

Report on the Status of K-5 Geosciences Education in the United States

A 50-State Analysis of K–5 Geosciences Education,
Number 2.1, March 2018



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isbn-13: 978-0-913312-87-2
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The research for this report is done through the generous contribution of the Society of Exploration Geophysicists (SEG).

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Suggested Citation:

Center for Geoscience and Society. (2018, March). *Report on the Status of K–5 Geosciences Education in the United States: A 50-State Analysis of K–5 Geosciences Education*, (Number 2.1). Alexandria, VA: American Geosciences Institute.



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Report on the Status of K–5 Geosciences Education in the United States

This "Report on the Status of K–5 Geosciences Education in the United States" presents a snapshot of geosciences education in the nation's elementary schools by highlighting K–5 geosciences education indicators pertaining to teacher preparation, curriculum, instruction, learning contexts, extra-curricular programs, monitoring systems, and accountability. This report is an update of the 2015 "Report on the Status of Geosciences Education in the United States," based on data collected by the American Geosciences Institute from State Education Agency (SEA) websites and from interviews with SEA officials for all 50 states and the District of Columbia between June 2017 and December 2017. Members of the Council of State Science Supervisors (CSSS) for each state were also asked to provide information on their state's education system. SEA officials and CSSS members are encouraged to provide any other information not listed, or information that has since changed, in this report. This report is available for download from AGI's website: www.americangeosciences.org.

Acknowledgements

The Center for Geoscience and Society would like to gratefully acknowledge the assistance and support of those scientists and educators who contributed to, reviewed this report, and provided invaluable comments and suggestions.

Cover photo: Students at a Virginia elementary school enjoy a geoscientist-led activity about sunlight.
Image credit Celia Thomas.

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Introduction

The intent of this report is to inform discussion and encourage action that enhances opportunities for children’s learning about the geosciences. The geosciences have an increasingly prominent role in social life. Daily news stories about energy resources, environmental change, hazardous events, and many other topics remind us of the importance of understanding the dynamic Earth systems on which we depend. Knowledge from diverse fields such as geology, oceanography, climatology, astronomy, and many others provide the information and conceptual models that guide decision-making at personal and societal levels. Individuals who are informed about the geosciences are able to take part in public discourse about current issues and have more informed personal decisions. Developing geosciences knowledge early in life provides a foundation for informed and thoughtful personal choices and civic engagement. As well, since experiences influence interests that develop later in life, early development of geosciences knowledge opens avenues for both personal and professional opportunities.

This report focuses on the development of geosciences knowledge in formal settings during childhood — that is, in Kindergarten through Grade 5 (K–5) classrooms. These settings provide important geosciences learning experiences. Yet, geosciences knowledge can also be gained through informal learning opportunities, such as museums and nature centers, and through personal interests and hobbies such as camping, star gazing, and others. Sometimes formal and informal opportunities overlap, as well (e.g., a school field trip to a museum could be seen as a combination of formal and informal learning). Therefore, the report at times uses data about informal, extra-curricular, and co-curricular opportunities for geosciences learning to contextualize data about K–5 classroom learning.

The report’s focus on K–5 classroom learning is also strategic. Informal learning opportunities are often related to discrete family and community factors that cannot be characterized well in the general terms required in a report such as this. As well, in that the intent of the report is to encourage action, having a focus for that action allows for greater clarity regarding what data are relevant. In this case, that focus is formal teaching of geosciences concepts, methods of inquiry, and even career awareness.

What occurs in K–5 classrooms is, of course, affected by many factors, which led to the collection of data at many levels for this report. The lessons teachers use to engage students are affected by standards, accountability measures, material support, scheduling, and many other elements. This report provides information regarding a large set of those factors.

That K–5 instruction is affected by many factors also demonstrates that a report such as this has many audiences. Teachers, school administrators, parents, politicians, and others all have a stake in the quality of geosciences instruction, and all have a role to play in enhancing that instruction. Therefore, the report has been developed to include information that is important to varied stakeholders. Ultimately, the intent is for this report to be a starting place for the important discussions that need to take place to bring about coherent and positive change in geosciences education, and ultimately in society’s responses to some of the most pressing issues of our time.

Report Structure

Geosciences education can be characterized by a host of indicators, including state policies, district structures, school supports, community involvement, parent expectations, and the availability of instructional resources, among others. The indicators presented in this report were selected and designed to provide a valid, state-by-state and national description on the condition of geosciences education in elementary schools. The key indicators are organized into seven major topical areas:

- Teacher preparation
- Curriculum
- Instruction
- Learning contexts
- Extra-curricular programs
- Monitoring systems
- Accountability

This study is designed to answer seven central questions for each state. Each of those questions is related to a major topical area:

1. What evidence can be provided that the state's teachers are prepared and supported with respect to teaching geosciences topics?
2. What evidence is there that there has been conscientious thought given to what is being taught to students with respect to the geosciences?
3. What evidence is there that the approaches to instruction that are promoted for use with respect to geosciences topics are given conscientious consideration?
4. What evidence is there that the contexts in which children learn geosciences topics are well suited to help students learn geosciences topics?

5. To what extent do children have access to extra-curricular and co-curricular opportunities to learn geosciences?
6. To what extent is student learning in the geosciences monitored?
7. In what specific ways do student outcomes related to geosciences education matter?

Each of the seven central questions is answered according to several narrower sub-questions. The findings are reported for each sub-question. The findings are descriptive and meant to present an overview of particular conditions related to geosciences education indicators at the elementary level. The findings do not infer a cause for reported trends or measure the effectiveness of educational approaches or policies.

Findings: Teacher Preparation

1. What evidence can be provided that the state's teachers are prepared and supported with respect to teaching geosciences topics?

a. Does state licensure require courses in geosciences areas?

States have varying licensing requirements, though there are some similar requirements across states. All states and the District of Columbia require a minimum of a bachelor's degree from an accredited college/university and completion of a state-approved teacher preparation program (or alternative certification program). Most states indicate required aspects of teacher preparation programs, which involve both coursework (e.g., curriculum content at their specified grade level and methodology courses) and practica (e.g., class trips, internships, and professional development experiences). The coursework portion is intended to prepare the teacher candidates with the knowledge base needed to instruct a class. The practicum (made of largely of time in schools) allows the candidates to use that knowledge in real-world environments, such as performing research at a geological site or observing and helping a professional in their classroom.

Teachers can be endorsed in two areas depending on the state. An Elementary Education license typically includes grades 1-5, but sometimes adds Kindergarten and/or Grade 6. Early Childhood Education licenses span from birth or preschool to grade 3. Forty-nine states and the District offer endorsement credentials in Elementary Education, and all elementary teachers are required to have them. Forty-five states offer credentials in Early Childhood Education.

All states require teaching candidates to pass either state-specific tests and/or commercial exams, such as the Praxis series. Assessments must be completed in the candidate's chosen endorsement area (Elementary Education or Early Childhood Education).

24 states require passing a separate educational practice exam for Elementary Education credentials. In this exam, topics such as human development, content pedagogy, instructional processes, and educational psychology may be covered. Content tests covering topics like reading

and writing or language arts (47 states) and mathematics (47 states) may also be required. An additional Elementary Education science test is also required for licensure in 42 states¹, measuring content knowledge in earth, life, and physical sciences. The remaining 9 states do not require the science portion.

For Early Childhood Education credentials, 31 of the 45 states require candidates to pass a separate educational practice assessment. 30 states are tested in reading and writing or language arts and math (31 and 41, respectively), and 26 states are required to take a science test.

For 43 states, a teaching license (professional and standard certificates) is valid for 5 years. Six states issue licenses that are renewable in less than 5 years (Delaware, Mississippi, New Hampshire, New Mexico, Vermont, DC), and two states (Arizona and New Jersey) allow renewing a license after more than five years. Note that some states, like New Jersey, have permanent certifications (unless revoked by the state) that do not need to be renewed as long as all requirements are met (e.g., maintaining professional development credits). Some states also have levels to teaching certifications. For example, Alaska teachers may have Initial, Professional, or Master teacher certifications. Certification levels such as these depend on factors such as number of years teaching, professional development hours, or National Board certification.

All states require that teachers renew their licenses by completing a certain number of professional growth activities. These activities may include university courses, workshops, and professional development opportunities, which are often approved by the teacher's school system using criteria that vary widely from school system to school system. The description of professional growth activities is often available at the local level. 39 states indicated that elementary teachers could receive certification renewal credit for experiences related to Earth and Space Sciences as long as the teacher's assignment includes those subjects. Most survey respondents refer to courses as eligible to count towards renewal credit if it was relevant to their academic subject areas. Six states report local agencies as responsible for certification renewal. Two states' information could not be gathered.

New Mexico's renewal process is unlike the other states' in that instead of completing a number of professional

¹ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

growth credits or clock hours, teachers are required to submit a portfolio of their work (lesson plans, projects, video or photos, etc.), which is reviewed by fellow educators.

b. Does the State Education Agency (SEA) provide support such as lesson plans and other resources?

In the United States, public education is a function that is the responsibility of each state or territory, so there is no mandated national science curriculum adopted by all 50 states and the District of Columbia. However, teachers must adhere to standards that are either issued at the state level or at a local level. All schools use their state's or community's elementary² science standards in curriculum planning and development.

Over half of the states (29) provide additional elementary curriculum development guidelines beyond the state's science standards. These resources outline guidelines for science frameworks, benchmark maps, curriculum unit and individual lesson templates, assessment guides, and other rubrics to be used by teachers. These resources are made accessible to teachers on the SEA websites.

