25	39	24	63
Learned about instructional methods for teaching technological design	38	33	21	8	29
Learned about content standards in science	9	20	34	38	72
Learned about curricular materials in science	14	29	36	22	58
Learned about effective use of ICT in science	34	36	22	8	30
Learned about effective use of lab activities in science	22	31	30	16	46
learned about how students learn science	13	29	38	20	58
Learned about methods for assessing in science	16	32	34	17	51
Learned about preparing students for district or state assessments	18	26	29	26	55
Learned about scientific inquiry and technological design	13	25	37	25	62
learned about teaching science to students from diverse backgrounds	29	34	24	13	37
Participated in activities associated with school improvement efforts directed at issues such as adequate yearly progress and state accountability standards?	Yes= 83 percent				

Source: NAEP Data Explorer

5. Science Physical Resources: Availability and Use

Quality physical resources for science and the use of these resources to support students' science learning are an important part of implementing effective science instruction. The middle school science years represent an important period where students are transitioning to more rigorous science content including seeing and doing in-depth science experiments. Students' middle school science activities need to be supported with adequate books, instructional materials, audio-visual equipment, access to computers and laboratory opportunities.

The National Science Teachers Association (http://www.nsta.org/about/positions/highschool.aspx) has established criteria covering an adequate science program including laboratory work for high schools, that is also relevant for middle schools. These criteria cover:

"Science rooms/laboratories should be used only for science classes and science activities and should be equipped with:

- Adequate laboratory space per student and sufficient gas, electrical, and water outlets for student laboratory activities
- Safety equipment, such as fire extinguisher, fume hoods, emergency showers, and eyewash stations
- Audiovisual equipment such as an overhead projector; videocassette recorder and monitor; slide projector; and one or more computers with Internet access, plus needed software and maintenance service
- Sufficient storage for equipment and supplies and preparation space close to the classroom
- Support equipment such as photocopying machines, typewriters, word processors, and telephone in a nearby and accessible area
- Textbooks for each student, laboratory guides, and references as appropriate and needed."

The next section examines the questions NAEP asks about the physical resources to teach science.

NAEP Science Resource Background Questions

The NAEP grade 8 science questionnaires cover the essential resource categories of safety, facilities, science-specific equipment and access to general resources. The questions are of two types. *One set of questions asks about the availability of these* *different science resources and a second set asks about use for instruction of many of these same resources.*

The background question responses are from three sources.

- Schools responded to questions about science resource availability of different types on a school-wide basis.
- Teachers responded to questions about both resources and use in their science instruction classes.
- Student responses provide responses from their personal respective about use of science resources.

The responses differ in their quantitative/qualitative nature. An example of those involving a more quantitative response is shown in Exhibit 5- 1. The questions ask specifically about the percent of classrooms with access to specific science resources; in this example, handheld devices and tablet PCs.

Exhibit 5-1. Quantitative questions about science resources

Type of Science Resource	Percent of Classrooms					
	0%	1-25%	26-50%	51-75%	76-99%	100%
Resources (School Reported)	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
percent classrooms with handheld device for 8th grade science	71	18	4	2	1	4
percent classrooms with tablet PC for 8th grade science	70	15	4	2	2	7

NAEP Data Explorer

Another type of question is qualitative and asks about relative resource availability in terms of small, moderate or large extent along with “not at all.” An example of these questions is shown in Exhibit 5- 2. The advantage of this format is that it is easy for the respondent to answer. However, the disadvantage is that respondents might differ in interpreting terms such as small, moderate and large. For example, respondents in schools that are generally resource rich may have a high standard for moderately available resources than respondents who are in generally resource poor schools.

Exhibit 5-2. Qualitative questions about science resources

	Not at all	Small extent	Moderate extent	Large extent
Type of Science Resource (School or Teacher Reported)	Percentage	Percentage	Percentage	Percentage
computerized science labs are provided for science (teacher reported)	60	19	14	7
have computerized science labs (school reported)	42	25	15	18

NAEP Data Explorer

Exhibit 5-3. Comparisons of teacher and school reported responses about resource availability

	Not at all	Small Extent	Moderate extent	Large extent
Science Kits are provided (teacher reported)	26	30	29	16
Science Kits are provided (school reported)	7	24	32	37
Science magazines and books are provided (teacher reported)	22	35	33	11
Science magazines and books are provided (school reported)	2	19	35	44

NAEP Data Explorer

Concerns about measurement error also occur from different patterns of responses to similar questions by schools, teachers and students. In general, the pattern of responses indicates that schools are likely to say they provide more science resources than teachers are. As illustrations (Exhibit 5-3):

- With respect to the availability of science kits, 26 percent of teachers report "none at all" available compared with 7 percent of the school responses.

- With respect to science magazines and books, 22 percent of the teachers report "none at all" compared with 2 percent of the school responses.

This analysis will report both teacher and school responses, but will generally use the teacher responses in the analyses for several reasons. First, schools have a psychological incentive to boost responses to resource availability, which are a school responsibility, while teachers do not. Second, teacher responses are more fine-grained so that a school might respond they have science kits even if only one teacher or classroom does.

Science Labs

The overall findings with respect to the characteristics of science labs at grade 8 are that they typically have many of the laboratory essentials, but that many labs are lacking more sophisticated equipment (gas for burners) or newer technology (computerized science labs).

Exhibit 5-4 presents the findings for the NAEP background questions on science lab resource availability. The responses within each type of question group are rank ordered from least to most science resource availability. The ranking is based on the response to the first column of "not at all" in the table.

- Most but not all science labs serving grade 8 have the essentials. Looking at the percentage responding *"not at all'* or *" a small extent,"* the responses were only:
  - 5 percent for safety equipment
  - 5 percent for running water
  - 8 percent for supply storage
  - 8 percent for internet connections
  - 12 percent for demonstration stations

- The science lab resource weaknesses at grade 8 are indicated by a relatively high percentage of *"not at all"* or *"a small extent"* responses in the area of computers and certain equipment:

  - 79 percent for computerized science labs
  - 54 percent for air hoses
  - 39 percent for gas burners

Exhibit 5-4

Science lab resource availability, school and teacher reported, grade 8, 201

	Not at all	Small extent	Moderate extent	Large extent
	Percentage	Percentage	Percentage	Percentage
computerized science labs are provided for science (teachr reported)	60	19	14	7
have computerized science labs (school reported)	42	25	15	18
science labs have hood or air hoses	35	19	13	33
science labs have gas for burners	26	13	14	47
science labs have computers [school reported)	5	12	14	69
science labs have student lab stations	5	10	22	63
space to conduct science labs is provided	4	15	30	51
lab supplies are provided for science	3	18	41	38
science labs have demonstration stations	3	9	23	65
science labs have Internet connection	2	6	9	83
have supplies for science labs	1	8	28	63
science labs have supply storage	1	7	19	74
science labs have running water	1	4	13	82
science labs have safety equipment	1	4	15	80
science labs have electricity	1	3	12	84

Source: NAEP Data Explorer

Instructional Technology for Science in Classrooms.

