

Earth and Space Sciences Education in U.S. Secondary Schools: Key Indicators and Trends

Earth and Space Science Report, Number 3.0,
November 2018



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ISBN-13: 978-1-941878-90-3

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Suggested Citation:

Center for Geoscience and Society. (2018, November). *Earth and space sciences education in U.S. secondary schools: Key indicators and trends* (Number 3.0). Alexandria, VA: American Geosciences Institute.



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Acknowledgements

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

Earth and Space Sciences Education in U.S. Secondary Schools: Key Indicators and Trends

The Center for Geoscience and Society, a service of the American Geosciences Institute, is pleased to release this latest update on the status of secondary Earth and space sciences education in the United States. This report includes information on the presence of the Earth and space sciences in:

- science education standards;
- high school graduation requirements;
- high stakes state-level science assessments;
- college admission requirements;
- the Advanced Placement program; and
- initial teacher preparation programs.

This report provides a snapshot of the health of the Earth and space sciences in our nation's school systems. This report is based on data collected by the American Geosciences Institute from State Education Agency (SEA) websites, from interviews with SEA officials for all fifty (50) states and the District of Columbia, and from a survey of education and science department chairs, directors, and professors between August and November 2018. This report is available for download from AGI's website: www.americangeosciences.org.

Table of Contents

iv Executive Summary

1 Introduction

2 Report Structure

3 Findings: Curriculum

5 Findings: Monitoring Systems

8 Findings: College Preparedness

11 Findings: Initial Teacher Preparation (ITP)

14 Discussion

15 Sources of Information

Tables

- 5 **Table 1:** Statewide Assessments in Science for Middle School – Grades Tested
- 5 **Table 2:** Statewide Assessments in Science for High School – Grades Tested
- 7 **Table 3:** Course Type and End-of-Course Statewide Assessments in Science
- 8 **Table 4:** Examples of the Required and Recommended Science Coursework for Admission
- 11 **Table 5:** Initial Teacher Preparation (ITP) State Institution Responses

Figures

- 4 **Figure 1:** Science Content in Secondary Standards
- 4 **Figure 2:** Number of Science Credit Requirements for Graduation, by State
- 4 **Figure 3:** Number of States Requiring Specific Science Courses for High School Graduation
- 6 **Figure 4:** States Assessing Life Science, Physical Science, and Earth and Space Science Concepts on Statewide Assessments in Science
- 6 **Figure 5:** States Assessing Life Science, Physical Science, and Earth and Space Science Concepts in Both Middle and High School
- 6 **Figure 6:** States Assessing Life Science, Physical Science, and Earth and Space Science Concepts in Middle School Only
- 7 **Figure 7:** Science Content of the 31 States that Administer Statewide Science Assessments that are Comprehensive
- 9 **Figure 8:** Recommended Number of Years of High School Science to Prepare for College
- 9 **Figure 9:** Course Disciplines Recommended to Prepare for College
- 10 **Figure 10:** Institutions accepting an Earth and Space Sciences course for admission
- 12 **Figure 11:** ITP Science Course Requirements by Science Discipline
- 12 **Figure 12:** Approaches for Demonstrating Competency in the Application of the NGSS
- 12 **Figure 13:** Approaches for Demonstrating Competency in Earth and Space Sciences Instruction

Executive Summary

This *Earth and Space Sciences Education in U.S. Secondary School: Key Indicators and Trends* report presents a snapshot of Earth and space sciences education in the nation's secondary schools by highlighting secondary level Earth and space sciences education indicators pertaining to several dimensions, including: curriculum, monitoring systems, and college preparedness. This report also includes a section, the results of the "Initial Teacher Preparation (ITP) Survey," that presents data about Earth and space sciences education in the nation's college-level ITP programs for secondary teacher candidates. The overall goal of this report is to work towards a set of indicators that can be used to track the role of the Earth and space sciences in secondary education, including in teacher preparation.

Curriculum

Standards: All states¹ (100%) include Earth and space science concepts in their middle school and high school science standards. All secondary state standards (100%) also include life science and physical science concepts.

Graduation Requirements: Almost all states (94%) require between two and four credits of science to graduate from high school. Most states (61%) require those credits to include a life science course. Many states (51%) require a physical science course. Few states (16%) require students to take a course that includes Earth and space science concepts. However, most states (57%) do allow students to satisfy a portion of their science credit requirements with an elective course in the Earth and space sciences.

Monitoring Systems

State Science Assessments: All states (100%) administer statewide assessments in science at the secondary level every year, at least once in grades 6-9 and at least once in grades 10-12. Statewide assessments are either comprehensive assessments that are delivered at a specific grade level or end-of course assessments that are given after the

completion of a specific course. All states (100%) assess life science at both the middle and high school levels. Most states (69%) assess physical science at the same levels. Fewer states (61%) assess Earth and space science concepts at both the middle and high school levels.

College Preparedness

Admission Requirements: A survey of 195 four-year institutions of higher learning revealed that a high school Earth and space sciences course is commonly accepted (75%) for admission purposes by colleges and universities in the United States.

Advanced Placement Courses: There are Advanced Placement (AP) examinations and courses for biology, chemistry, physics, and environmental science. There is no AP examination or course for the Earth and space sciences. However, AP environmental science course topics include Earth science concepts.

Initial Teacher Preparation

Teacher Preparation: A survey of Initial Teacher Preparation (ITP) programs at thirty-five institutions of higher learning revealed that teacher candidates who focus on secondary-level science education must complete some number of science

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.

courses. Programs report that coursework requirements in science include biology (66%), chemistry (57%), physics (54%), environmental science (17%), and Earth and space science (63%).

Readiness: Programs use a variety of approaches to determine a teacher candidate's competency for Earth and space sciences instruction in a secondary classroom. These include the use of lesson plans, content knowledge examinations, portfolio artifacts, field trip experiences, and the development of a collection. In many programs, candidates must also demonstrate competency in applying the Next Generation Science Standards (NGSS), often through these same approaches.