Table 1: **Guidelines for Elementary Science Curriculum Development and Number of States**³

Resource	Description	# States
Science Frameworks	Identify the key scientific ideas and practices all students should learn.	9
Curriculum maps	Outline the content, skill, assessments, and activities to be administered by teachers.	7
Learning progressions	Provide pathways that students travel as they progress toward mastery of foundational science content and skills.	9
Benchmark maps	Present standards designed to assess student mastery as a result of instruction and to serve as indicators for student success.	5

² US Department of Education. (2017). "It is States and communities, as well as public and private organizations of all kinds, that establish schools and colleges, develop curricula, and determine requirements for enrollment and graduation." <https://www2.ed.gov/about/overview/fed/role.html>.

³ Note: Definitions of these resources vary somewhat from state to state.

Resource	Description	# States
Templates for unit design	Delineate the key components of a science curriculum unit.	4
Curriculum development guides	Provide a series of steps to follow in creating a curriculum document.	8
Model units	Serve as exemplar curriculum units that teachers can use as models for developing their own curriculum units.	6
Lesson plan templates/ guides	Delineate the key components of a science lesson plan.	3
Web-based lesson plan portals	Allow teachers to access science lesson plans that have been developed by educators from the state.	7
Model lesson plans	Serve as exemplar lesson plans that teachers can use as models in the development of their own lesson plans.	5
Assessment guidelines	Provide suggestions for selecting assessment types, examples of assessments, rubrics, and recommendations for implementation.	10

c. Are there instructional programs adopted that address geoscience instruction?

This question focuses on the adoption of formal programs of curriculum materials (e.g., textbooks, online resources). The level at which these materials are adopted varies from state to state. In fifteen states educational materials (e.g., textbook programs) are chosen at the state level. All others are chosen by local systems. Arkansas allows local districts to make their own decisions about how to spend their funding for instructional materials; they have the ability to adopt state-approved materials or choose locally. Hawaii is also an exception, where the entire state is comprised of one local district.

In locations that use a state-wide adoption model, information like title and publisher are made available to the public. For this report, titles were reviewed to determine the degree to which geoscience content is made available. Seventeen states adopted textbooks with titles referring directly to a geoscience (e.g., weather and seasons, natural resources, fossils, rocks and minerals). Information could not be collected from the remaining

states.⁴ All state standards contain geoscience-related concepts at the elementary level, which would imply that state's textbook edition contain geosciences content.

d. Are school systems provided with financial resources to develop their own geosciences material and/or acquire supplies for instruction?

As stated, instructional materials go through a vetting process at either the state or local level (29% and 71%, respectively). Teachers use those basal resources, and often supplement them in other ways. Teachers are required to at least align their teaching to the standards, which is often through the use of a textbook or other adopted program. That said, there is great variation in materials used; some educators use only the materials provided to them by the state or school system, while others are more flexible about locating their own resources to use.

Although ultimately education standards are the state's responsibility, local entities (districts, schools, and teachers) are tasked with adhering to those standards in their teaching. In the event that standards are changed or revised, there are multiple options for support in realigning content to new standards, including workshops and other teacher professional development opportunities, curriculum guidance, and other guidance (e.g., what may be called "crosswalk maps") aligning the old standards to new ones. 32 SEAs report supplying those types of support at the state level. 8 SEAs report that support is handled at the local level. 3 SEAs gave no such support, and the remaining 8 SEAs support information could not be collected.

e. Does the SEA provide professional development, that is, at least in part, specific to the geosciences (e.g., GLOBE Program⁵, Project WET⁶, Project WILD⁷)?

Professional development (PD) can come in many forms throughout a teacher's career. Depending on the state,

PD policies are determined: (1) at the state level where the state is the head PD information center; (2) at the state level but with districts choosing specific strategies; or (3) at the local/district level.

Some states offer PD that is related to, at least in part, geosciences. The Project WILD website lists coordinator contacts for all states, occurring independently of SEAs (e.g., through Departments of Natural Resources, Departments of Fish & Game, parks, or informal science centers). This suggests that regardless of SEA and LEA policy, all educators have access to this type of PD, though in some cases it may be that the teacher must pay for it themselves and/or take part in it during personal time (e.g., summer break).

12 states rely on their SEAs for geosciences PD. 14 are determined at the local/district levels (LEAs) and an additional eleven have access independent from their SEA. 3 states report that PD related specifically to geoscience is not currently offered. The remaining 11 states' information could not be collected. While it was difficult to collect data on what was included in geoscience-related PD, it became clear that both the quality and range of content of these experiences is likely to vary. For example, Alabama's Alabama Math, Science, and Technology Initiative (AMSTI) aims to improve math and science teaching statewide, providing geosciences materials and professional development targeted for grades in which the subject is taught. Washington has a similar program with the Washington State Leadership and Assistance for Science Education Reform (LASER). Vermont teachers participate in the GLOBE Program as well as Project WET and Project WILD, although participation records are not kept so the coverage of attendance could not be determined. Though there are no established state programs that provide PD in geosciences in Georgia and Wisconsin, an SEA consultant or university may provide that PD if a need is seen or if it is requested by a local agency. School systems often partner with colleges and universities to provide geosciences PD, as seen in Indiana, Iowa, and Oklahoma.

⁴ Besides physical textbooks, 8 states partnered with a non-profit foundation (CK-12 foundation, <https://www.ck12.org/>) to provide online (geoscience) educational resources aligned to each state's standards, though this is not a requirement. These states provided geoscience-specific titles, with one of those states having state-specific resources.

⁵ Global Learning and Observation to Benefit the Environment (GLOBE) Program. <https://www.globe.gov/>.

⁶ Water Education for Teachers (Project WET). <https://www.projectwet.org/>.

⁷ Project WILD. <http://www.projectwild.org/>.

Findings: Curriculum

2. What evidence is there that there has been conscientious thought given to what is to be taught to students with respect to the geosciences?

a. What is the organization of the standards? To what extent do standards have geosciences separate from other sciences, or are they combined?

In 2015, the Every Student Succeeds Act (ESSA) replaced the No Child Left Behind Act (NCLB). Each state⁸ is required to submit a consolidated state plan outlining long-term goals in preparing students for higher education. The ESSA requires states to implement assessments in all subjects, including science, that are aligned to the state’s standards.

For this report, standards were analyzed along several dimensions. First, the grade-level standard arrangements were examined, with 47 states having grade-specific standards (i.e. separate standards for each grade). 3 states have standards arranged in grade-level bands (i.e. K-2 and 3-5). Benchmark grade levels (e.g., grades 4, 8, and 11) are used in the remaining state.

Next, groupings of science disciplines are examined. All states and the District of Columbia have standards divided into three major science disciplines (i.e. Physical Science, Life Science, and Earth and Space Sciences) at each grade level, grade-level band, or benchmark grade level. Earth and Space Science standards are further examined to see the level at which subdisciplines are addressed specifically (e.g., meteorology, astronomy, oceanography) or more generally. 45 states have Earth and Space Science standards identified by core ideas in geosciences (e.g., structure of the Earth, Earth history, Earth’s systems, Earth in the solar system, weather, natural resources, and Earth materials.)

b. How are the ideas to be taught outlined (e.g., objectives, outcomes, performance indicators)?

All states and DC provide statements about what students are expected to learn and/or be able to do at various points within elementary science instruction. The level of detail of those statements varies from state to state.

Standards can be presented on two levels, the first being overarching standard statements that apply to either multiple grade levels or to a single grade, and the second being more specific statements that provide details about the overarching standards. The more specific level is dedicated to explaining what students should know and/or be able to do at that level, demonstrating an understanding of the overarching statements. 29 states have standards in which learning outcomes are presented on both of these levels, with statements like “Content Standards,” “Standards,” or “Content Statements.” 21 states are presented by a single level of overarching statements. Hawaii is the only state that expresses standards solely on the more detailed level.

Table 2: Nomenclature States

Nomenclature States	
Benchmarks	Florida, Minnesota, Montana, Utah, Wyoming
Benchmark Expectations	North Dakota
Clarifying Objectives	North Carolina
Content Elaboration	Ohio
Evidence Outcomes	Colorado
Grade-Level Expectations	Tennessee
Grade Band Standards	Nebraska
Indicators	Indiana
Objectives	Idaho
Performance Indicators	New York, South Carolina
Performance Indicators and Descriptors	Maine
Performance objectives	Arizona, Mississippi
Performance Standards	Alaska, Georgia, New Mexico

10 states have no overarching standard statements, instead referring to them using terms such as Content Standards (Alabama), Learning Standards

⁸ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

(Massachusetts), Performance Standards (Wisconsin), Performance Descriptors (West Virginia), Standard Statements (Pennsylvania), Anchor Standards (South Dakota), Essential Knowledge and Skills (Texas), or just Standards (Louisiana and Virginia).

There are also states that follow or are based on the Next Generation Science Standards (NGSS), describing their standard statements as Performance Expectations: Arkansas, California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Missouri, Michigan, Nevada, New Hampshire, New Jersey, Oregon, Rhode Island, Vermont, Washington, and the District of Columbia. Oklahoma standards are similar to the NGSS, and use Performance Expectations as a measure of what students should know and be able to do.

c. To what extent are students encouraged/guided to investigate current issues in the geosciences?

The elementary standards for all states are examined to find the extent to which state standards demonstrated attention to current issues in geosciences (e.g., Earth science processes altered by human activities, or Earth science processes that affect human well-being). Topics might include energy resources, climate modification, waste disposal, mining resources, and natural hazards. 45 states include such issues in geosciences in their curriculum.

d. To what extent is information about geosciences-related careers intentionally included in instruction?

15 states include content related to careers in geosciences: Arizona, Arkansas, California, Georgia, Hawaii, Maine, Minnesota, New Mexico, North Dakota, Ohio, Oklahoma, Texas, Virginia, West Virginia, and Wisconsin. The remaining 35 states did not include career information, and data could not be collected for one state.

e. When were the standards last reviewed/revised?

States routinely go through a review process every few years to update their standards. This is typically carried out by school staff, including educators, administration, education officials, and/or other education staff or community partners. The public is also sometimes asked to review standards. That said, standard review timelines for each state vary.