Exhibit 5-5 shows school-reported availability of instructional technology for science by percent of classrooms having a particular instructional technology resource.

- Some instructional technology items are quite common for grade 8 science. At least 75 percent of the schools have half or more of their grade 8 science classrooms equipped with digital projectors, CD/ROM, online software and a desktop computer.

- The least common items for which 75 percent or more of the schools have less than half their grade 8 science classrooms equipped with instructional technology include handheld devices, tablet PC's, digital music,.

- Examples of mid-range items in terms of limited availability are graphing calculator, which less than half the science classrooms have available in 54 percent of the schools and cable or satellite TV with less than half the science classrooms having available 41 percent of the schools.

Exhibit 5-5

Instructional technology for science in classrooms (school reproted), grade 8, 2011

Type of Science Resource	Percent of Classrooms					
	0%	1-25%	26-50%	51-75%	76-99%	100%
Type of Science Resources (School Reported)	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
percent classrooms with handheld device for 8th grade science	71	18	4	2	1	4
percent classrooms with tablet PC for 8th grade science	70	15	4	2	2	7
percent classrooms with digital music device for 8th grade science	56	19	6	4	4	12
percent classrooms with data collection sensor for 8th grade science	46	23	9	6	4	13
percent classrooms with cable or satellite TV for 8th grade science	33	6	2	2	5	52
percent classrooms with online course management for 8th grade science	27	9	4	3	6	52
percent classrooms with digital whiteboard for 8th grade science	26	17	10	7	7	34
percent classrooms with digital camera for 8th grade science	21	31	12	7	4	26
percent classrooms with graphing calculator for 8th grade science	21	20	13	10	7	29
percent classrooms with laptop computer for 8th grade science	21	19	8	7	7	38
percent classrooms with desktop computer for 8th grade science	9	9	2	2	6	72
percent classrooms with online software for 8th grade science	8	8	4	5	10	64
percent classrooms with CD/ROM for 8th grade science	5	4	3	3	9	75
percent classrooms with digital projector for 8th grade science	3	6	4	6	11	70

Source: NAEP Data Explorer, Science 2011

Science non-technology instructional materials in classrooms

These include measuring instruments, books and audiovisual materials (Exhibit 5-6).

- The most widely available instructional technology items with less than 10 percent of the respondents reporting "not at all" or a "small extent" for availability include science textbooks (3 percent), scientific measurement instruments (8 percent) and supplies for science demonstrations (6 percent).

- The least available science non-technology resources are science kits and science magazines and books, with more than half the teachers reporting availability "not at all" or "small extent." The scarcity of these resources may indicate some lack of depth in conducting hands-on science activities without access to specialized kits or scientific reading material.

Exhibit 5 –6

Classroom Access to Non-instructional technology resurces in claasrooms when teeaching grade 8 science

Type of Science Resource (School or Teacher Reported)	Not at all	Small extent	Moderate extent	Large extent
	Percentage	Percentage	Percentage	Percentage
science kits are provided for science (Teacher reported)	24	30	29	16
science magazines and books are provided for science (Teacher reported)	22	35	33	11
have science kits (School reported)	7	24	32	37
audiovisual materials are provided for science (Teacher reported)	6	21	40	32
supplies for demonstrations are provided for science (Teacher reported)	3	18	43	36
have science magazines and books (school reported)	2	19	35	44
Textbooks are provided for science (Teacher reported)	2	6	21	72
scientific measurement instruments are provided (Teacher reported)	2	16	41	40
have science textbooks (Teacher reported)	1	2	7	90
have scientific measurement instruments (school reported)	0	8	31	61
have supplies for science demonstrations (Teacher reported)	0	6	28	65

Source: NAEP Data Explorer, Science 2011

Use of available science resources

Exhibit 5-7. Science resource use: teacher and student reported, grade 8, 2011

Type of Science Resource	Not at all	Small extent	Moderate extent	Large extent
	Percentage	Percentage	Percentage	Percentage
Teacher Reported				
use handheld device for science	86	9	3	1
use tablet PC for science	83	7	5	5
use graphing calculator for science	77	17	4	2
use digital music device for science	75	17	5	2
use cable or satellite TV for 8th grade science	69	21	7	3
use data collection sensor for science	65	25	8	2
use digital whiteboard for science	51	9	10	30
use digital camera for science	48	37	12	4
use online course management for science	34	15	16	35
use laptop computer for science	31	16	17	36
use CD/ROM for 8th grade science	25	37	25	13
use online software for science	21	34	29	17
use desktop computer for science	20	18	20	42
use DVDs and player for science	13	44	32	11
use digital projector for science	7	7	18	69

Teacher Reported	Never or hardly ever	Once or twice a month	Once or twice a week	Every day or almost every
students science book or magazine	43	44	11	1
students use computer to chart or graph science projects	39	43	16	2
students use computer to simulate physical or biological process	38	43	16	3
students use computer to search for science information	30	53	14	3
students read science textbook	11	21	45	24

Student Reported	Never or hardly ever	Once every few weeks	About once a week	2-3 times a week	Every day or almost every day
	Percentage	Percentage	Percentage	Percentage	Percentage
use library resources for science	67	21	7	4	1
use computers for science	40	36	13	7	4
watch teacher do science experiment	24	35	24	11	6
watch science movie, video or DVD	20	42	22	12	5

Source: NAEP Data Explorer, Science 2011

Having science resources available does not necessarily translate into science resources being used for instruction. The NAEP background variables also ask explicitly about frequency of use of the science resources by teachers and students. Exhibit 5-7 organizes the responses into three tables by whether the information about use is teacher or student reported and for teacher reported into the two different response formats. Based on the responses, resource use falls into three categories: commonly used, uneven use and uncommon use.

- *Science resources commonly used for science instruction are the familiar and traditional activities*. The four with the lowest percentages (20 percent or less) of "not at all" or "never or hardly ever" used are *the teachers use DVD and player for science, teachers use a digital projector for scienc*e, *teachers use a desk top computer for science, and students read science textbook.*

- Science resources in the *mid-range (21- 50 percent) of use* based on percentages of "not at all" or "never or hardly ever" include students *use a computer to : search for science information (30 percent); simulate a physical or biological process (38 percent); or use a computer to chart a graph (39 percent).* Perhaps surprisingly, also not having regular use *is students reading a science book or magazine*. About 43 percent of the teachers indicate that students "never or hardly ever" read a science book or magazine.