Maximizing Resources: Of the thirty-five institutions surveyed, 57% have an academic division that focuses on one or more geoscience disciplines. However, the interaction between the faculty of that division and the faculty of the ITP program is reported as 'close' in only half of those institutions (n = 10). Additionally, only slightly more than half of all programs (n = 18) include off-campus experiences in which candidates are exposed to the geosciences.

Introduction

The status of secondary Earth and space sciences education has been under review for years. In the early 2000s, the National Science Foundation supported two conferences for members of the education community to assess the status of Earth and space sciences education in the United States. These conferences, entitled *Revolution in Earth and Space Science Education* (2001) and *The Second Revolution in Earth and Space Science Education* (2004), had the goal of promoting Earth and space sciences instruction in U.S. schools. Recommendations from the first conference report² included forming state-based alliances and developing an “Annual Snapshot” of the status of Earth and space sciences education in the United States. The second meeting brought together representatives from four states (New York, California, North Carolina and Texas), as well as members of geoscience organizations, to explore how such alliances could work to promote Earth and space sciences education.

As a follow-up to the recommendations arising from both “Revolution” meetings, the American Geological Institute (AGI – now the American Geosciences Institute) produced reports on the status of Earth and space sciences education in 2002³ and 2004⁴. AGI also created the Pulse of Earth Science website in 2007 featuring state-by-state information on standards, assessments, teacher certification requirements, and other pertinent data. In addition, with support from the National Science Foundation and private entities, AGI hosted a K-12 Earth and space sciences education summit meeting in early 2010 in Houston, Texas.⁵ The purpose of the summit was to

bring together leaders in U.S. Earth and space sciences education to discuss the status of the Earth and space sciences in K-12 schools, define problems, and suggest methods for addressing those problems.

Attendees at the summit, which included representatives from federal and state agencies, universities, science societies, school districts, and industry, formed working groups to explore what was happening across the country regarding:

- Perception of Earth and space science courses by school systems (graduation requirements, high stakes assessments, and standards);
- Status of college acceptance of high school Earth and space science courses;
- Challenges to teaching Earth and space science topics such as evolution and climate change in schools;
- Possibility of an AP Earth and space sciences course and examination; and
- Preparation of Earth and space science teachers.

After the summit, AGI and partners planned and implemented several studies to gauge the status of the Earth and space sciences in the U.S. educational system. The first of these produced the “Earth and Space Sciences Education in U.S. Secondary Schools: Key Indicators and Trends” report in 2013.⁶ The report was updated and released again in 2015.⁷ This 2018 report updates and expands the 2015 report and provides the most current information available about the status of the Earth and space sciences in U.S. secondary schools.

² Barstow, D., Geary, E., & Yazjian, H. (Eds.). (2002). *Blueprint for change: Report from the national conference on the revolution in earth and space science education*. Cambridge: TERC.

³ Smith, M., et al (2002). *Earth science in our nation's schools: AGI national status report on K-12 earth science education*. Alexandria, VA: American Geological Institute.

⁴ Smith, M., et al (2004). *Earth science in our nation's schools: AGI national status report on K-12 earth science education*. Alexandria, VA: American Geological Institute.

⁵ Benbow, A. (2010). *Earth science education summit: Conference report*. Retrieved from http://www.agiweb.org/education/summit/Summit_Public_Report.pdf.

⁶ Center for Geoscience Education and Public Understanding. (2013). *Earth and space sciences education in U.S. secondary schools: Key indicators and trends* (Number 1.0). Alexandria, VA: American Geosciences Institute.

⁷ Center for Geoscience and Society. (2015). *Earth and space sciences education in U.S. secondary schools: Key indicators and trends* (Number 2.1). Alexandria, VA: American Geosciences Institute.

Report Structure

Earth and space sciences education can be characterized by several 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 of the condition of Earth and space sciences education in secondary schools. The key indicators are organized into four major topical areas:

- Curriculum
- Monitoring systems
- College preparedness
- Initial teacher preparation

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

1. What evidence is there that there has been conscientious thought given to what is to be taught to secondary students with respect to the Earth and space sciences?
2. To what extent is student learning in the Earth and space sciences being monitored at the secondary level?
3. What are the expectations of colleges and universities for the learning of the Earth and space sciences by high school students?
4. To what extent are new teachers being actively prepared for Earth and space sciences instruction?

Findings: Curriculum

1. What evidence is there that there has been conscientious thought given to what is to be taught to secondary students with respect to the Earth and space sciences?

a. What is the organization of the standards? To what extent are the Earth and space sciences represented?

Educational standards are the learning goals for what students should know and be able to do at each grade level. Each State Education Agency (SEA)⁸ creates standards for schools within the state. These standards become the basis for the way teachers are trained, what they teach, and what is on state assessments that students take.

Standards intended for widespread adoption by several states can be created by a variety of organizations. Attempts to produce broad recommendations for science instruction have been made in 1996 through the *National Science Education Standards*⁹ from the National Research Council (NRC) and *Benchmarks for Science Literacy*¹⁰ from the American Association for the Advancement of Science (AAAS). As states began developing their science education standards around that time, many were based on the guidance these documents provided. In 2013, a substantial update to recommendations for science teaching standards was made through the development of the *Next Generation Science Standards* (NGSS).¹¹ The NGSS were developed over the course of two years by a consortium of 26 states. The 40-member writing team included experts in science, engineering, state standards, assessment, workforce development, English language acquisition, and students with disabilities. The team was managed by Achieve, Inc., a nonprofit education organization. The writing team based their work on the *Framework for K-12 Science Education*¹², which was devel-

oped by the NRC of the National Academy of Sciences and was released in July 2011.

The core scientific learning goals of the NGSS are referred to as performance expectations. Each performance expectation incorporates three elements, or dimensions. The first of these is the science and engineering practices, which describe the behaviors and methods of scientists and engineers as they build models, develop theories, and create systems. The second dimension is the cross-cutting concepts of science, which are underlying ideas common to all the domains of science. Finally, the disciplinary core ideas are specific content and subject areas and are grouped into the four domains: the physical sciences; the life sciences; the Earth and space sciences; and engineering, technology, and applications of science.