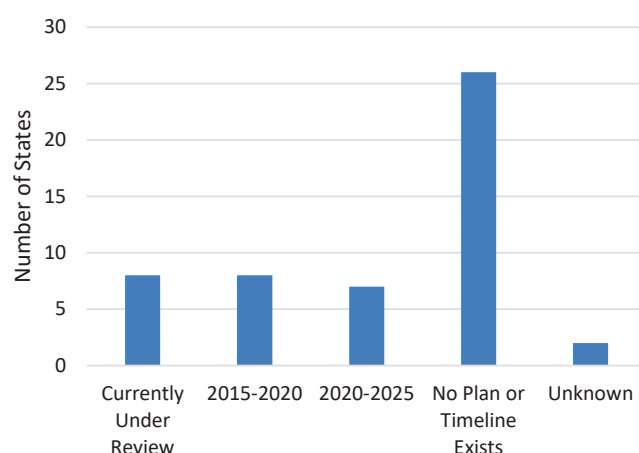
This report examines the timelines for these reviews for each state's elementary science standards. The dates are an indicator for when the states last reviewed or revised their science standards. As of writing, 20 states reviewed or revised their science standards within the last two years. Another 15 states reviewed their standards between 3 and 6 years ago (2011-2014). 11 states reviewed their standards between 7 and 10 years ago (2007-2010). The remaining 5 states have not reviewed or revised their elementary science standards in the last 10 years.

f. How often are the standards reviewed?

As indicated, states are required to review their standards periodically for accuracy and adherence to current research and academic advances. It is intended that these review processes identify and correct inaccuracies and/or updates, which can lead to the adoption of new standards, revisions of current standards, or development new ones. This process can be costly for the state, and some opt to wait until funds are available.

This report examines the most recent review process that each state's elementary science standards went through. It should be noted that some states have recently completed a review process. 8 states are currently reviewing their standards. Another 8 states reviewed their standards within the last 5 years. 7 states have completed a review between 5 and 10 years ago. No plan exists for 26 states, and information for the remaining 2 states could not be collected.

Figure 1: **Timeframes for Revising State Science Standards**



Findings: Instruction

3. What evidence is there that the approaches to instruction that are promoted for use with respect to geosciences topics are given conscientious consideration?
- a. What specific instructional approaches are promoted to teachers in a coherent manner? (e.g., 5E learning cycle, use of kits that include inquiry activities, problem-based learning)

As discussed in the Teacher preparation section, all states⁹ have some manner of curriculum standards for elementary science on which educators base their planning and development of science curricula. However, 29 states have extra guidelines for curriculum development, including geosciences content.

The standards and additional guidelines were examined to determine to what extent teachers were being encouraged to use specific approaches in science instruction at the elementary level. Instructional approaches in this context are described as methods or strategies teachers use to engage their students in learning science content. Teachers working toward meeting specific learning objectives use these strategies to guide their instruction.

49 states provide guidelines to approaches in science instruction, with 2 states either giving no guidelines or not being able to collect the information. An inquiry-based approach (e.g., inquiry-based learning, science as inquiry and process, scientific inquiry) is used in some form in 22 states. 23 states call for instruction that includes the NGSS Science and Engineering Practices. The remaining 2 states use approaches like Phenomena focused instruction and Characteristics and Processes of Science. Therefore, most states use a form of active investigation in K–5 science instruction. Information could not be collected for 4 states.

Table 3: Approaches to Learning Science Promoted in State Elementary Science Standards

Name of Approach	State
Characteristics and Processes of Science	AR
Inquiry	FL, NE, NM
Inquiry-Based Learning	AL, GA, IN
Inquiry Process	AZ
Phenomena Focused Instruction	NJ
Science and Engineering Practices	CA, CT, DE, HI, ID, IL, KS, KY, LA, MD, MA, MI, MS, NV, NH, NY, OK, OR, RI, SC, VT, WA, DC
Science as Inquiry	ND, PA, TX
Science as Inquiry and Process	AK, NC
Science Inquiry	WI
Scientific Inquiry	ME, MO, OH, SD, TN, VA
Scientific Inquiry and Investigation	MN
Scientific Inquiry and Process Skills	CO
Student Inquiry	UT
Unknown	IO, MT, WV, WY

In addition to general guidance with inquiry-based approaches, 7 states offer more specific guidance for science instruction that facilitate active science investigation by students. Seven states (Alabama, Alaska, Arizona, Maryland, New Jersey, Ohio, and Oregon) advocate for more specific guidance, such as the 5E learning cycle,¹⁰ K-W-L model,¹¹ and/or student sense making.

⁹ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

¹⁰ 5E Learning Cycle https://sites.nationalacademies.org/cs/groups/dbassite/documents/webpage/dbasse_073327.pdf
¹¹ Know, Want to Know, Learned (K-W-L) model. <http://www.nea.org/tools/k-w-l-know-want-to-know-learned.html>

b. What is the relationship between instructional approaches that are promoted for use with respect to the geosciences and the standards?

As stated in the previous sub-question (sub-question 3a), all state elementary standards suggest an active investigation-based approach to the learning of science concepts, which include the geosciences.

c. What justification is given for why these approaches are promoted? To what extent is the rationale specific to the nature of the geosciences?

An examination of the extent to which states provided a rationale for using particular approaches in elementary science instruction found that 36 states have a rationale, while 13 do not. This information could not be collected for the remaining 2 states. States with no rationale use standards and guidelines to describe the skills students should apply in the classroom, but with no justification as to why students should use them to demonstrate an understanding of science concepts. States adopting or basing their standards off of the Next Generation Science Standards (NGSS) use this approach:

“Engaging in the practices of science helps with students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the world of engineers, as well as the links between engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students’ knowledge more meaningful and embeds it more deeply into their worldview.”¹²

The rationales used by non-NGSS states tend to be similar. Generally, they suggest that students learn best when they can build an understanding of science concepts using methods and thinking processes not unlike the work and construction of knowledge by practicing scientists. Simply put, students learn best when they mirror professional scientists’ work and research.

¹² Next Generation Science Standards: For States, By States (Appendix F – Science and Engineering Practices in the Next Generation Science Standards). 2013. Retrieved February 1, 2018 from <https://www.nap.edu/read/18290/chapter/12>.

Table 4: Example Rationales for Inquiry-Based Approaches to Teaching Science

State	Rationale
Alabama	Effective science instruction emphasizes critical thinking and investigative processes that reveal consistencies, relationships, and patterns. The science laboratory, therefore, should be thought of as any place where scientific inquiry occurs, whether it be the traditional laboratory, classroom, playground, science museum, amusement park, or beach. ¹³
Arizona	"Science as inquiry is basic to science education and a controlling principle in the continuing organization and selection of students’ activities. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry..." (NSES 1995). Inquiry Process establishes the basis for students’ learning in science. Students use scientific processes: questioning, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, and communicating results. ¹⁴
Massachusetts	Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students’ knowledge more meaningful and embeds it more deeply into their worldview. ¹⁵

Table continued on next page

¹³ 2015 Alabama Course of Study — Science <https://www.alsde.edu/sec/sct/COS/2015%20FINAL%20Science%20COS%2010-1-15.pdf>
¹⁴ Arizona Academic Content Standards — Science <https://cms.azed.gov/home/GetDocumentFile?id=550c5129aadebe15d072a8d1>
¹⁵ 2016 Massachusetts Science and Technology/Engineering Curriculum Framework <http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf>

Table continued from previous page

State	Rationale
Pennsylvania	Understanding of science content is enhanced when concepts are grounded in inquiry experiences. The use of scientific inquiry will help ensure that students develop a deep understanding of science content, processes, knowledge and understanding of scientific ideas, and the work of scientists; therefore, inquiry is embedded as a strand throughout all content areas. Teaching science as inquiry provides teachers with the opportunity to help all students in grades K-12 develop abilities necessary to understand and do scientific inquiry. These are very similar across grade bands and evolve in complexity as the grade level increases. ¹⁶
Wisconsin	Students should experience science in a form that engages them in actively constructing ideas and explanations and enhances their opportunities to develop the skills of doing science. Such inquiry (problem solving) should include questioning, forming hypotheses, collecting and analyzing data, reaching conclusions and evaluating results, and communicating procedures and findings to others. ¹⁷
Wyoming	Today, quality science education enables students to learn science by being actively involved with scientific and engineering practices as they progress from kindergarten through 12th grade. They are encouraged to be inquisitive, to actively explore their environment, and become productive, scientifically literate citizens. The standards we present here provide the necessary foundation for local school district decisions about curriculum, assessments, and instruction. Implementation of the new standards will better prepare Wyoming high school graduates for the rigors of college and/or careers. In turn, Wyoming employers will be able to hire workers with a strong science and engineering base — both in specific content areas and in critical thinking and inquiry-based problem solving. ¹⁸

¹⁶ Academic Standards for Science and Technology and Engineering Education [http://static.pdesas.org/content/documents/Academic_Standards_for_Science_and_Technology_and_Engineering_Education_\(Secondary\).pdf](http://static.pdesas.org/content/documents/Academic_Standards_for_Science_and_Technology_and_Engineering_Education_(Secondary).pdf)

¹⁷ Wisconsin Standards for Science <https://dpi.wi.gov/sites/default/files/imce/science/WI-Standards-for-Science-2017.pdf>

¹⁸ 2016 Wyoming Science Content and performance Standards <https://edu.wyoming.gov/downloads/standards/2016/2016WYScienceCPS.pdf>

d. What kinds of technology are used to present content?

Advances in computer technology and use of education-based software reform use of technology in classrooms. For this report, SEA officials were asked what kinds of technology, if any, were available for use in classrooms at the elementary level. In 43 states the uses of technology are decided at the local level, with 19 respondents stating that those uses varied from school system to school system. Data could not be collected for 3 states. Officials describing varied uses of technology across the state listing funding, availability of broadband networks, and WiFi availability as reasons for the differences.