- In terms of least use of science resources, over 50 percent of the teachers report not using more recent technology including handheld devices, PC tablets, graphing calculators, digital music devices, cable or satellite TV, data collection sensors or whiteboards. As noted, access to these newer technology resources is limited, so these use findings are expected. These findings should not be interpreted as necessarily meaning that technological resources would not be used if there were greater availability.

And as noted in Introduction section of this report on the list of current topics under discussion among science educators, how such science resources are used is at least as important as the quantity and type of resources available. Computers and lab equipment used only to confirm accepted knowledge, or for drill and practice, may be associated with very different outcomes than using those resources in inquiry pedagogies.

Equity in distribution of science resources

Another resource issue is whether science education resources are equitably distributed across populations. Exhibit 5-8 compares resource availability for students by their school lunch eligibility. The measure of resource availability is the percent of classrooms in grade 8 science with the designated resource. The percent measure is preferred to a subjective relative measure, such as small, moderate or large extent, as schools with fewer overall economic resources may have a lower standard of meaning for terms such as small, moderate or large extent.

Overall, school lunch eligible students have slightly less access to science resources. For example, comparing the average percentage of schools with a hundred percent of their classrooms having access to particular resources, there is a 4 percentage point advantage for non-school lunch eligible students (43 percent) compared with school lunch eligible students (39 percent) across all the resource categories listed.

Exhibit 5-8. Availability of specific science resources by students' school lunch eligibility and percent of classrooms with resources, grade 8, 2011

Type of Resources		0%	1-25%	26-50%	51-75%	76-99%	100%
		Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
Average of all resources	**Eligible**	**28.6**	**14.3**	**6.1**	**4.9**	**7.1**	**39.2**
	Not eligible	**26.7**	**13.7**	**6.1**	**4.6**	**5.7**	**43.2**
percent classrooms with cable or satellite TV for 8th grade science	Eligible	35	6	2	2	5	50
	Not eligible	29	6	2	1	5	57
percent classrooms with CD/ROM for 8th grade scienc	Eligible	5	4	3	4	11	73
	Not eligible	4	4	3	3	8	78
percent classrooms with data collection sensor for 8th grade science	Eligible	48	23	9	6	4	11
	Not eligible	43	23	10	6	3	15
percent classrooms with desktop computer for 8th grade science	Eligible	8	9	2	2	7	72
	Not eligible	9	8	2	2	5	73
percent classrooms with digital camera for 8th grade science	Eligible	22	33	12	7	4	23
	Not eligible	19	31	12	7	4	27
percent classrooms with digital music device for 8th grade science	Eligible	57	19	5	4	4	11
	Not eligible	54	20	6	3	3	12
percent classrooms with digital projector for 8th grade science	Eligible	3	6	4	6	12	69
	Not eligible	2	5	4	6	11	72
percent classrooms with digital whiteboard for 8th grade science	Eligible	25	17	10	6	8	33
	Not eligible	25	17	10	7	7	34
percent classrooms with DVDs and player for 8th grade science	Eligible	6	7	5	6	11	66
	Not eligible	3	4	4	5	9	75
percent classrooms with graphing calculator for 8th grade science	Eligible	22	21	13	10	8	26
	Not eligible	20	19	14	10	6	31
percent classrooms with handheld device for 8th grade science	Eligible	71	18	4	2	2	4
	Not eligible	70	18	4	2	1	4
percent classrooms with laptop computer for 8th grade science	Eligible	19	18	9	8	9	37
	Not eligible	22	19	8	7	7	39
percent classrooms with online course management for 8th grade science	Eligible	29	10	4	3	7	47
	Not eligible	24	8	4	3	5	57
percent classrooms with online software for 8th grade science	Eligible	9	8	5	5	12	60
	Not eligible	7	8	4	5	9	67
by percent classrooms with tablet PC for 8th grade science	Eligible	70	15	4	3	2	6
	Not eligible	69	16	4	2	2	7

Source: NAEP Data Explorer

6. Curriculum and Instruction

Research and Context

Science curriculum and instruction, like mathematics and reading, is undergoing extensive review and will likely see major future changes as a result of nationwide efforts to improve and strengthen science education standards in the U.S. Although the U.S. has no official science standards, the standards prepared by the National Research Council (1996) have become the basis for many of the state frameworks.

A national coalition of organizations involved in science education (The National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve) have come together to develop the "Next Generation Science Standards." The Next Generation Science Standards are based on the Framework for K–12 Science Education (National Research Council, 2012) developed by the NRC. The major weaknesses in current standards and instruction that are cited to be addressed by the new standards include (http://www.nextgenscience.org/development-overview):

- Teaching too many science content topics at each grade.
- The science content that is taught tends to be shallow and lacks depth at providing students a real understanding of how things work. Instead, much of science teaching is about memorization. At least in part, this is the result of having to cover so many science content topics.
- The standards and curriculum lack coherence over the grades. That is, they do not build on prior knowledge but instead present fragmented learning from year to year.
- A lack of meaningful teaching of scientific and engineering practices about how scientific knowledge is acquired and applied. Scientific inquiry is often taught as a mechanical, isolated activity and disconnected with major cross-cutting concepts and disciplinary ideas.

The new "Next Generational Science Standards" (Achieve, 2013) offer a potential opportunity to provide a framework to build greater coherence, focus, and depth of understanding in science instruction and curriculum. Combined with the potential advances in teaching and learning from instructional technology, they also offer an opportunity to get across the "integration of scientific explanations and practices needed to engage in scientific inquiry and engineering design."

The NAEP science background variables around curriculum and instruction offer an opportunity to establish a baseline and chart progress and challenges as new standards and practices are being implemented. The NAEP analyses cover all states and it will be helpful to monitor the changes in standards and instruction both in states participating in the new standards and those states that do not choose to participate. In this context, the grade 8 questions that these background questions will explore below include:

- How important are standards and other factors perceived at the school level in driving the school curriculum and instruction?
- How much time weekly is spent on grade 8 science?
- What scientific disciplines (life science, earth or space science, physics or chemistry) are focused on at grade 8?
- What aspects of science receive the greatest and least emphasis in curriculum and instruction?
- How frequently are different modes of instruction (e.g., hands-on activities, working with others) employed in teaching?

Because the NGSS also have far greater stress on engineering and engineering design than previous standards and most current educational practice, the new Technology and Engineering Literacy assessment [National Assessment Governing Board, 2011] being developed for NAEP also has great potential to monitor the changes which result in these areas of instruction. Indeed, because so many students have more access to technology outside of the classroom than inside, through smart phones and other devices, background variables related to use of information and communication technologies outside of school could provide exceptional valuable information for developers and users of the NGSS.