As of October 15, 2018, the District of Columbia and nineteen states have officially decided to adopt the NGSS at the secondary level: Arkansas, California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Hampshire, New Jersey, New Mexico, Oregon, Rhode Island, Vermont, and Washington. For each of these states, the Earth and space sciences domain is included to the equivalent extent as the life and physical sciences.

To assess whether and where the Earth and space sciences are also included in the states that have not adopted the NGSS, AGI reviewed their secondary science standards as given on their SEA websites. The review was solely to identify if Earth and space science topics were included in each state's standards and to what extent--not to evaluate the quality of those standards. The topics in states' standards included Earth systems interactions, plate tectonics, weather, climate, Earth's changes over time, astronomy, oceanography, Earth structure, surface processes, Earth resources, natural hazards, and others. The results of this analysis revealed that Earth and space science concepts are included in the state secondary science standards of each of the thirty states that have not adopted the NGSS. Each of these states also includes the life and physical sciences within their standards.

⁸ State Education Agency (SEA) means the state department of education or other agency primarily responsible for the supervision of public elementary and secondary schools.

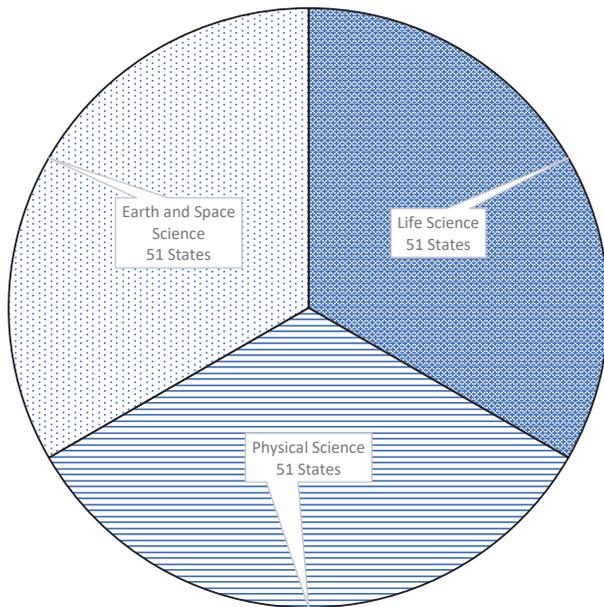
⁹ National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

¹⁰ American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

¹¹ Achieve, Inc. (2013). *Next generation science standards*. Retrieved from <http://www.nextgenscience.org/next-generation-science-standards>.

¹² National Research Council. (2012). *A Framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Figure 1: Science Content in Secondary Standards



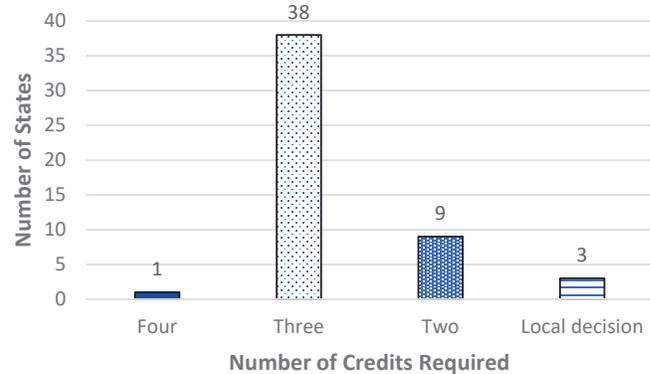
b. To what extent are students required to learn Earth and space science topics?

Graduation requirements ensure that all students in a state are exposed to and receive specific science content. Forty-seven states, plus the District of Columbia, have requirements for graduating high school and earning a diploma. These are expressed as the minimum courses to be completed by a high school student prior to graduation. Individual school districts or local education agencies may adopt graduation requirements above and beyond those mandated by the state. For Colorado, Nebraska, and Vermont, minimum graduation requirements are determined at the local level.

As discussed previously, the Earth and space sciences are represented in the science education standards of the District of Columbia and every state in the nation. To assess whether this equality was borne out in practice, AGI examined the graduation policy of each state to determine science course requirements for high school students. Except for Colorado, Nebraska, and Vermont, states require between two and four science credits¹³. Most states (n = 38) require at least three credits of science prior to graduation. Nine states require two credits while only one state requires four credits.

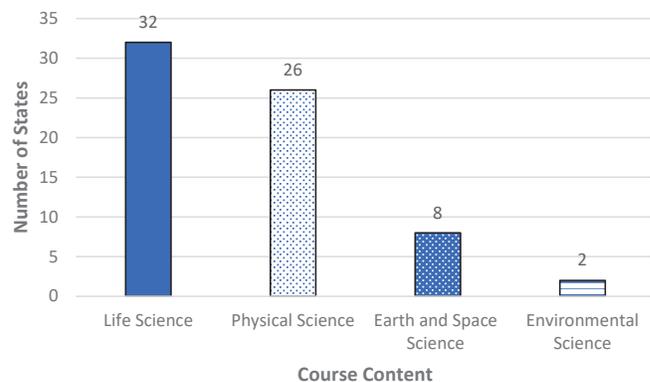
¹³ The default assumption is that one credit equals a year-long science course.

Figure 2: Number of Science Credit Requirements for Graduation, by State



In terms of course specificity, states define the content for fulfilling course requirements differently. Two states require a year-long Earth/environmental science course for graduation, whereas thirty-two states require a year-long life science¹⁴ course and twenty-six states require a year-long physical science¹⁵ course for graduation. Eight states require the study of Earth and space science concepts as a requirement for graduation. Twenty-nine states accept an Earth and space sciences course for graduation. Of these, thirteen specifically state that the science requirement must be “laboratory-based.” Fourteen states and the District of Columbia have science course requirements but do not mandate the content of those courses. Of these, five specifically state that the science requirement must be “laboratory-based.”

Figure 3: Number of States Requiring Specific Science Courses for High School Graduation



¹⁴ The definition of a life science course varies from state to state, but typically encompassed biology or biological science.