Types of technology one might find in an elementary classroom include: desktop computers or personal laptops (e.g., Chromebooks), personal or class iPads or other tablet-style devices, mobile labs, interactive white boards, and virtual labs.

Findings: Learning Contexts

4. What evidence is there that the context in which children learn geosciences topics are well suited to help students learn geosciences topics?

a. What are the typical class sizes? What is the range in class sizes?

The number of students in a classroom is widely considered to have an impact on classroom instruction and student learning. While some researchers have not found a strong correlation between smaller classes and higher student achievement, it is generally thought there is a relationship between student achievement and class size drops, up to a point.

SEA officials were interviewed and/or SEAs were reviewed to research the average and maximum sizes of classrooms in each state¹⁹. Data availability is varied, as some states only report class sizes at the local/district level, class sizes vary per school, or the information is unavailable. For average class sizes, ranges are found in 18 states. 2 states have varying numbers that do not allow an average to be identified or calculated, and the remaining 31 states' data could not be collected. The maximum class size information was also collected, with 16 states giving a maximum number of students and 32 states reporting an unknown or "not available" amount. Only Georgia, North Dakota, Vermont, and Wyoming were able to give information for both average and maximum class sizes.

Table 5: Reported Number of Students in Elementary School Classrooms

State	Average	State	Maximum
Connecticut	18-21	Alabama	24
Florida	15-17	Alaska	30
Georgia	23	Arizona	25
Indiana	20-30	Arkansas	25
Minnesota	24	Delaware	20
Missouri	22	Georgia	33
New Hampshire	18	Louisiana	33
North Carolina	22	Mississippi	27
North Dakota	20	Montana	28
Ohio	25	New Jersey	25
Oregon	25	New Mexico	24
Rhode Island	20	North Dakota	30
South Carolina	16	Vermont	25
Utah	25	Virginia	30
Vermont	22	West Virginia	20
Wisconsin	20	Wyoming	20
Wyoming	17-20		
DC	20-25		

b. What is the general expectation as to the time that will be devoted to geosciences instruction? At what level is this defined (SEA, state, system, teacher)?

All states are mandated to have teaching standards for science at the elementary level, as per the Curriculum Finding section in this report. All states are mandated to teach three disciplines of science, including Physical Sciences, Life Sciences, and Earth and Space Sciences at the elementary level.

Beyond those parameters, an additional question emerges regarding the amount of time teachers must spend on science instruction. Most (23) states give local systems the authority to determine time requirements. Another 20 states do not have any science teaching time requirements. Data could not be collected for 3 states. The remaining 5 states (Arizona, Connecticut, Missouri, Nebraska, DC) did have time requirements that teachers must follow.

¹⁹ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

Table 6: States with Time Requirements for Science Instruction at the Elementary Level

State	Requirement
Arizona	Recommended minutes of science instruction for elementary schools: Primary Grades (1-3): 30 min daily, 150 min weekly (this is half of recommended minutes for math and language arts); Upper Elementary (4-6): 40 min daily, 200 min weekly (this is 2/3 of recommended minutes for math and language arts) ²⁰
Connecticut	The Position Statement states that equity must be provided for reading, math and science. ²¹
Missouri	The state recommends 30 minutes for grades 1-3 and 40 minutes for grades 4-6. ²²
Nebraska	Rule 10 and Rule 14 require that each elementary school have on file a representative weekly schedule for each classroom teacher encompassing experiences in reading and language arts, mathematics, social studies, science, health, physical education, art, and music. These requirements are intended to assure that all children experience a well-rounded curriculum on a weekly basis, while giving the school flexibility in organizing the elementary program. ²³
DC	45 minutes per day for one semester. ²⁴

- c. If a child has an IEP (Individualized Education Plan), ILP (Individualized Learning Plan), or other personalized instructional plan, how might that affect the learning of geosciences? (e.g., Are ESL or ILP pulled out of science class on a repeated basis?)

Students who do not achieve expected competencies in certain academic areas may receive instructional assistance. Depending on the issues affecting the student's learning, such as English as a Second Language (ESL) and some learning or cognitive disabilities, students

²⁰ Sample Recommended Instructional Time, Standards-Based Teaching and Learning <https://cms.azed.gov/home/GetDocumentFile?id=56cb92ebaadebe16d8c83df3>

²¹ Connecticut State Board of Education, Position Statement on Science Education http://www.sde.ct.gov/sde/LIB/sde/pdf/board/Position_Statement_Science_Ed.pdf

²² Missouri Department of Elementary & Secondary Education — Minutes of Instruction <https://dese.mo.gov/quality-schools/mo-school-improvement-program/minutes-instruction>

²³ Planning the Weekly Schedule in the Elementary Grades <https://2x9dwr1yq1he1dw6623gg411-wpengine.netdna-ssl.com/wp-content/uploads/2017/07/Planning-Elementary-Doc.pdf>

²⁴ DCPS FY2017 School Budget Guide, Scheduling Requirements <http://www.dcpsschoolbudgetguide.com/changes/schedreq.html>

may be eligible for academic support services. Special Education services are often outlined in an Individualized Education Program (IEP) and ESL accommodations are given through more or less formal plans, sometimes called an Individual Learning Plan (ILP). These plans are developed through consultation between the student, parents, teacher(s), and specialized instructional staff (e.g., special education teacher).

These specialized support plans are designed to help students build essential skills and achieve educational goals and objectives. Assistance may include classroom modification and/or formal accommodations (e.g., more time on assignments, particular seating). In some states, students may be removed from classrooms in “pull-out” programs to participate in one-on-one or small group work with a specialist. When this occurs, students may miss classroom instruction, which may occur during science, history, art, or other subjects. A specialist can also work with the student during classroom instruction, in co-teaching or “push-in” models.

SEA officials were asked to detail the models used with IEP and ILP students during classroom instruction. 24 states report the decision to use support plans like “pull-out” or “co-teaching” as a local one. 18 states report the type of support given to IEP, ILP, and ESL students depends on the specifications of their individual plans. For all of these groups of students, teachers must follow specific practices regarding science in 4 states: Arizona, Florida, Minnesota, and Virginia. The data for the remaining 5 states could not be collected.

Table 7: States Reporting Policies on Services for Students with IEPs or ILPs

State	Policy (Reported by SEA Official)
Arizona	A multi-tiered system of support is used with our students.
Florida	Students are pulled from “specials” (e.g., art, music, physical education) and not from content classes like science.
Minnesota	Some students receive special assistance from another adult during science. Most of the assistance is push in. Sometimes students are pulled out for other remediation but this is not a standard practice.
Virginia	If science is taught, students are usually pulled out of science for remediation. ESL teachers have received professional development in teaching science concepts.

Findings: Extra-Curricular Programs

5. To what extent do children have access to extra-curricular and co-curricular opportunities to learn geosciences?

a. What kinds of geosciences are available to students beyond the classroom (e.g., through academic clubs, after school programs, and informal education networks)?

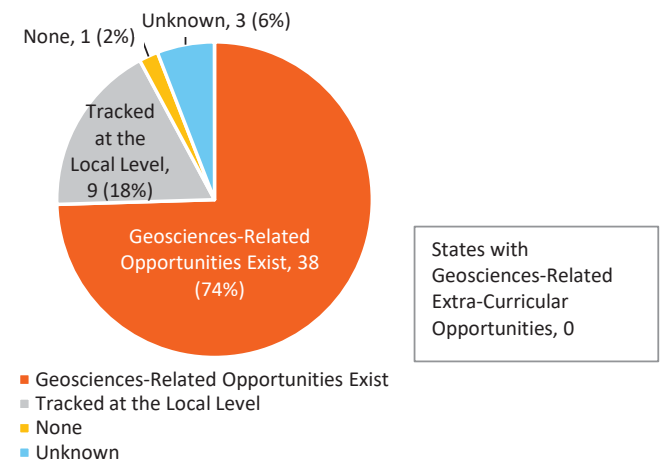
Enrichment beyond the classroom is available in a variety of ways. Many after school programs across the United States combine educational and recreational activities, some of which are available to students for a fee (or that require students to incur some costs). Participation is not required, as these programs are voluntary and take place before or after school hours. In recent years, afterschool participation across the country has grown. The number of children participating rose by 29% between 2004 (6.5 million) and 2009 (8.4 million), and another 21% between 2009 and 2014 (10.2 million). Another 20 million children would choose to participate in afterschool activities if they were available to them.²⁵

Informal education differs from formal education in that enrichment is provided outside of a classroom setting (e.g., museums, libraries, other locations gone to voluntarily) by instructors that may or may not be certified in teaching. Informal education is not bound to the same parameters as formal education (i.e. those that have been discussed previously with respect to teacher preparation, curricula, and instruction).

For this report, SEA officials²⁶ were asked to provide details about programs that are offered outside of formal classroom settings that are geosciences-related. Programs listed included Project WET and Project WILD, the GLOBE Program, Project Learning Tree, and afterschool geosciences-related clubs. Programs could also be available at public sites, like museums, nature and science centers, zoos, and universities. Organizations like state environmental agencies, NASA, and state parks also offer enrichment programs. Respondents in 38 states report having these types of programs available to their students at the elementary level. 9 states report the use

of these programs was a local decision. One state does not offer such programs and opportunities, and data for the remaining 3 states could not be collected.

Figure 2: **States with Geosciences-Related Extra-Curricular Opportunities**



b. What remedial supports are in place for geosciences topics with which students are struggling?

Remedial education is offered in instances where a student lags significantly behind their counterparts with respect to academic performance. Remedial support is designed for any student, with or without special needs, unlike support outlined through the IEP process, which is intended for students with identified special needs. Remedial support can vary depending on the student's current understanding of the content. Support can take the form of individualized basic skills instruction, or curricula and teaching strategies can be adapted to fit the student's learning style.