NAEP Background Variables For Science Instruction and Curriculum

NAEP background variables are available to address each of these questions. The NAEP background questions are arrayed by curriculum, instructional time and modes of instruction or classroom activities.

Several challenges in the specification of the NAEP background variables for science instruction and curriculum arise.

- The science instructional time variable interval range is: Less than 1 hour, 1-2.9 hours, 3-4.9 hours, 5-6.9 hours, 7 hours or more. Two-thirds of the responses are in the under 5 hours a week but almost all between 3-4.9. Eliminating the less than an hour and breaking-up the 3-4.9 into 3-3.9 and 4-4.9 would add a lot of information about instructional time amounts under 5 hours.
- Again, a lot of the question formats involve qualitative interpretations of amounts (little, some, a lot) rather than quantitative responses and the interpretation of qualitative amounts may depend upon respondents'' context. For example, the question about class time spent on earth or space

science asks for responses of "none, little, some or a lot." But a more precise response is obtained for the question about how frequently students design a science experiment, which asks for a quantitative response by selecting among "never or hardly ever, once every few weeks, once a week," etc.)

Analyses and Findings

Exhibit 6-1

Percentages of students by weekly hours of science, mathematics and reading-language arts instruction for grades 8: 2011

Jurisdiction	less than 5 hours	5-6.9 hours	7 or more hrs
	Percentage	Percentage	Percentage
Science	66	26	8
Mathematics	63	28	9
Reading	46	32	22

NAEP, Data Explorer

How much weekly time is spent on science instruction?

Exhibit 6-1 displays the amount of weekly time spent on instruction in science, mathematics and reading for 2011. At grade 8, weekly instructional time spent on science is comparable to that for mathematics, but less than the weekly instructional time allocated for reading. Approximately, two-thirds of the students spend less than 5 hours a week in science, equivalent to an hour a day. At the upper end of the time range, slightly less than 10 percent of all grade 8 students spend 7 or more hours a week on science. Research exploring how science instruction varies as student time increases and the relationship of instructional time to student learning could be useful in understanding how schools could better use greater instructional time more effectively.

Exhibit 6-2 explores how the distribution of science instructional time per week differs by whether students are low-income, as defined by school-lunch eligibility, or by their race/ethnicity. *To the extent that differences in weekly instructional time in science are observed, the differences in time of exposure to science favor at –risk students groups, suggesting the extra instructional time may be compensatory.*

- Non low-income students who are ineligible for school-lunch at grade 8 are 6 percentage points more likely to receive less than 5 hours of science instruction a week than are school-lunch eligible students.

- White and Asian grade 8 students are 11 percentage points more likely to receive less than 5 hours of weekly science instruction than Black students.

Exhibit 6-2

Percentages of students by weekly hours of science, instruction for grades 8:2011

Jurisdiction	Weekly hours of science Instruction: Grade 8		
	less than 5 hours	5-6.9 hours	7 or more hrs
	Percentage	Percentage	Percentage
Low-income			
•School-lunch eligible	62	28	9
•School-lunch ineligible	68	25	7
Race/Ethnicity			
• White	69	25	6
• Black	58	31	11
• Hispanic	64	27	9
• Asian/Pacific Islander	69	24	7
• American Indian/Alaska Native	67	23	10

NAEP, Data Explorer

What is the basis for structuring a school's science program?

Understanding the basis for structuring science education programs is important to understanding how to leverage changes intended to improve science education. In particular, the potential impact of the proposed changes from the Next Generation Science Standards will depend upon how closely school curriculum and instruction align with adopted standards.

Exhibit 6-3 reports on the schools' responses when asked about the basis for how they structure their school's science education program. *The responses clearly support the central importance of state and district standards and assessment results in driving the structure of schools' science education programs:*

- 86% of the students were in schools that structured their program "a lot" according to state standards.
- 71% of the students were in schools that structured their program "a lot" according to district standards.

Exhibit 6-3

Basis for structuring grade 8 science education program, percent of students in schools with varying percentages, 2011	None	Little	Some	A lot
	Percentage	Percentage	Percentage	Percentage
science program structured according to commercial programs	47	32	16	6
science program structured according to discretion of teachers	15	40	33	13
science program structured according to district standards	6	6	18	71
science program structured according to in-school standards	8	16	32	44
science program structured according to school assessment results	5	18	35	42
science program structured according to science department	8	26	38	28
science program structured according to state or district assessment results	6	11	29	54
science program structured according to state standards	2	2	10	86

NCES NAEP Data Explorer

- 54% of the students were in schools that structured their program “a lot” according to state or district assessment results.

Potential leverage points over instruction that are relatively weaker, based on school responses, include:

- 6% of the students were in schools that structured their program to a large extent according to commercial programs.
- 13% of the students were in schools that structured their program to a large extent according to the discretion of teachers.

What science content areas are taught at grade 8?

A key element in leveraging and strengthening science education is knowing what science content domains are taught at different grades. Is instructional time about evenly divided among the major content domains: earth and space science, engineering and technology, life science, and physical science? Alternatively, are there concentrations in the teaching of particular science domains at certain grades? If so, these grade concentrations represent leverage points to focus on to improve content and instruction. Moreover, knowing present domain emphasis of instruction at a grade establishes a baseline against which to measure changes.

Exhibit 6-4 shows that instructional emphasis on different science content domains varies considerably at grade 8. Given the preponderance of grade 8 teachers with a major in the life sciences (Exhibit 6- 4), this domain may be expected to receive the greatest attention, but life science was in fact among the least commonly taught in terms of spending a lot of class time.

- The top two content areas in terms of "a lot" of class time were the physical science, taught "a lot" by 61 percent of the school respondents, and earth and space science, at 39 percent.

- By contrast, only about 20 percent of the teachers indicated that life science received a lot of instructional emphasis at grade 8.

- Despite efforts over the past few years to integrate engineering and technology into science instruction, at least at grade 8 that is not happening, with only 5 percent of the teachers giving this a lot of emphasis.

Exhibit 6-4

Science Content Domains By Grade 8 Class Time

	None	Little	Some	A lot
Science Domain	Percentage	Percentage	Percentage	Percentage
class time spent on earth and space science	11	17	32	39
class time spent on engineering and technology	19	44	32	5
class time spent on life science	26	27	27	20
class time spent on physical science	4	8	27	61

NCES, NAEP Data Explorer

What are the science practices and attitudes that receive the greatest instructional emphasis?