¹⁵ The definition of a physical science course varies from state to state, but typically encompassed physical science, chemistry, and/or physics.

Findings: Monitoring Systems

2. To what extent is student learning in the Earth and space sciences being monitored at the secondary level?

a. How often, and in which grades, are states administering assessments in science at the secondary level?

Statewide assessments are annual, summative measurements of student achievement that are used, along with many other school and classroom assessments, to evaluate student learning. The *Every Student Succeeds Act* (ESSA) calls for statewide assessments in reading and mathematics every year from grades three through eight, plus once in high school.¹⁶ Statewide assessments in science also occur every year but must only be administered once per grade band 6-9 and once per grade band 10-12. Consequently, states administer statewide assessments in science in different grades throughout middle and high school. At the 6-9 grade band level, five states test students at more than one grade: Arkansas, Louisiana, South Carolina, Tennessee, and Utah. One state assesses students at grade 6, four states at Grade 7 and forty-one states at grade 8. Arkansas also administers an assessment in science at grade 9.

Table 1: **Statewide Assessments in Science for Middle School – Grades Tested**

Grade Tested	States
Grade 6	AR, IN, LA, SC, TN, UT
Grade 7	AL, AR, ID, KY, LA, NM, TN, UT
Grade 8	AK, AR, AZ, CA, CO, CT, DE, DC, FL, GA, HI, IL, IA, KS, LA, ME, MD, MA, MI, MN, MS, MO, MT, NE, NV, NH, NJ, NY, NC, ND, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VT, VA, WA, WV, WI, WY
Grade 9	AR

For all states, the format of the statewide assessment in science that is administered in grades 6-9 is comprehensive. This means that it is administered to all students at a specific grade level and covers a variety of topics. For

¹⁶ "Every Student Succeeds Act (ESSA)," *Every Student Succeeds Act (ESSA)* | U.S. Department of Education. Retrieved from <https://www.ed.gov/essa>.

grades 10-12, the statewide assessment in science takes one of two forms: either comprehensive or end-of-course. End-of-course assessments are taken by students at the end of a specific course of instruction (e.g., biology) and focus on the subject matter of that course. These can occur at any grade level. Nineteen states, plus the District of Columbia, administer end-of-course assessments in science. Nine states administer a comprehensive assessment in grade 10 and sixteen states in grade 11. Six states allow districts to select the high school grade level at which the comprehensive assessment is administered.

Table 2: **Statewide Assessments in Science for High School – Grades Tested**

Grade Tested	States
End-of-Course Assessment	DE, DC, FL, GA, HI, ID, IL, IN, LA, MA, MS, MO, NY, NC, PA, SC, TN, TX, UT, VA
Grade 10 Comprehensive Assessment	AL, AK, AR, CO, IA, KY, MT, NV, WY
Grade 11 Comprehensive Assessment	CT, KS, ME, MI, NE, NH, NJ, NM, ND, OK, RI, SD, VT, WA, WV, WI
Grade 10, 11, or 12 Comprehensive Assessment	AZ, CA, MD, MN, OH, OR

b. What is the content of statewide assessments in science at the secondary level?

Because state standards include Earth and space science concepts in approximately the same quantity as the life and physical sciences, AGI set out to determine whether statewide assessments in science evaluate students' understanding of Earth and space science concepts to the same extent as their understanding of life and physical science concepts.

Earth and Space Science Concepts Assessed

Forty-nine states, plus the District of Columbia, assess Earth and space science concepts at the secondary level. Of these, nineteen states assess Earth and space science concepts only at the middle school level; no states assess Earth and space science concepts only at the high school level, and thirty-one states assess Earth and space science concepts at both the middle and high school levels.

Life Science Concepts Assessed

Fifty states, plus the District of Columbia, assess life science concepts at the secondary level. Of these, no states assess life science concepts only at the middle school level; no states assess life science concepts only at the high school level, and fifty states, plus the District of Columbia, assess life science concepts at both the middle and high school levels.

Physical Science Concepts Assessed

Fifty states, plus the District of Columbia, assess physical science concepts at the secondary level. Of these, sixteen states assess physical science concepts only at the middle school level; no states assess physical science concepts only at the high school level; and thirty-five states assess physical science concepts at both the middle and high school levels.

Figure 4: States Assessing Life Science, Physical Science, and Earth and Space Science Concepts on Statewide Assessments in Science

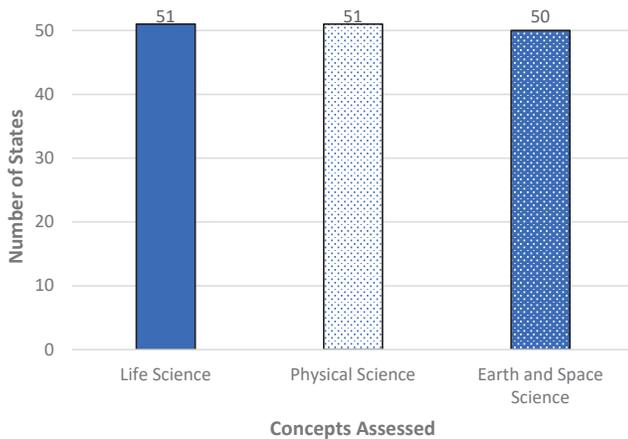


Figure 5: States Assessing Life Science, Physical Science, and Earth and Space Science Concepts in Both Middle and High School