35 SEA officials report that decisions concerning remedial support are made at the local level. 6 states are required to provide remedial report in science. 4 states provide no remedial support in science. The remaining 6 states' data could not be collected.

²⁵ Afterschool Alliance. (2014). America After 3PM: Afterschool Programs in Demand. Washington, D.C.

²⁶ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

Table 8: Six States Reporting Remediation Support in Elementary Science

State	Description of remedial Support (reported by SEA Official)
Arkansas	Students are required to receive remediation services if they do not perform satisfactorily on the 5th grade assessment.
Delaware	Students are provided differentiated instruction to meet their needs.
Florida	Remediation is required for science. Districts use Gizmo, an online science simulation program for struggling science students.
Minnesota	Some tutoring is also available from 3M and other industries.
New York	Schools must provide Academic Intervention Services to students who have failed or are at risk of failing.
West Virginia	Through Support for Personalized Learning initiatives students with difficulty in all subject areas are addressed.

Findings: Monitoring Systems

6. To what extent is student learning in the geosciences monitored?

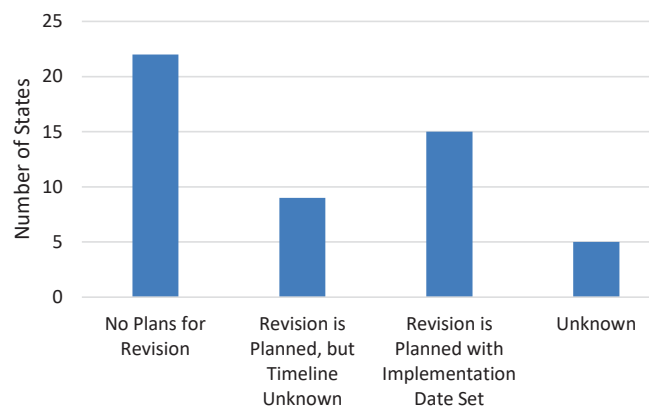
a. What is the relationship between the monitoring system(s), instructional approaches that are promoted for the geosciences, and standards?

Per the Every Student Succeeds Act (ESSA), each state²⁷ is required to administer a statewide science assessment no less than once between grades 3 and 5. These science assessments must also be aligned to state standards.

At the time of writing, each state implements a standards-aligned assessment in elementary science between grades 3 and 5. Some states have recently adopted new standards, such as the Next Generation Science Standards (NGSS) or revised their own state standards, while others are using older standards. Since all states are in different stages of standard-alignment, SEAs were asked to what extent the development of assessments were in flux, and to describe any planned changes to their state elementary science assessment.

22 states currently have no plans to revise or change their elementary level science assessment. 24 states are in a state of planning, 9 with an unknown timeline and 15 with an implementation date set. The remaining 5 states' data could not be collected.

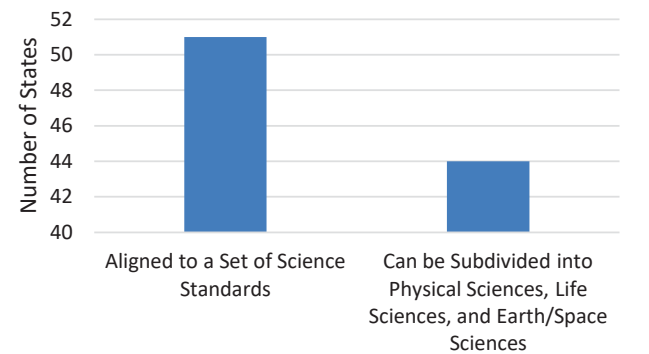
Figure 3: Revision Plans for Statewide Elementary Science Assessments



²⁷ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

For this report, state assessment blueprints, test item documents, and reports were reviewed to determine the content of the science assessments. 44 states subdivided content into major science disciplines (Physical Sciences, Life Sciences, and Earth and Space Sciences). 5 states did not subdivide assessment content. Data for 2 states could not be collected.

Figure 4: Characteristics of Statewide Elementary Level Science Assessments



b. Are student scores on geosciences assessments reported at the district level? What are they?

Performance Level Descriptors (PLDs) are required to define a student's performance on state assessments, and are organized into distinct levels that describe the content and processes that a student should know, demonstrate and perform at specific grade levels. PLDs provide a general conception of student's understanding of science content and application of the scientific process. Students must demonstrate the performance described at that level. These PLDs are not scored per type of science, but rather a general understanding of Physical Sciences, Life Sciences, and Earth and Space Sciences.

At minimum, 3 levels of performance are scored (basic, proficient, advanced) as seen in 11 states. 31 states have a fourth PLD (below basic, basic, proficient, advanced), and 8 states have a fifth PLD (novice, below mastery, mastery, above mastery, distinguished). Nevada's PLDs are yet to be determined.

Table 9: Sample PLDs — Missouri Assessment Program (MAP) Science Grade 5

PLDs — Missouri Assessment Program (MAP) Science Grade 5	
Below Basic	Students identify the relationship between mass and force; classify bodies of water; identify weather instruments and their uses; identify characteristics of the solar system; compare amounts/measurements given in a simple format; identify appropriate tools for simple scientific measurements; identify how technological advances may be helpful to humans.
Basic	Students explain the relationship between mass and force; describe how specialized body structures help animals survive; match environments to the plants and animals they support; identify environmental problems and find solutions; construct part of a graph; determine the appropriate scientific tool and its function in an investigation; determine how technological advances address problems and enhance life.
Proficient	Students describe changes in properties of matter; identify uses of simple machines; explain how work is done; identify forces of magnetism; describe the motion of objects; identify plant parts and their functions; classify vertebrates and invertebrates; classify producers, consumers, or decomposers; predict changes in food chains; identify the effects of human activities on other organisms; describe the Sun as a source of light and heat, or the moon as a reflector of light; explain the day/night cycle; identify characteristics and variables of a fair test; interpret data and make predictions; draw conclusions based on evidence; distinguish between man-made and natural objects; apply problem solving skills to a situation.
Advanced	Students identify energy transformations; predict the effect of heat energy on water; diagram a complete electrical circuit; predict how simple machines affect the force needed to do work; describe the effects of weathering and erosion on Earth's surface; describe relationships in weather data; explain how the Sun's position and the length and position of shadows relate to the time of day; interpret and apply knowledge from a data table; identify appropriate steps, tools and metric units in an investigation; construct a graph and plot data; formulate a question for an investigation.

SEA websites were reviewed to see the extent to which states reported student assessment data from districts and to the public. All 50 states and DC report results of student assessments at the district level to the public. Furthermore, 27 states break down assessment scores into three disciplines in science: Physical Sciences, Life Sciences, and Earth and Space Sciences. Assessment reports with sub-divided science scores are not available from the remaining 22 states because they are not sub-divided to that level, they are only available to school officials, or the data could not be collected from the SEA website.

c. Are student scores on geosciences assessments reported at the state level? What are they?

SEA websites were also reviewed to see the extent to which they reported statewide assessment results at the state level and to the public. All but 2 states report results to the public, with the remaining 2 not reporting at all or having information that could not be collected. Furthermore, 24 states divided the science results by 3 disciplines (Physical Sciences, Life Sciences, Earth and Space Sciences). 16 states made those results available to the public.

d. Are student scores on geosciences assessments included in international comparisons? What are they?

The only assessment that measures elementary-level science achievement of US students comparatively to other countries is the *Trends in International Mathematics and Science Study* (TIMSS), which is administered in the US by the United States Department of Education's National Center for Education Statistics (NCES).

TIMSS data was collected from students at grade 4 in 1995, 2003, 2007, 2011, and 2015. Assessment items are divided into content domain (Physical Sciences, Life Sciences, and Earth and Space Sciences), main topic, and cognitive domain. The next TIMSS assessment will take place in 2019.

18 states participated in TIMSS assessments between 1995 and 2015. 6 states participated in 1995. 1 state participated in 2003. 2 states participated in 2007. 9 states participated in 2011. Just 1 state participated in 2015. 5 states participated in more than one TIMSS assessment between 1995 and 2015.

e. How often are the monitoring programs (e.g., state assessments) administered?

As mentioned earlier, the NCLB required all states to implement annual assessments in science. Because of waivers from the NCLB Act, only 48 states implemented statewide assessments in science at the elementary level. While many states are retaining the schedule developed under NCLB, some are in the process of adjusting that in response to ESSA. This is an area for which data are very tentative at this time.

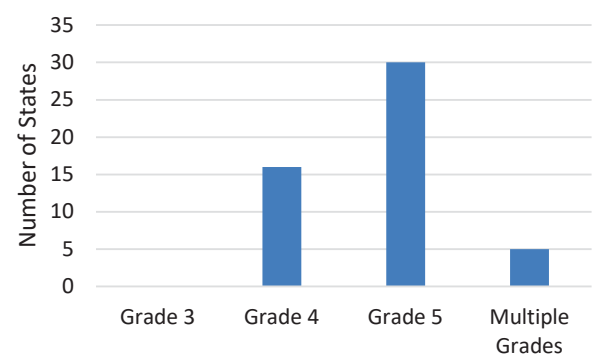
f. At what grade(s) are the monitoring programs administered?

The NCLB required states to assess their students in elementary science no less than one time between grades 3-5. Many states continue those practices. No state solely tests students in grade 3. A single assessment is given to students in grade 4 (16 states) and grade 5 (30 states). 3 states administer annual science assessments in grades 3, 4, and 5. Another 2 states administer annual assessments in grades 4 and 5. 5 states total implement an annual science assessment in more than one grade at the elementary level.

Table 10: States that Implement Elementary Level State Science Assessment at More than One Grade

State	Grade Levels
Louisiana	3, 4, 5
South Carolina	4, 5
Tennessee	3, 4, 5
Utah	4, 5
West Virginia	3, 4, 5

Figure 5: Grade Level Implementation of State Science Assessments



g. To what extent can student outcomes in the geosciences be compared to student outcomes in other areas of science?