Exhibit 6-5

Teacher reported emphasis on science practices and attitudes, 2011

	None	Little	Some	A lot
Area of emphasis	Percentage	Percentage	Percentage	Percentage
emphasis on applying science to environment	3	31	45	21
emphasis on further study	#	8	42	49
emphasis on importance of science in daily life	#	8	38	54
emphasis on inquiry skills	#	11	43	46
emphasis on interest in science	#	4	37	58
emphasis on problem-solving skills	1	19	42	38
emphasis on scientific facts and principles	#	3	35	61
emphasis on scientific methods	#	8	41	50
emphasis on scientific writing skills	4	38	43	16
emphasis on skills in lab techniques	2	24	45	29
emphasis on systematic observation skills	1	19	49	31

is approximately zero
Source: NCES, NAEP Data Explorer

Exhibit 6-5 presents teacher responses to questions about degree of emphasis given in instructional to different practices and attitudes. Practices represent the types of behaviors scientists engage in, such as inquiry skills, lab techniques or scientific writing. Attitudes are about interest in science and are associated with NAEP achievement scores (Exhibit 3-2).

Among the practices and attitudes taught, four received a lot of emphasis by half or more of the teachers (Exhibit 6-5).

- The science practices emphasized by half or more of the teachers of grade 8 science are scientific facts and principles (61 percent) and scientific methods (50).

- The student attitudes toward science given "a lot" of emphasis by more than half the teachers are "interest in science" (58 percent) and the importance of science in daily life (54 percent).

Teacher instructional emphasis is consistent with the research on the importance of positive attitudes towards science. Note that the final version of the *Next Generation Science Standards* (NGSS) mentions the importance of the soft variables (or "21st-century skills"), including positive student attitudes toward science, in their Executive Summary: "The affective domain, the domain of learning that involves interests, experience and enthusiasm, is a critical component to science education" (Achieve 2013). But the NGSS authors decided not to include any performance expectations for interest or motivation. NGSS restrict themselves to "endpoints of learning," not incorporating standards for any factors which are known or suspected of influencing student learning. If NGSS-related assessments follow the same endpoint focus, they may fail to provide information on those noncognitive variables. This makes NAEP background variables even more crucial to help understand how NGSS or other new standards are implemented and their impacts on factors like interest and motivation. Out of school factors may provide a significant source of soft skills, which could also be informed by appropriate new background variables.

How frequently and in what content areas do teachers do hands-on science activities?

A priority in science education is for students to understand and be able to apply at their own level *the practices that scientists engage in* as they explore and understand the world around them. Rather than having students being passively taught about scientific practices, a more authentic way for students to learn about the practices of science is for students to engage in their own hands-on, minds-on scientific inquiry activities. These activities range from design activities, through investigation, to analysis, writing and presenting results. Because the terms "hands-on" and "inquiry" are used with a variety of meanings in education, it may be desirable in the future for these items to provide a definition in the assessment, or to break these practices down so that individual elements of inquiry pedagogy are reported.

Exhibit 6-6

Frequency of students carryingout hands-on science projects including designing, measuring and discussing results of science projects, 2011 (Student Reported)					
	Never or hardly ever	Once or twice a month	Once or twice a week	Every day or almost every day	
Type of Hands-on Science Project/Activity	Percentage	Percentage	Percentage	Percentage	
how often students do hands-on science activities	2	25	56	16	
	Yes	No			
	Percentage	Percentage			
do hands-on projects with chemicals	70	30			
do hands-on projects with electricity	36	64			
do hands-on projects with living things	32	68			
do hands-on projects with magnifying glass or mic	41	59			
do hands-on projects with rocks or minerals	43	57			
do hands-on projects with simple machines	33	67			
do hands-on projects with thermometer or barome	58	42			
	Never or hardly ever	Once every few weeks	About once a week	2-3 times a week	Every day or almost every day
	Percentage	Percentage	Percentage	Percentage	Percentage
design a science experiment	39	36	16	6	2
discuss measurements for science project	35	33	19	9	4
discuss results of science project	24	35	23	12	6
NCES, NAEP Data Explorer					

Exhibit 6-6 presents teachers' responses about the range of coverage of hands-on science activities. *Teachers nearly universally conduct hands-on activities with their grade 8 students, but from 24 percent to 39 percent of the students do not design a science experiment (39 percent), discuss measurement (35 percent), or discuss the results of their science project (24 percent). A surprising result is that although the most commonly taught science domain at grade 8 was physics, electricity and simple machines were among the least frequent hands-on activities, which may raise questions about how this physics is taught.* Specific findings about hands-on activities include:

- Only 2 percent of the students respond they never carryout a grade 8 hands-on science activity.

- Students indicate students most frequent grade 8 hands-on project is with chemicals (70 percent) and the least frequent is with living things (32 percent), electricity (36 percent) and simple machines (33 percent).

- Although doing grade 8 hands-on science activities is nearly universal, carrying out the steps of an investigative process is not. Twenty-four percent of the grade 8 students never discuss their results, thirty-five percent never discuss measurement for their science project and thirty-nine percent of the grade 8 students don't design an experiment.

Many science educators have become skeptical of using "hands-on" as a proxy term for inquiry or experimental work, since merely touching an apparatus does not guarantee that the apparatus is actually being used for investigation, rather than simply to confirm or demonstrate what the teacher or textbook is saying. "Inquiry" too is a suspect term, because there are so many interpretations of inquiry as a learning pedagogy. NAEP background items could help clarify what activities are actually being conducted, by asking teachers the extent to which their use of instruments in labs is for students to explore and create hypotheses, or to test and confirm previously discussed hypotheses.

7. Assessment and Ability Grouping/Differentiated Instruction

Assessment and ability grouping/differentiated instruction are often treated as independent education activities, but in practice they should be linked in organizing classroom instruction. That is, while science assessment serves summatively to produce student grades or for teacher accountability, science assessments can also be powerful drivers of achievement, when assessments are used formatively for feedback to guide instructional improvement (Black & Wiliam, 1998; Ruiz-Primo & Furtak, 2006). Ability grouping and differentiated science instruction are practices designed to respond to student performance by providing different students with different pathways for accessing instruction.

The NAEP background questionnaires ask both about assessment and ability grouping/differentiated instruction. With respect to assessment, the NAEP questions ask teachers of grade 8 science about:

- How they assess students – with multiple choice, short-written responses and long written responses?

- How are assessments used with specific students – adjust teaching strategies, discuss current performance, discuss progress toward previous goals, or set specific progress goals?

- How prevalent is the grouping of students for grade 8 science across classes and the use of differentiated instruction for different students within classrooms.

What types of assessments are used to assess science?

In contrast with the state standardized assessments in which multiple choice items are used because they are easier to grade, responses of grade 8 teachers of science indicate *that multiple-choice assessments are less common in their classrooms than short answer responses (Exhibit 7-1).* Teachers probably see no advantage in having to develop four answers for each question given that the assessments are hand-graded in any case. On the other hand, long-written responses take the most time to grade and are time consuming in terms of test time, so they remain the least frequently employed assessment by grade 8 science teachers.