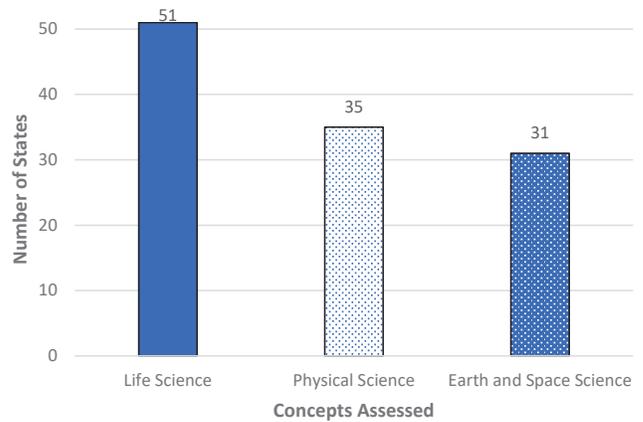
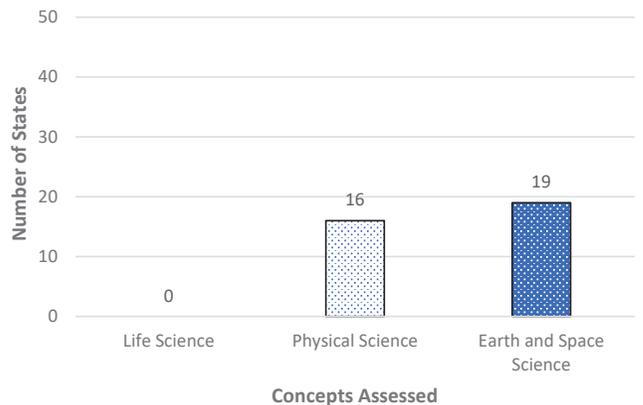


Figure 6: States Assessing Life Science, Physical Science, and Earth and Space Science Concepts in Middle School Only



- c. How does the content of statewide assessments in science that are end-of-course compare to statewide assessments in science that are comprehensive?

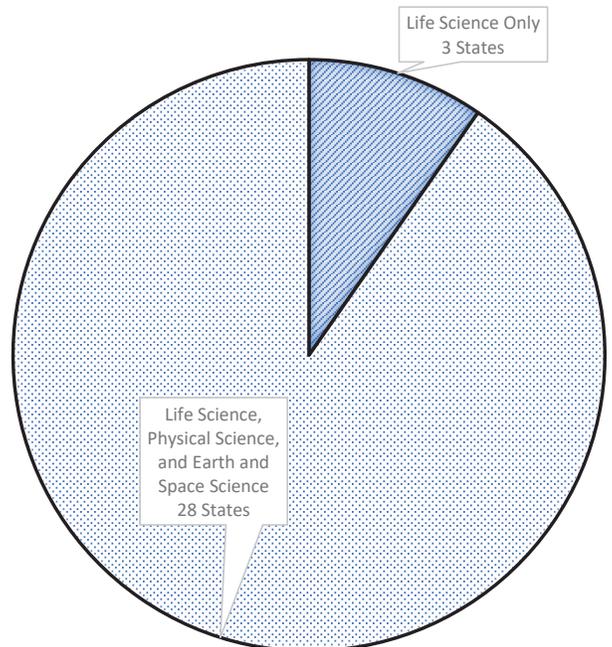
As stated previously, statewide assessments in science for grades 10-12 that are end-of-course are administered by nineteen states, plus the District of Columbia. All these states offer an assessment in biology. Seven states offer additional end-of-course assessments. Two states offer a physical science assessment, five states offer a chemistry assessment, three states offer a physics assessment, three states offer an Earth science assessment, and one state offers a technology/engineering assessment.

Table 3: **Course Type and End-of-Course Statewide Assessments in Science**

State	Biology	Chemistry	Physics	Physical Science	Earth Science	Technology/ Engineering
DE	X					
DC	X					
FL	X					
GA	X			X		
HI	X					
ID	X	X				
IL	X					
IN	X					
LA	X					
MA	X	X	X			X
MS	X					
MO	X			X		
NY	X	X	X		X	
NC	X					
PA	X					
SC	X					
TN	X					
TX	X					
UT	X	X	X		X	
VA	X	X			X	
TOTAL	20	5	3	2	3	1

The statewide assessment in science in grades 10-12 for the remaining thirty-one states is a comprehensive assessment. The assessment of every one of these states contains questions in which students consider life science concepts. The assessment of twenty-eight states contains questions in which students must also consider physical science as well as Earth and space science concepts.

Figure 7: **Science Content of the 31 States that Administer Statewide Science Assessments that are Comprehensive**



Findings: College Preparedness

3. What are the expectations of colleges and universities for the learning of the Earth and space sciences by high school students?

a. To what extent are students required to learn Earth and space science topics?

As stated previously, with only three exceptions, states require between two and four credits of science to graduate from high school. Also, an examination of the types of prerequisite science courses for graduation revealed that states place a significantly greater emphasis on the life sciences and physical sciences over the Earth and space sciences.

To determine the alignment of course requirements in the Earth and space sciences for high school graduation to the admission requirements of four-year colleges or universities, AGI examined the acceptance policies of 261 four-year institutions of higher learning. The high school science course admission requirements for at least four colleges and universities in each state and the District of Columbia were reviewed. Colleges and universities were selected in order that both public and private institutions of various sizes be represented. First, information was collected from the admissions policy provided on the web site of each institution. Then, AGI staff contacted admissions offices directly to clarify course requirements and the acceptance of a high school Earth and space sciences course for admission.

Table 4: **Examples of the Required and Recommended Science Coursework for Admission**

Institution	High School Course Recommendations for Science
University of Kansas	Complete three units during high school from the following, one of which must be chemistry or physics: <ul style="list-style-type: none"> • Biology • Advanced biology (second-year biology) • Earth/space science • Chemistry • Physics • Principles of technology • Physical science¹⁷
Fort Hays State University	Natural Science: 3 approved units, one of which must be a full unit of Chemistry or Physics ¹⁸
Central Washington University	2 years of Science ¹⁹
Virginia State University	2 units of Science (must include a laboratory science, i.e. Biology, Chemistry or Physics) ²⁰
University of South Carolina	Laboratory science - 3 units 2 units from different fields: biology, chemistry, physics or Earth science 1 additional unit from biology, chemistry, physics or earth science or any other laboratory science with biology, chemistry, physics and/or earth science as a prerequisite ²¹

¹⁷ KU Undergraduate Admissions, College Prep Curriculum. Retrieved from <https://admissions.ku.edu/freshman-requirements-deadlines/college-prep-curriculum>