As stated in sub-question 6c, 49 states created state-level reports. 16 states made their data available to the public.

Findings: Accountability

7. In what specific ways do student outcomes related to geosciences education matter?

a. In student evaluation?

48 states²⁸ produce individual student diagnostic reports. 48 states produce an Individual Student Report (ISR) that describes a student's performance on the state science assessment, aligned to the state standards. The remaining 3 states' status on ISRs is unavailable.

An ISR can report on a student's performance in terms of scale score and achievement level. 47 states have ISRs with these scores. Information on 4 states in terms of scale scores could not be collected. Within those scores, an ISR may subdivide results by science discipline (Physical Sciences, Life Sciences, and Earth and Space Sciences). 42 states subdivide their results, while 3 do not. The remaining 6 states information could not be collected.

SEA officials were asked about the extent to which these ISRs were produced, available to each student's parent or guardian, and available to each student's teacher. 48 states made ISR results available to the student's parents or guardians. It is unknown whether the remaining 3 states report results to each student's parents or guardians. 45 states report ISR results to teachers, with the remaining 4 states data not available.

b. In teacher appraisal?

Like their standards, states are either required to adopt a single evaluation system across all districts or give power to the LEAs with a guide they can choose to follow. Regardless, the majority of teacher assessments are based on multiple measures of performance (e.g., classroom observation, student and parent surveys, lesson plan reviews, self-assessments).

Student achievement may also be accounted for in teacher assessments. For this report, SEAs were asked to what extent student achievement on state science assessments played a role in teacher evaluation systems. 27 states do not count student achievement in their

teacher's evaluation. Only 7 states (Georgia, Kentucky, Louisiana, New Mexico, South Carolina, Virginia, and Wyoming) include student state assessment results in teacher evaluation systems. Another 9 officials stated student results could be used, but it is not mandatory. 3 states give local districts the decision to include student assessment scores in teacher evaluations. Data could not be collected for 5 states.

c. In district accreditation?

Besides individual teachers, the services and operations of the schools as a whole is also evaluated to determine if certain standards set by the state (and sometimes regional accrediting agencies) are met. This is the school's accreditation. Criteria for accreditation includes curriculum, school administration, instruction, attendance and enrollment, student performance, personnel, support services, and facilities and equipment.

SEA officials were asked if student results on state assessments were used as criteria in measuring district level public school accreditation, to which 8 officials stated "Yes" and 1 more "in the future." 19 states do not use student assessment results in the accreditation process. 5 states let local districts decide to use student results or not. Data could not be collected for 18 states.

d. In statewide accreditation?

In the United States, each state is required to ensure each student has access to quality education, which is done through developing policies and procedures to make sure schools are educationally adequate. Statewide monitoring of such things as facilities, curriculum, and educational outcomes is used to measure school adequacy.

Student statewide science assessments at the elementary level are used to monitor school educational adequacy in half of the states (26). It is unknown whether assessment scores are used in 19 states, and the remaining 6 do not use assessment results to measure educational adequacy in their schools.

e. Are trends in student outcomes over time in geosciences learning reported in some way? What are they?

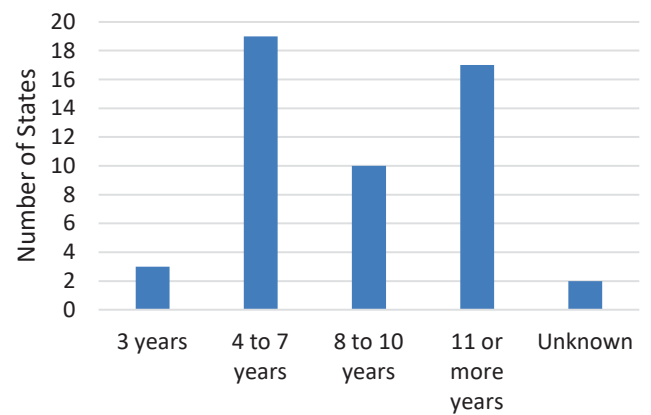
Student assessment data are typically reported as percentages of students performing at certain achievement

²⁸ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

levels (PLDs) in the state science assessments, but also list science subdivisions (Physical Sciences, Life Sciences, and Earth and Space Sciences) for those states where it is available (11 states). These subdivisions are not provided in 39 states. Data for one state could not be collected.

SEA officials were asked if their state reported these results over time. 50 states do have historical data for state assessments and student achievement over a period of time, a single state, Nevada, reporting release of historical data “to be determined.” Historical data since 2013-2014 could be accessed for 3 states. Data dating back to 2009-2010 is available for 19 states. 10 states have data dating back 10 years (2006-2007), and 17 states have data from more than 11 years ago (before 2006-2007). Data for 2 states could not be collected.

Figure 6: **Reporting of Historical Achievement Data for Elementary Science Assessments**



Summary

Teacher Preparation

All states²⁹ have similar elementary teacher licensing requirements, namely a minimum of a bachelor's degree from a state-approved teacher preparation program that includes a combination of coursework and field-work (time spent in a classroom). Teachers are licensed in either Elementary Education or Early Childhood Education, both of which have specific requirements for each state the license is attained in. Knowledge in science concepts are tested in 42 states for Elementary Education credentials and 26 states for Early Childhood Education credentials. Most states teaching licenses are valid for 5 years and are up for renewal after completing an amount of professional growth activities. These can include professional development courses or programs specific to geosciences.

All states provide elementary-level science standards (including geosciences) for use in the development of science curricula. Over half of the states (57%) provide both standards and additional resources, including curriculum and benchmark maps, templates for unit and lesson designs, model lesson plans, and assessment guidelines. The remaining 43% of states rely only on the state's science standards.

Adoption of curriculum materials like textbooks or online resources is also separated between local and state. 29% of states choose these materials at the state level. The remaining 71% are chosen locally. Most elementary textbooks approved by the state are geoscience-specific titles.

Professional development (PD) comes in many forms throughout a teacher's career. PD offered by the state, by local agencies, or independent from the state are generally equal amounts (24%, 27%, and 22% respectively). The range of geoscience specific PD varies, ranging from college or university courses, state-run programs, or programs run by geoscience organizations.

Curriculum

All states provide elementary curriculum standards that provide guidance on what is to be taught in science. These are presented as standards stating what knowledge and skills students should possess at each level of instruction. 57% of states provide both an overarching standards statement as well as sub-standard statements.

²⁹ For the purposes of this report, in the interest of brevity, Washington, DC, will be included in states in a generic sense, making the total 51.

Most states (92%) use grade-level specific standard, with the rest arranged in grade level bands or benchmark levels. All states divide their standards into specific disciplines of science: Physical Sciences, Life Sciences, and Earth and Space Sciences. Furthermore, 88% of states identify those science standards by core ideas in the geosciences. This means that the United States is overall establishing clear targets for learning geosciences.

80% of states include current issues in geosciences in their standards. These can include Earth science processes altered by human activity or processes that affect human well-being in topics such as energy resources, climate modification, waste disposal, mining resources, and natural hazards.

Only 29% of states emphasize career options in geosciences within their elementary science standards.

All states periodically review their standards for quality and adherence to current research and academic advances. However, issues like subject controversy or budget restrictions may cause some standards to stay in place despite their revision schedule. 39% of states reviewed their standards within the last two years, with another 29% having reviewed standards in the last six years. 51% of states had no plan or timeline for future standards review, as of the time of this writing.

Instruction

State standards are designed to promote the active investigation of science, with each state providing certain guidelines to teachers for science instruction, including that of geosciences. Inquiry-based approaches are used in 43% of states. 45% of states, those that use the Next Generation Science Standards (NGSS), use inquiry-based approaches as well as Science and Engineering Practices. The remaining states use approaches that help facilitate inquiry in science instruction.

Most states (71%) provided a rationale for using an inquiry-based approach in science teaching. Justification for these standards often includes mimicking real-life scientific practices and gaining a better understanding when students use thinking processes that parallel work and construction of knowledge by professional scientists.

The role of technology in science is increasingly prevalent, just as the role of technology in professional scientists' work is accomplished through use of sophisticated equipment and other advances in science. The decision

on what technology to use in science instruction, however, is left up to local districts. That said, it is not possible to describe the extent of technology use in classrooms as it varied wildly from district to district and is often dependent on local resources.

Learning Contexts

The impact of class size remains controversial. It is reasonable to assume that class size can affect certain instructional scenarios in science in particular (e.g., hands-on activities and labs). Most states do not provide data on class average or maximum sizes. 27% of states collect data on class averages, often giving a range of sizes. 24% of states give maximum classroom sizes. Four states (8%) collect data on both average and maximum class sizes. This variation suggests unequal opportunities in active science learning across the states.

Allotted time for science instruction is also a controversial topic. All states are mandated to teach science at the elementary level, including geosciences. Only 10% of states have specific state-wide guidelines on science instruction time. Most states leave the decision up to local districts or do not require a time limit.

Students needing English as a Second Language (ESL) support as well as those with Individualized Education Plans (IEPs) or individualized Learning Plans (ILPs) receive specialized services designed to help them build those essential skills and objectives. This specialized instruction sometimes removes students from classrooms to receive that support. This means that some students miss instruction in some academic areas, including science. The decision on when and how to give this support is made locally in 47% of states. Most other states make the decision depending on the student's IEP/ILP. Specific practices for specialized support are only mandated in 8% of states. Therefore, the level of geoscience instruction for students with specialized support is difficult to determine.

Extra-Curricular Programs

Students receive an array of educational and recreational activities beyond the classroom via afterschool and informal programs. 75% of states offer geoscience-related programs for students at the elementary level. Types of programs vary from state to state.