Exhibit 7-1

Types of assessments used for grade 8 science, teacher reported, 2011

	Never or hardly ever	Once or twice a month	Once or twice a week	Almost every day
Type of Assessment	Percentage	Percentage	Percentage	Percentage
assess science with multiple-choice tests	7	70	21	2
assess science with short written responses	3	32	40	25
assess science with long written responses	24	53	22	2

NCES, NAEP Data Explorer

- Assessments with short-answer questions were used at least weekly by science teachers of 65 percent of the students.
- Multiple choice and long written responses were used at least weekly by science teachers of only 23 percent and 24 percent of the students. In fact, science teachers of 24 percent of the of students never or hardly ever used long written responses.

How are the uses of assessments tied to educational purpose?

How frequently assessments are used depends upon purpose (Exhibit 7-2)

- The most frequent use of assessments was to guide teachers in adjusting their teaching strategies, as teachers make these adjustments routinely in relation to class performance.

- Virtually all teachers use assessments to discuss current student's performance level at least a few times a year.

- While a substantial majority of teachers use assessments to set goals or assess progress toward goals, close to 20 percent do not use assessments to set student goals and measure progress.

Exhibit 7-2

Frequency of uses of assessments (or other student evaluations) for grade 8 science, teacher reported,					
	Never or hardly ever	A few times a year	Once or twice a month	Once or twice a week	Every day or almost every day
	Percentage	Percentage	Percentage	Percentage	Percentage
adjusting teaching strategies to meet needs	8	24	26	22	20
discussing current performance level	5	30	39	22	4
discussing progress toward goals	18	37	31	12	2
assess science students by setting goals for specific progress	17	40	29	12	3

NCES, NAEP Data Explorer

How prevalent is ability grouping and differentiated instruction in science education?

Ability grouping is the assignment of students to classes based on their perceived ability as indicated by student performance. Differentiated instruction is the adjustment of instruction within classrooms to students with different needs or abilities. The NAEP background variables provide information from school and teacher respondents about how common it is for students to be assigned to science classes by a student's ability and for instruction to be differentiated within science classrooms.

Exhibit 7-3 indicates that 24 percent of the students are in schools in which students are assigned to classrooms based on ability. The NAEP trend data also suggest that this percentage has changed very little since 1996.
The NAEP data (Exhibit 7-4) indicate that it is far more common for teachers to differentiate instruction by student ability or other attributes within science

Exhibit 7-3

Percent of grade 8 students assigned to science class based on ability, 1996–2011	
Year	% Yes
2011	24
2000	26
1996	21

NCES, NAEP Data Explorer

classrooms than to differentiate students by ability across classrooms.

- Differentiating instructional methods and materials when teaching science is used to a moderate or large extent by about 75 percent of the teachers.
- Creating ability groups with classrooms is used by 44 percent of the teachers. This compares with 24 percent of the schools responding that they assign students to classrooms based on ability.
- It is also quite common for teachers to set different standards for some students when teaching (48 percent) and to engage students in different science activities (44 percent).

Exhibit 7-4

Percent of grade 8 students by strategies used within a science classroom to differentiate science instruction for some students, 2011

Type of Strategy	Yes or Moderate/Large Percentage
• create groups within this class for science instruction on the basis of ability (% Yes)	44
• engage some students in different activities when teaching science (% moderate/large extent)	44
• set different standards for some students when teaching science (% moderate/large extent)	48
• use different methods for some students when teaching science (% moderate/large extent)	75
• use other materials for some students when teaching science (% moderate/large extent)	73

NCES, NAEP Data Explorer

8. Improving the NAEP Science Background Questions and Their Use

The current NAEP background questions have provided useful information about a number of aspects of the current status of science education. At the same time, it is helpful to guide development of future NAEP questionnaires to return to the list of expert-identified "hot issues," and the requested indicators from the NRC (2013), as described in the introduction to this report. Exhibit 8-1 shows that while none of the top "hot issues" were fully addressed by the 2011 science questionnaire, six of ten were partially addressed, while four were not explored at all.

Exhibit 8-1. How well NAEP addresses "hot" science issues identified by leading STEM educators			
Expert Identified "hot" topics	Issue Explored	Provides Some information	Issue Not Explored
• Are school systems prepared to respond to reforms underway in science education to focus on big cross-cutting topics and issues in science and teach these with greater depth and understanding?			X
• What factors motivate students to learn science?		X	
• Which topics in STEM are of the greatest interest to students? How does their performance relate to their interests?		X	
• Do out-of-school time activities, such as science clubs and museum visits, impact classroom performance?		X	
• How extensive is participation in "citizen science" projects, such as bird counts and other research by non-specialists, and do they contribute to science learning?			X
• What kinds of teacher professional development are commonly available, such as online, blended, active, or passive, and does the kind or duration chosen correlate with student performance?		X	
• How do teachers deal with student misconceptions and wrong answers about science?			X
• To what extent are student laboratories using virtual science experiments, or data and instruments available online?		X	
• Are school laboratories used for exploring or for confirming?			X
• How much time is spent in teaching science using various strategies such as lecture, laboratory, and discussion?		X	

Exhibit 8-2. How well NAEP addresses indicators requested by the National Research Council's 2013 report (NRC, 2013)			
	Issue Explored	Provides Some information	Issue Not Explored
1. Number of, and enrollment in, different types of STEM schools and programs in each district.		X	
2. **Time allocated to teach science in grades K-5.**		X	
3. Science-related learning opportunities in elementary schools.		X	
4. **Adoption of instructional materials in grades K-12 that embody the *Common Core State Standards for Mathematics* and *A Framework for K-12 Science Education.***			X
5. **Classroom coverage of content and practices in the *Common Core State Standards* and *A Framework for K-12 Science Education.***			X
6. **Teachers' science and mathematics content knowledge for teaching.**		X	
7. Teachers' participation in STEM-specific professional development activities.		X	
8. Instructional leaders' participation in professional development on creating conditions that support STEM learning.		X	
9. **Inclusion of science in federal and state accountability systems.**			X
10. Inclusion of science in major federal K-12 education initiatives.			X
11. State and district staff dedicated to supporting science instruction.			X
12. States' use of assessments that measure the core concepts and practices of science and mathematics disciplines.			X
13. State and federal expenditures dedicated to improving the K-12 STEM teaching workforce.			X
14. **Federal funding for the research identified in *Successful K-12 STEM Education.***			X

The boldface items in Exhibit 8-2 are the NRC's most important indicators selections. Our judgment on the extent to which the NAEP questionnaires currently cover these points includes the following observations:

- Main NAEP has data for 4, 8, and 12th grade, while the NRC calls for more grades, as in indicator 2, which asks for K-5.
- NAEP asks about teacher backgrounds, but doesn't measure teacher knowledge, as in indicator 6.
- NAEP doesn't collect any data funding, as requested for indicator13 and 14.
- Data on state and federal policy and funding requested by the NRC would be much more efficiently collected by separate means from NAEP, which is organized around assessments administered to tens or hundreds of thousands of individual students, teachers, and administrators, but not state or federal officials.