¹⁸ Fort Hays State University, Admissions, Qualified Admissions Pre-College Curriculum. Retrieved from <https://www.fhsu.edu/admissions/qualified-admissions-pre-college-curriculum/index>

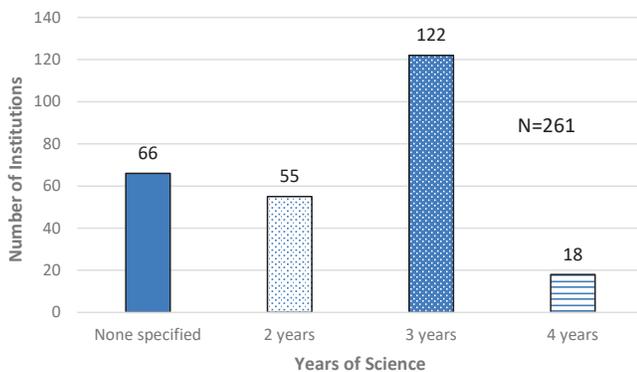
¹⁹ Central Washington University, Admissions, Freshman. Retrieved from <https://www.cwu.edu/admissions/freshman>

²⁰ Virginia State University, Admissions, Freshman Requirements. Retrieved from <http://www.vsu.edu/admissions/apply/freshman-apply/freshman-requirements.php>

²¹ University of South Carolina, Office of Undergraduate Admissions, Required High School Courses. Retrieved from https://sc.edu/about/offices_and_divisions/undergraduate_admissions/requirements/for_freshmen/required_high_school_courses/index.php

Of the 261 admission policies that were reviewed, sixty-six institutions (25%) did not specify any high school science coursework for incoming first-year students. Rather, the minimal standard for these institutions was simply that entering students be graduating from an accredited high school. For these institutions, the courses required are determined by the high school's requirements as to what is needed to graduate. All courses are looked at and accepted, as long as they are a part of the high school's curriculum. 195 admission policies (75%) suggested that applicants complete a certain number of years of high school science to be eligible for admission. Of these, 122 (47%) required students to have three years of science. Fifty-five (21%) expected students to have two years while only eighteen (7%) expected students to have four years of science.

Figure 8: Recommended Number of Years of High School Science to Prepare for College

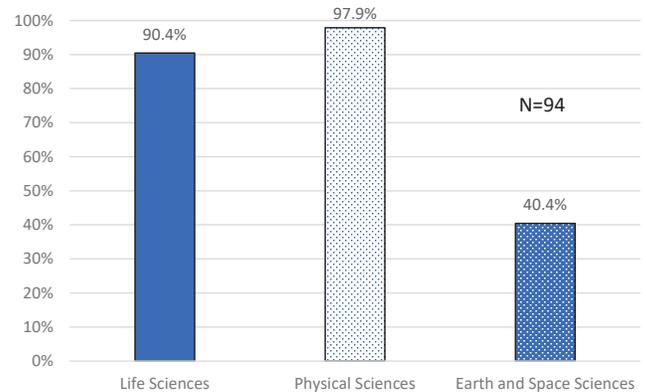


The suggested coursework in science that prepares high school students for college varied from one institution to another. Of the 195 institutions that suggested that students complete a certain number of years of science, 101 (52%) did not provide any specific information about the scientific disciplines of the coursework that would satisfy the requirement. The remaining 94 (48%), however, explicitly identified course types that were required or recommended for satisfying the requirements, either in part or completely. Of these 94 institutions, eighty-five (90%) specified courses in the life sciences²², ninety-two (98%) specified courses in the physical sciences²³, and thirty-eight (40%) specified courses in the Earth and space sciences.

²² The definition of a life science course varies, but typically encompassed biology or biological science.

²³ The definition of a physical science course varies, but typically encompassed physical science, chemistry, and/or physics.

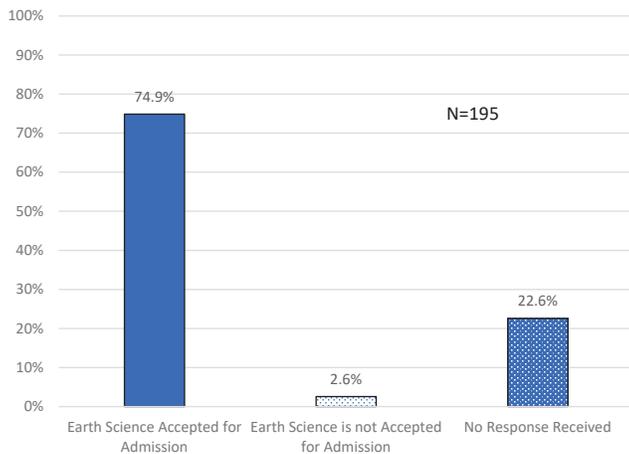
Figure 9: Course Disciplines Recommended to Prepare for College



For each of the 101 institutions that suggested students complete a certain number of years of science but did not list specific courses for admission, the admissions officer was contacted and asked whether they would accept an Earth and space sciences course for admission purposes. Of the 72 responses received, 70 stated that an Earth and space sciences course would be acceptable for admission while only two stated it would not. Additionally, admissions officers from the institutions that specified courses in the life sciences and/or physical sciences (but not the Earth sciences) were contacted and asked whether they would accept an Earth and space sciences course for admission. Of the 41 contacted, 38 stated that they would.

This means that of the 195 institutions that suggested that applicants complete a certain number of years of high school science to be eligible for admission, 146 (75%) would accept an Earth and space sciences course for admission. Only five (3%) stated they would not, while no responses were received for the remaining forty-four institutions (23%).

Figure 10: Institutions accepting an Earth and Space Sciences course for admission



b. To what extent are high school students able to pursue advanced courses in the Earth and space sciences?

Advanced Placement (AP) courses are frequently perceived as indicators of which high school science subjects are acceptable to colleges. This is important, since a student’s intent in taking AP courses is often to gain college credit by scoring highly enough on the relevant AP examination.