Remedial education can also be provided for students in subjects where the student lags behind their counterparts. The type of remediation can vary depending on the

student's understanding of the subject, but can include individualized instruction or teaching strategies. Most remedial education programs are decided at the local level (in 69% of states). State support in remedial education is far less, being required for only 12% of states.

Monitoring Systems

All states implement an annual test in science as part of their statewide testing system at the elementary level, most commonly between grades 3 and 5. 6% of states administer tests to more than one grade (e.g., grades 4 and 5, or 3, 4, and 5). No state reported testing students at the K-2 level. All assessments are aligned to state science standards and measures achievement of those standards. That said, standards go through periods of revision after a set amount of time, and some states are currently revising or adopting new standards. 86% of states identify their assessments as being divided into three scientific disciplines: Physical Sciences, Life Sciences, and Earth and Space Sciences.

All states report student achievement on science assessments according to a set of Performance Level Descriptors (PLDs) that provide a student's general understanding of science content and application of scientific processes. These PLDs are often listed as basic, proficient, and advanced/mastery. A minimum of 3 levels is seen in 23% of states, four levels are used in 61%, and 16% have a fifth PLD. All states report this assessment data to the public at the district level and 96% at the state level.

Scores can be further subdivided into Physical Sciences, life Sciences, and Earth and Space Sciences, though this data is normally only available to school, state, and district officials. This makes monitoring geosciences learning impossible in some locations.

The Trends in International Mathematics and Science Study (TIMSS) is the only assessment that measures US students' abilities with those of international students at the elementary science level. The TIMSS scores have been recorded 5 times in the past 2 decades, with 5 states participating in more than one year. The next TIMSS assessment will take place in 2019.

Accountability

At the individual level, 94% of states provide Individual Student Reports (ISRs) that describe student achievement at the state science assessments. Most ISRs provide information on student's achievement on

subdivided science disciplines to the parents or guardians and teachers.

Teacher evaluation systems are also used to measure teacher effectiveness. Evaluations are based on multiple measures, like classroom observations, student and parent surveys, lesson plan reviews, and self-assessments. Student achievement may also be counted in teacher evaluations. Most states (53%) do not use student achievement scores to evaluate teachers. Very few states required student assessment scores to be used or offered it as another measure of teacher effectiveness.

Schools and school districts are also evaluated by accrediting agencies using a variety of criteria. Half of states use student assessment scores in statewide accreditation. Only 27% of states required student assessment for accreditation purposes at the district level or left the decision to local districts.

States have been implementing statewide assessments at the elementary level in science for at least 10 years. All states³⁰ record historical data on state assessments over a period which is made available to the public. 37% of states have data for at least 8 years, 20% of states' data date back 10 years, and 33% of states have data from more than 11 years ago. Data is reported as a percentage of students performing at each PLD level. 22% of states further provide student performance data according to scientific discipline (Physical Sciences, Life Sciences, and Earth and Space Sciences).

³⁰ Nevada reported historical data recordings as "to be determined."

Sources of Information

State Education Agency Web Sites, last accessed 1 December 2017.

Alabama: <https://www.alsde.edu/>

Alaska: <https://education.alaska.gov/>

Arizona: <http://www.azed.gov/>

Arkansas: <http://www.arkansased.gov/>

California: <https://www.cde.ca.gov/>

Colorado: <https://www.cde.state.co.us/>

Connecticut: <http://www.sde.ct.gov/sde/site/default.asp>

Delaware: <https://www.doe.k12.de.us/>

Florida: <http://www.fldoe.org/>

Georgia: <http://www.gadoe.org/Pages/Home.aspx>

Hawaii: <http://www.hawaiipublicschools.org/Pages/Home.aspx>

Idaho: <https://www.sde.idaho.gov/>

Illinois: <https://www.isbe.net/>

Indiana: <https://www.doe.in.gov/>

Kansas: <http://www.ksde.org/>

Kentucky: <https://education.ky.gov/Pages/default.aspx>

Louisiana: <https://www.louisianabelieves.com/>

Maine: <http://www.maine.gov/doe/>

Maryland: <http://www.marylandpublicschools.org/Pages/default.aspx>

Massachusetts: <http://www.doe.mass.edu/>

Michigan: <http://www.michigan.gov/mde/>

Minnesota: <http://education.state.mn.us/mde/index.html>

Mississippi: <http://www.mde.k12.ms.us/>

Missouri: <https://dese.mo.gov/>

Montana: <https://opi.mt.gov/>

Nebraska: <https://www.education.ne.gov/>

Nevada: <http://www.doe.nv.gov/>

New Hampshire: <https://www.education.nh.gov/>

New Jersey: <http://www.state.nj.us/education/>

New Mexico: <http://www.ped.state.nm.us/ped/index.html>

New York: <http://www.nysed.gov/>

North Carolina: <http://www.ncpublicschools.org/>

North Dakota: <https://www.nd.gov/dpi>

Ohio: <https://education.ohio.gov/>

Oklahoma: <http://www.sde.ok.gov/sde/>

Oregon: <http://www.oregon.gov/ode/Pages/default.aspx>

Pennsylvania: <http://www.education.pa.gov/Pages/default.aspx>

Rhode Island: <http://www.ride.ri.gov/>

South Carolina: <https://ed.sc.gov/>

South Dakota: <http://doe.sd.gov/>

Tennessee: <https://www.tn.gov/education/>

Texas: <https://tea.texas.gov/>

Utah: <https://www.schools.utah.gov/>

Vermont: <http://education.vermont.gov/>

Virginia: <http://www.doe.virginia.gov/>

Washington: <http://www.k12.wa.us/>

West Virginia: <https://wvde.state.wv.us/>

Wisconsin: <https://dpi.wi.gov/>

Wyoming: <https://edu.wyoming.gov/>

Initial Teacher Prep (ITP)

Introduction

This section of the report provides results from the “Initial Teacher Preparation (ITP) Survey” that was used to collect data about geosciences education in the nation’s college-level ITP programs for preK–5 teacher candidates. The data were collected by the American Geosciences Institute using an online survey of education and science department chairs, directors, and professors between November 2016 and February 2017. A total of 162 responses were collected, which provide data for 46 states (see Table 11). As with the rest of this report, the goal of the ITP survey is to initiate a set of indicators that can be used to track the role of geosciences in K–5 teacher preparation, and allow leaders of ITP programs to learn from Each other’s experiences and program structures.

This report is available for download from AGI’s website: www.americangeosciences.org. We welcome comments about the ITP survey, the results reported here, changes in programs that may have taken place since the survey was conducted, and other aspects of this report.

What indicators are there that ITP programs are designed to prepare K–5 teachers to teach Earth and Space Science effectively at their level?

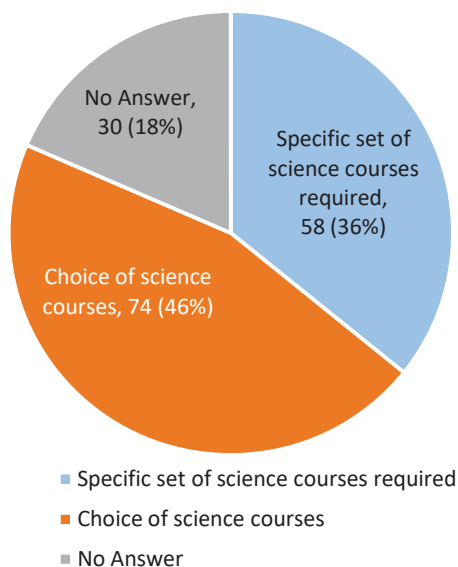
There are several indicators of a teaching candidates’³¹ readiness to lead a K–5 classroom in geoscience instruction. These include having strong knowledge of the content to be learned by candidates. This content knowledge can be developed by candidates through course taking. Ninety-three percent (n=150) of respondents indicated that candidates are required to take some number of science courses in their teacher preparation program. Seventy-four (46%) candidates were able to choose which sciences they take, while 58 (36%) were required to take a specific set of courses (see Figure 7). The remaining 18% (n = 30) gave no response. Out of six science areas (biology, chemistry, environmental science, geoscience, physics, or other), 82 programs (50%) reported offering at least one geoscience course and 109 (67%) offered courses in environmental sciences.

Table 11: Initial Teacher Preparation (ITP) State Institution Responses

State	# Responses	State	# Responses	State	# Responses
Alabama	4	Maine	3	Ohio	4
Arizona	2	Maryland	4	Oklahoma	2
Arkansas	4	Massachusetts	8	Oregon	3
California	3	Michigan	3	Pennsylvania	5
Colorado	2	Minnesota	6	Rhode Island	1
Connecticut	2	Mississippi	4	South Carolina	4
Delaware	1	Missouri	4	Tennessee	3
Florida	12	Montana	1	Texas	10
Georgia	5	Nebraska	3	Vermont	1
Hawaii	2	Nevada	1	Virginia	3
Illinois	5	New Hampshire	1	Washington	3
Indiana	2	New Jersey	3	West Virginia	3
Iowa	4	New Mexico	1	Wisconsin	4
Kansas	5	New York	4	Wyoming	2
Kentucky	3	North Carolina	6		
Louisiana	2	North Dakota	4		

³¹ Throughout this report the use of the term “candidate” or “teaching candidate” will refer to individuals who are in higher education programs that prepare them to be teachers. Generally, “students” will refer to people in kindergarten through grade 12.