Recognizing the severe limitations of respondent time and the overall structure of NAEP, we propose three additional question areas to strengthen the NAEP questionnaire's ability to monitor key changes underway in science education in several of the areas mentioned above.

Expanding current questionnaire topics:

- Recommendation 1: *NAGB consider adding questions about the amount of time spent learning science and the nature of these activities in out-of-school or after-school settings, and the coordination of these activities with schools.*

  Increasingly, instructional technology is making the learning of science through computers and the Internet feasible in a variety of settings such as after-school programs or in the home. Moreover, science museums are increasingly partnering with schools to extend and enrich school science programs, yet currently NAEP has little information about these activities.

  NAEP background questions could ask students about unique out-of-school and informal science learning activities like building apps, using high-tech toys such as remote controlled airplanes, participating in citizen science projects, taking courses in science museums or nature centers, watching science shows on television or following science expeditions live on the Internet. All these could inform policy makers about new opportunities for synergies between in-school and out-of-school learning.

- *Recommendation 2. NAGB consider expanding background questions about teacher professional development to obtain information on the nature, duration and quality of that professional development.*

  The range of quality and quantity of professional development is huge, and practice is inconsistent from year to year and from topic to topic. How much professional development time do teachers receive and what is the fraction devoted to science? To what extent does the professional development for science involve inquiry or hands-on activity by the teachers? To what extent have teachers changed their science teaching based on professional development? What are areas in which teachers would like to have increased professional development and are there areas where current professional development has not been useful?

Adding a new questionnaire topic:

- *Recommendation 3: NAGB consider adding NAEP background questions to monitor how changes in science standards are affecting instruction, the challenges schools and teachers face in implementing new or changed standards, and whether they are receiving the needed technical assistance and* *professional development to bring about effective implementation of the new standards.*

NAEP teacher surveys can go beyond documenting the formal adopted changes in standards and can ask on a regular basis schools and teachers directly about the how the standards are affecting their instruction and the challenges faced in implementing changes in standards.

Technical background questionnaire issues:

Several technical survey recommendations are also proposed for offsetting the data burden of additional questions and to better understand survey responses.

- *Recommendation 4. NAGB explore offsetting the additional time burden from adding additional science background questions through rotating questions in and out of the science assessments and matrix sampling so that a respondent answers only a sample of the background questions.*

  Holding down background questionnaire time is a NAEP priority especially for the student questionnaire, which is administered to the student along with taking the NAEP science assessment. Rotating items recognizes that for many questions it is sufficient to have broad trend data spaced perhaps every half decade, so that questions can be interlaced among science surveys without adding to overall survey burden. Matrix sampling of background questions would parallel the matrix sampling of science assessment items so that no respondent answers all the background questions. However, statistical analyses should be carried out to assess the impacts of the reduced sample for any single question on the ability to disaggregate findings by student subgroups.

A fifth recommendation to NAGB is that certain science items be designated as priority for NCES to conduct cognitive science labs to clarify and better understand survey responses to background variable questions.

- *Recommendation 5. NAGB should recommend to NCES the use of their cognitive science laboratory to clarify questions and responses in three areas of the science background variables: (1) understanding the schools generally more positive responses than teachers to questions about resource availability; (2) exploring the accuracy of school, teacher or student question responses when responses are qualitative and judgmental, such as “a little” or “a lot;” and (3) taking advantage of future science assessments that will be done on the computer to replace interval responses (e.g. 0-2 hours, 2-5 hours) with continuous sliders enabling respondents to drag an arrow to any point along a continuum.*

Extending the Usefulness of the Findings

The ultimate value of the NAEP science background findings is when they are used to inform decisions, which policymakers, educators and researchers make regularly about science education and how to improve it.

- *Recommendation 6. NAGB should explore ways to support the use of the current findings by policymakers and educators and to stimulate further analyses by other researchers. NAGB should explore with NCES coordinated support for the further use of the NAEP science background variables.*

  NAGB in cooperation with NCES could provide technical online guidance, workshops or financial support to facilitate: (1) **Policymakers** developing current and leading indicators for the state of science education; or tracking and making adjustments when the data shows trends in background variables that they are trying to support (e.g., new standards or new strategies for professional development); 2) **Educators** comparing their own system to national (or state) averages on science education characteristics (e.g., % of science teachers with a major in science); and (3) **Researchers** conducting follow-up research including multivariate analyses based on interesting/provocative/counter-intuitive correlations (e.g., Buckley (2009), cited earlier, employed student response-style adjustments by country on international PISA survey results to find a positive but non-linear attitude-achievement relationship within countries.

Acknowledgements

The authors would like to thank Arthur Eisenkraft, Dennis Schatz, Martin Storksdieck, and Gerald Wheeler, who consented to discuss with us for this article the kinds of issues that science educators engaged currently, and which NAEP background variables might illuminate. We also thank the Board, Executive Director, and senior advisor of the Noyce Foundation, which examined a draft of Exhibit 2-1 and gave us major suggestions for improvements. We appreciate all this generous input, but of course responsibility for any errors and the conclusions made here remains with the authors.

References

Achieve (2013). "*The next generation science standards/executive summary*", p. 6-7. Available April 2013 online: http://www.nextgenscience.org/sites/ngss/files/Final%20Release%20NGSS%20Front%20Matter%20.pdf

Akey, T. (2006). *School context, student attitudes and behavior, and academic achievement: an exploratory analysis.* MDRC. Available online March 2013 at: http://www.mdrc.org/sites/default/files/full_519.pdf.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. Assessment in Education, 5,7–74..

Buckley, J. (2009). *Cross-national response styles in international educational assessments: evidence from PISA 2006. Available May 2013 online: https://edsurveys.rti.org/PISA/documents/Buckley_PISAresponsestyle.pdf.*

Constantine, J., Player D., Silva, T., Hallgren, K., Grider, M., and Deke, J. (2009). An Evaluation of Teachers Trained Through Different Routes to Certification, Final Report (NCEE 2009- 4043). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

Council of Chief State School Officers CCSSO (2012). *Our responsibility, our promise: transforming educator preparation and entry into the profession. Âvailable July 2013 online: http://www.ccsso.org/Documents/2012/Our%20Responsibility%20Our%20Promise_2012.pdf.*

Druva, C.A., and Anderson, R.D. (1983). Science teacher characteristics by teaching behavior and student outcome: A meta-analysis of research. *Journal of Research in Science Teaching, 20*(5), 467-479.