Currently, there are AP examinations and courses for biology, chemistry, physics and environmental science²⁴. However, there is no Advanced Placement examination or course for the Earth and space sciences. In contrast, AP environmental science is offered to some extent in all fifty states, plus the District of Columbia. Students taking the AP examination for environmental science can range from the tens to the thousands/state²⁵, but this only represents a subset of all students taking the AP course in this topic area. It is worth noting that a review of the most recent AP environmental science course topics revealed that a significant number of those topics cover Earth science concepts.²⁶ The presence of this Earth science content, however, is not reflected in the title of the course or the examination.

²⁴ College Board. (2018). AP Courses and Exams. Retrieved from <https://apcentral.collegeboard.org/courses>

²⁵ College Board. (2014). *The tenth annual AP report to the nation*. Retrieved from <https://research.collegeboard.org/programs/ap/data/nation/2014>

²⁶ College Board. (2013). Environmental science course description. Retrieved from <https://secure-media.collegeboard.org/apc/ap-environmental-science-course-description.pdf>

Findings: Initial Teacher Preparation (ITP)

4. To what extent are new teachers being actively prepared for Earth and space sciences instruction?
- a. What indicators are there that ITP programs are designed to prepare teachers to teach the Earth and space sciences effectively at the secondary level?

Initial Teacher Preparation (ITP) programs are offered by postsecondary institutions to prepare those aspiring to a career in teaching. These programs provide formal professional preparation for classroom instruction to teacher candidates. Typically, candidates can select from a range of endorsement areas or teaching fields within a program. For secondary-level teacher candidates, these include: Art, Music, Social Studies, English, Bilingual Education, Mathematics, and Science. In some cases, the candidates can specialize within those fields (e.g., becoming licensed specifically in Biology, Chemistry, or Earth and Space Science, or others). Candidates are educated in their disciplines as well as in theories of learning and instructional methods. Upon completion of a program, candidates are eligible to receive a professional educator’s certificate (i.e. license) in their endorsement area from the state.

States control the quality of ITP programs through several mechanisms. First, SEAs set requirements and standards that ITP programs must meet. Second, many states encourage or require institutions to be accredited by an accrediting agency, such as the Teacher Education Accreditation Council (TEAC), or the Council for the Accreditation of Educator Preparation (CAEP). Finally, states require that candidates meet certain standards for certification. These include passing state knowledge tests and completing coursework in specific endorsement areas.

To determine the preparation of secondary level teachers for Earth and space sciences instruction, AGI carried out a survey of accredited ITP programs from across the United States. Surveys were completed by science department chairs, deans, directors, programs coordinators and professors between October and November of 2018. Survey questions centered on the requirements and standards of ITP programs and the availability of Earth and space sciences content and instructional approaches to secondary level teacher candidates focusing specifically on science education.

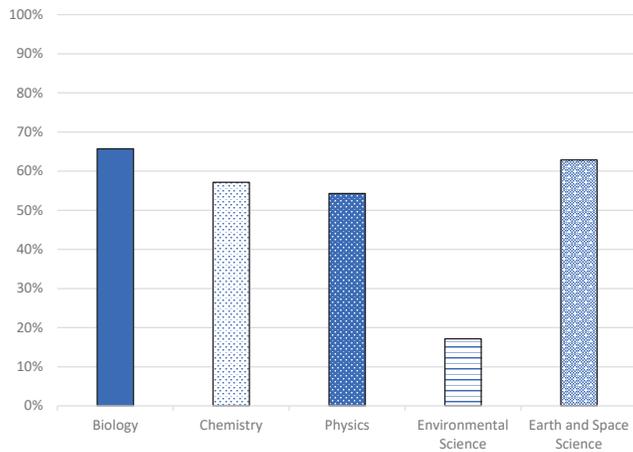
Results were obtained from thirty-five institutions of higher learning from twenty-four different states. The number of licensed secondary-level science teachers graduating from these programs in the last 12 months ranged from less than fifty (77% of programs), 50 to 100 (11.5% of programs) to more than 100 (11.5% of programs). Fifteen of the institutions surveyed (43%) offered a minor and/or specialization in a subject area which includes a geoscience field.

Table 5: Initial Teacher Preparation (ITP) State Institution Responses

State	# Responses	State	# Responses
Alabama	1	Michigan	1
California	2	Missouri	1
Colorado	1	New Jersey	1
Florida	2	New York	1
Georgia	1	North Carolina	2
Hawaii	1	North Dakota	1
Illinois	2	Ohio	2
Indiana	2	Oregon	2
Iowa	2	Pennsylvania	1
Kansas	2	South Carolina	1
Maine	1	Tennessee	1
Maryland	1	Texas	3

Institutions guide the development of a teacher candidate through an ITP program according to a plan of study that delineates the coursework that must be completed by the candidate. For the ITP programs that were surveyed, the progress of candidates in their plan of study is measured by the number of required courses they have completed or by completed credit hours, which can be translated into coursework. Within a plan of study, thirty respondents (86%) indicated that candidates are required to take some number of science courses. The specific disciplines of those courses varied among programs with twenty-three (66%) requiring biology, twenty (57%) requiring chemistry, nineteen (54%) requiring physics, six (17%) requiring environmental science, and twenty-two (63%) requiring geoscience (also known as Earth and space science).

Figure 11: ITP Science Course Requirements by Science Discipline



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 (86%) of the respondents reported that candidates within their program develop competency in applying the Next Generation Science Standards (NGSS) to classroom instruction.

b. How do ITP programs require candidates to demonstrate their readiness to teach the Earth and space sciences?

A variety of approaches can be used to assess and monitor a teacher candidate’s progress in an ITP program. These include written tests of teacher knowledge and skills as well as performance-based assessments that capture how candidates apply what they have learned to their teaching practice. Respondents were asked to provide examples in which candidates demonstrate their competency in Earth and space sciences teaching. Given the prominence of the NGSS in ITP programs, respondents were first asked to describe the ways in which candidates demonstrate the application of the NGSS to classroom instruction. Respondents reported a range of approaches, including: teaching portfolio artifacts (69%), lesson plans (83%), content knowledge examination (37%), field trip experience (20%), and the development of a collection (e.g., rock collection) (0%). Next, respondents were asked the extent to which the same examples were used to demonstrate competence in Earth and space sciences instruction. In this context, respondents reported: teaching portfolio artifacts (37%), lesson plans (57%), content knowledge examination (51%), field trip experience (20%), and the development of a collection (e.g., rock collection) (6%).