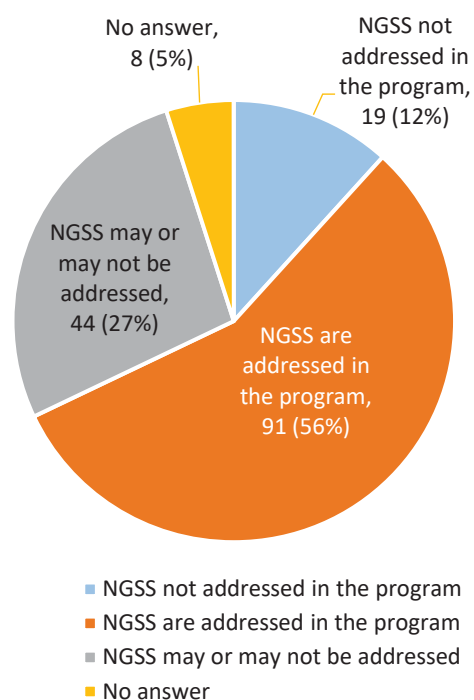
Figure 7: ITP Candidates Science Course Requirements



Along with content knowledge, readiness to guide instruction is enhanced by the ability to relate that knowledge to the relevant science standards that the candidate will address in her/his classroom teaching. Most (56%; $n = 91$) of the respondents reported that the Next Generation Science Standards (NGSS) are addressed by candidates in their program, as it is integral to the coursework and/or methods courses (see Figure 8). Forty-four (27%) of respondents indicated that the NGSS may or may not be addressed in the program. The NGSS was unlikely to be addressed or there was no response from 19 (12%) and 8 (5%) of respondents, respectively. This means that the NGSS are currently highly influential in more than half of ITP programs responding to the survey at the K–5 level.³²

³² Note that since ITP programs prepare varied numbers of pre-service teachers, the total number of programs does not necessarily correspond to the total number of teachers entering the K–5 profession.

Figure 8: Next Generation Science Standards (NGSS) Addressed in ITP Programs



How do ITP programs require candidates to demonstrate their readiness to teach Earth and Space Science?

Table 12: Evidence Required for Candidate Readiness to Teach Earth and Space Science

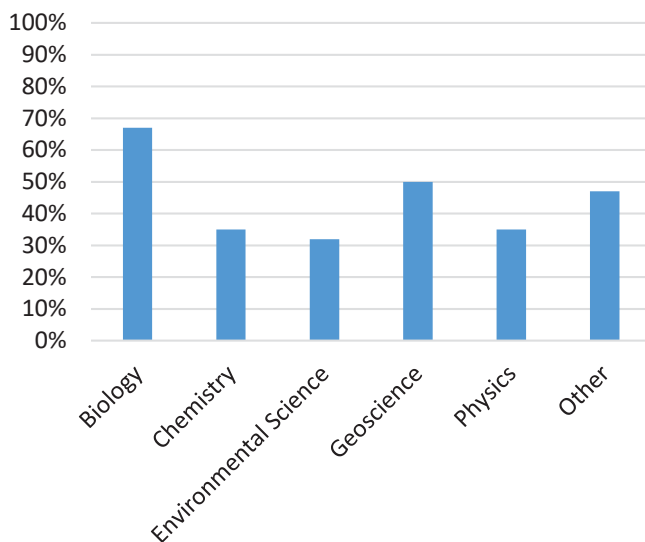
Types of Evidence	% of respondents ($n =$ number of respondents)
Teaching Portfolio Artifacts	31% ($n=50$)
Lesson Plans	57% ($n=92$)
Content Knowledge Examination	49% ($n=80$)
Field Trip Experience	14% ($n=22$)
Development of Collection (e.g., rock collection)	2% ($n=4$)

Twenty-six respondents indicated that candidates in the program are to show geoscience competency not only through these approaches (see Table 12), but also through approaches including lab work and demonstrations, self-evaluations, methodology courses with aspects of geoscience, field and research projects, class presentations, and training courses (e.g., workshops in *Project WILD*, or *Project Learning Tree*).

Do ITP programs also have requirements for science courses? Are there options for the types of sciences candidates are required to take?

As indicated above, most programs (93%; n = 150) required candidates to take science courses. Of the total of all respondents, 58 (36%) stated that the required courses are specified, 69 (43%) stated there is a choice of the courses that can fulfill the program requirements, 5 (3%) stated that the courses are not specified or required, 10 (6%) stated “other”), and the remaining 12% (n = 20) did not indicate an answer. Generally, between 3-4 units in geosciences (geology, meteorology, astronomy, oceanography) and environmental sciences are required or offered as electives. In most cases, other sciences, like biology /life sciences, are indicated to have a greater overall audience among teaching candidates who are allowed to select the courses they take (see Figure 9).

Figure 9: Science Subject Areas Required by ITP Programs



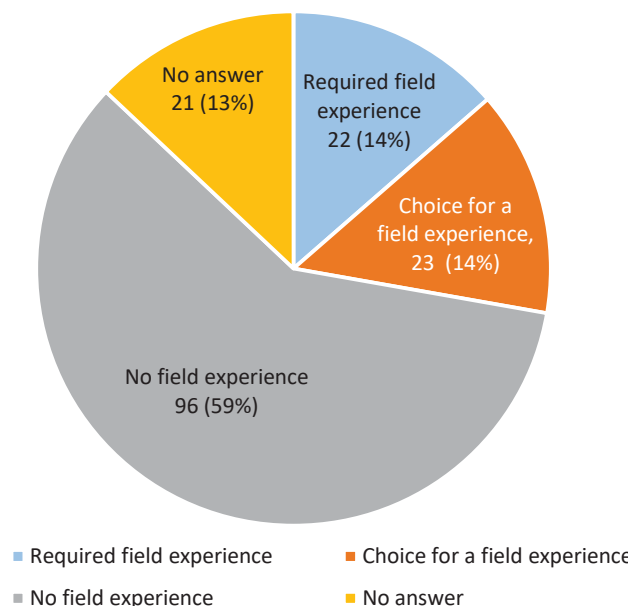
Some teacher programs (n = 45, 27%) offer choices in elective science courses, including physical sciences, natural sciences, and nature of science courses. Besides typical choices for science content courses (biology, chemistry, environmental science, geology, physics), respondents noted that other courses, such as science teaching methods courses and science laboratories, also provide some exposure to geoscience content.

Furthermore, some participants are required to show competency in geosciences through off-campus geoscience-related experiences (see Figure 10). Many of the candidates can travel to locations close to their school location (e.g., planetarium, landfill, or local forested

area). There, candidates participate in astronomical, geological, and/or environmental studies. Candidates may also be assigned tasks at these sites like identifying rocks or geologic outcrops, core drilling, and performing other investigation-based work. Candidates can also travel farther from their campus, such as to nature centers and national parks for more intensive experiences; glaciology, hydrogeology, and volcanology were given as examples of the areas addressed in those options. Lastly, candidates could participate in specific professional development programs, like Project WET or Project WILD as a way of augmenting their preparation for geoscience teaching.

The specific nature of field experiences varies widely from examining examples in the field of what is studied during courses to more sophisticated investigations using field-based data. One respondent noted that in the program she/he was describing, field experiences are graded based on numerous conditions, including: personal observations; comparison of their personal observations with colleagues; and using those observations to solve problems. Candidates made observations, collected data, and provided a written report. Then, those reports were compared with those of their colleagues and against published literature. Finally, problems in that environment are identified and, using their previous observations, mitigation strategies are identified and communicated in another report. These field experiences are meant to enhance the candidates' understanding of the geosciences, while giving them a chance to practice coming to evidence-based conclusions in the real world.

Figure 10: Off-Campus Geoscience Field Experiences



Out of the total 162 respondents, only 22 described programs in which candidates are required to complete a field experience. Another 23 indicated having the choice to partake in one or not, leaving the majority of survey participants (n = 96) without school-mandated geoscience field experience. Twenty-one respondents did not answer.

Summary

The ITP survey results indicate that, compared to other science courses, geoscience and environmental sciences were more likely to be optional. This may decrease the number of candidates taking those courses. Also significant is that there were very few reported off-campus experiences (observatory visits, specimen collecting, etc.) to help further candidate learning in geoscience.

(Footnotes)

- ¹ 2015 Alabama Course of Study – Science <https://www.alsde.edu/sec/sct/COS/2015%20FINAL%20Science%20COS%2010-1-15.pdf>
- ² Arizona Academic Content Standards – Science <https://cms.azed.gov/home/GetDocumentFile?id=550c5129aadebe15d072a8d1>
- ³ 2016 Massachusetts Science and Technology/Engineering Curriculum Framework <http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf>
- ⁴ Academic Standards for Science and Technology and Engineering Education [http://static.pdesas.org/content/documents/Academic_Standards_for_Science_and_Technology_and_Engineering_Education_\(Secondary\).pdf](http://static.pdesas.org/content/documents/Academic_Standards_for_Science_and_Technology_and_Engineering_Education_(Secondary).pdf)
- ⁵ Wisconsin Standards for Science <https://dpi.wi.gov/sites/default/files/imce/science/WI-Standards-for-Science-2017.pdf>
- ⁶ 2016 Wyoming Science Content and performance Standards <https://edu.wyoming.gov/downloads/standards/2016/2016WYScienceCPS.pdf>
- ⁷ Sample Recommended Instructional Time, Standards-Based Teaching and Learning <https://cms.azed.gov/home/GetDocumentFile?id=56cb92ebaadebe16d8c83df3>
- ⁸ Connecticut State Board of Education, Position Statement on Science Education http://www.sde.ct.gov/sde/LIB/sde/pdf/board/Position_Statement_Science_Ed.pdf
- ⁹ Missouri Department of Elementary & Secondary Education – Minutes of Instruction <https://dese.mo.gov/quality-schools/mo-school-improvement-program/minutes-instruction>
- ¹⁰ Planning the Weekly Schedule in the Elementary Grades <https://2x9dwr1yq1he1dw6623gg411-wpengine.netdna-ssl.com/wp-content/uploads/2017/07/Planning-Elementary-Doc.pdf>
- ¹¹ DCPS FY2017 School Budget Guide, Scheduling Requirements <http://www.dcpsschoolbudgetguide.com/changes/schedreq.html>



Participant in Earth Science Week's 2017 Photo Contest, themed "Earth and Human Activity Here."

Image credit Arabella Sunga.



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