Fowler, R.C.,(2003). "The Massachusetts Signing Bonus Program for New Teachers: A Model of Teacher Preparation Worth Copying?" Education Policy Analysis Archives, 11 (13).

Kirsch, Irwin, John de Jong, Dominique Lafontaine, Joy McQueen, Juliette Mendelovits, and Christian Monseur. 2002. Reading for Change: Performance and Engagement Across Countries, Results from *PISA 2000* . Paris: Organization for Economic Co-operation and Development.

Loveless, Tom (2006). "The happiness factor in education." In *The 2006 brown center report on american education: how well are american students learning?* Brookings Institution. Available online March 2013: http://www.brookings.edu/research/reports/2006/10/education-loveless

McCallie, E., Bell L., Lohwater, L., , Falk, J. H., Lehr, J. L., Lewenstein, B. V., Needham, C., and Wiehe, B. 2009*. Many experts, many audiences: public engagement with science and informal science education*. A CAISE Inquiry Group Report. Washington, D.C.: Center for Advancement of Informal Science Education (CAISE). http://caise.insci.org/uploads/docs/public_engagement_with_science.pdf

Monk, D. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review, 13*(2), 125-142.

Murayama, K., Pekrun, R., Lichtenfeld, S. and Hofe, R (2012). "Predicting long-term growth in students' mathematics achievement: the unique contributions of motivation and cognitive strategies." *Child Development.* Dec. 20.Murayama, et. al., 2012).

National Assessment Governing Board (n.d.). *Science issue paper: Potential Background issues for the NAEP science assessments based on the 2009 science framework*

National Assessment Governing Board (2002). *Background Information Framework for the National Assessment of Educational* Progress. Available May 2013 online: http://www.nagb.org/content/nagb/assets/documents/publications/frameworks/backinfoframenew.pdf

National Assessment Governing Board (2011). *Technology and Engineering Literacy Framework for the 2014 National Assessment of Education Progress,* available April 2013 online: http://www.nagb.org/content/nagb/assets/documents/publications/frameworks/prepub_naep_tel_framework_2014.pdf.

National Research Council (1996). *National science education standards.* National Academy of Sciences. Available April 2013 online: http://books.nap.edu/catalog.php?record_id=4962.

National Research Council (2005). *America's Lab Report: Investigations in High School Science.* Committee on High School Science Laboratories, EDS: Singer, S., Hilton, M. and. Schweingruber, H. Washington, DC: The National Acadamies Press. Available March 2013 online: http://www.nap.edu/openbook.php?isbn=0309096715.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Committee on Science Learning, Kindergarten Through Eighth Grade. R.A. Duschl, H.A. Schweingruber, and A.W. Shouse (Eds.). Washington, DC: The National Academies Press.

National Research Council (2009). *Learning science in informal environments : people, places, and pursuits* / Philip Bell … [et al.], editors ; Committee on Learning Science in Informal Environments, Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Available April 2013 online: http://www.nap.edu/catalog.php?record_id=12190#toc.

National Research Council (2010). *Preparing teachers: building evidence for sound policy*. "Committee on the Study of Teacher Preparation Programs in the United States, Center for Education Division of Behavioral and Social Sciences and Education." Available March 2013 online: http://www.nap.edu/catalog.php?record_id=12882.

National Research Council (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. Washington, DC: The National Academies Press, 2011. Available July 2013 online:* http://www.nap.edu/catalog.php?record_id=13158 .

National Research Council (2012). *A framework for k-12 science education: Practices, cross-sutting concepts, and core ideas.* Available April, 2013 online: http://www.nap.edu/catalog.php?record_id=13165.

National Research Council. (2013). Monitoring progress toward successful K-12 STEM education: A nation advancing?. Available June 2013 at http://www.nap.edu/catalog.php?record_id=13509.

National Science Tachers Association (2002). *NSTA position statement: Learning conditions for high school science.* Available July 2013 online:

National Science Teachers Association (2012). *NSTA Standards for Science Teacher Preparation.* Available April 2013 online: http://www.nsta.org/about/positions/highschool.aspxhttp://www.nsta.org/pd/ncate/docs/2012NSTAPreserviceScienceStandards.pdf.

Policy and Program Studies Service (2009). *State and local implementation of the no child left behind act volume VIII—teacher quality under NCLB: final report.* U.S. Department of Education. Available July 2013 online: http://www2.ed.gov/rschstat/eval/teaching/nclb-final/highlights.pdf

Ruiz-Primo, M. & Furtak, E. (2006). Informal formative assessment and scientific inquiry: Exploring teachers' practices and student learning in *Educational Assessment (3&44), 205-235.* Available April 2013 online: http://www.stanford.edu/dept/SUSE/SEAL/Reports_Papers/k12_papers/R-P%20%26%20Furtak%20Informal%20Formative%20Assessment%20and%20Scientific%20Inquiry%20Exploring%20Teachers%20Practices%20and%20Student%20Learning.pdf.

Sawchuck, S. (2010). "Professional development for teachers at crossroads" in *Education Week. November 10.* Available July 2013 online: http://www.edweek.org/ew/articles/2010/11/10/11pd_overview.h30.html

Schmidt, W., Tatto, M., Bankov, K., Biomeke, S., Cedillo, T., Cogan, L., Han, S., Houang, R., Hsieh, F., Paine, L., Santillan, M., and Schwille, J. (2007). *The preparation gap: teacher education for middle school mathematics in six countries.*MSU Center for Reserch in Mathematics and Science Education. Available March 2013 online: http://usteds.msu.edu/MT21Report.pdf.

TIMSS (2012). Martin, M., Mullis, I., Foy, P., & Stanco, G., *TIMSS 2011 international results in science.*International Education Association. Available April 2013 online: http://timss.bc.edu/timss2011/downloads/T11_IR_Science_FullBook.pdf.

WestEd & the Council of Chief State School Officers (2006). *Suggested background variables to accompany the 2009 NAEP science assessment.* Paper prepared for NAGB

Wellcome Trust (2012). This publication is comprised of three inter-related essays Lloyd, R., Neilson, R., King, S., and Dyball, M., *Review of Informal Science Learning;* Falk, J., Osborne, J., Dierking, L., Dawson, E., and Wenger, M., and Wong, B., *Analyzing the UK Science Education Community: The contribution of informal providers*; and Matterson, M. and Holman, J., *Informal Science Learning Review: Reflections from the Wellcome Trust*. All published online and available in April 2013 at http://www.wellcome.ac.uk/About-us/Publications/Reports/Education/WTP040865.htm. The quotation cited is from Matterson and Holman, p. 2.