Figure 12: Approaches for Demonstrating Competency in the Application of the NGSS

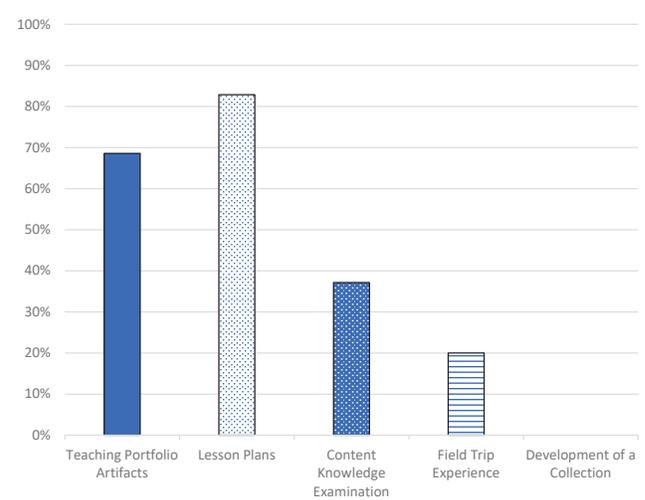
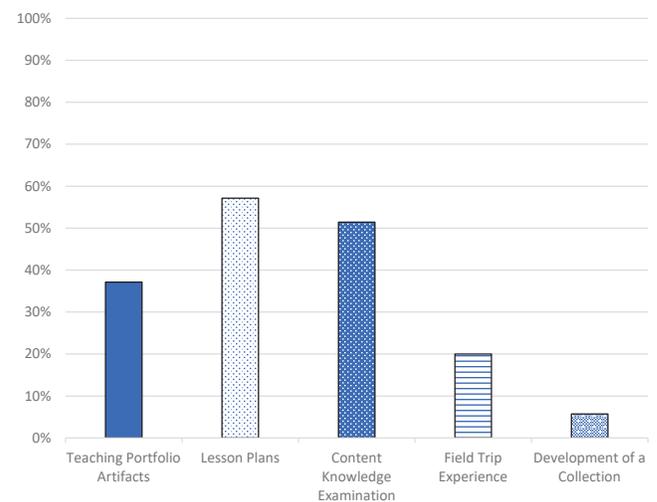


Figure 13: Approaches for Demonstrating Competency in Earth and Space Sciences Instruction



c. How do ITP programs maximize their resources for Earth and space sciences education?

As indicated, most ITP programs require candidates to take science courses. Among programs, subject-matter science courses for teachers vary in level and rigor. In many institutions, faculty from teacher education and disciplinary departments work together to align the experiences of teacher candidates. In some institutions,

faculty coteach courses across content and pedagogy, while in others, there is less alignment. AGI asked respondents to describe the involvement of subject-matter experts in the Earth and space sciences in their programs. 57% of respondents (n = 20) reported their institution having an academic division that focuses on one or more geoscience disciplines (e.g., “geology department,” “astronomy department,” or “school of geoscience”).

Of those, when asked about the collaboration between the faculty of that division and the faculty of the ITP program, half (n = 10) reported that interaction to be close and/or frequent (i.e., high degree of collaboration and/or contact). The remaining reported interaction to be minimal or limited (i.e., low degree of collaboration and/or contact). When asked about dual appointments, only three respondents reported having faculty members with a dual appointment in a geoscience academic division and their ITP program.

Coursework is the primary method for delivering science content to teacher candidates. However, certain disciplines, such as the Earth and space sciences, lend themselves to learning outside of the classroom. 51% of respondents (n = 18) reported that their programs include off-campus experiences that are intentionally designed to relate to the Earth and space sciences. Specific examples of field experiences included visits to: museums, aquariums, planetariums, marine sanctuaries, wildlife areas, and nature centers. Additionally, some respondents reported field trips as an Earth and space sciences course component, such as astronomy viewing sessions, examination of geologic outcrops and structures, fossil collection, and the use of weather stations.

Discussion

This report, while only a snapshot of a landscape that is continually shifting over time, provides a perspective on the current state of the Earth and space sciences in U.S. secondary education. Although the Earth and space sciences are accorded equal status with the life and physical sciences in national standards and guidelines, this emphasis is not manifested in practice, as indicated by state graduation requirements and secondary science assessments. The absence of an AP Earth and space sciences course and examination further attests to the subject's subordinate status as compared to other sciences.

Furthermore, when colleges and universities list the science courses that they expect students to have completed in high school; when stated, these courses usually include biology, chemistry, and/or physics. However, many of these colleges and universities also accept Earth and space science courses. Additionally, most colleges and universities that do not specifically outline their science requirements find an Earth and space sciences course acceptable for admission.

Typically, secondary-level initial teacher preparation programs require the completion of a set of courses in an endorsement area as well as a core set of professional education courses. For programs with a science education focus, required courses in the Earth and space sciences are common. Additionally, Earth and space science, as part of an area of specialization, is offered by many initial teacher preparation programs. Many programs also include opportunities for exposure to the Earth and space sciences through off-campus experiences. Most institutions with ITP programs have an academic division with an Earth and space sciences focus. However, the interaction between that division and the division administering the ITP program is not always close.

For the Earth and space sciences to be considered as equal in rigor and importance to the life sciences and the physical sciences, states will need to find ways to raise the status of the Earth and space sciences in their secondary programs. This could be accomplished through changes in the subject's relevance to graduation requirements, presence on assessments, the designation of Earth and space science courses as laboratory courses, through the establishment of an AP Earth and space sciences program, or through other methods yet to be developed. As the importance of the Earth and space sciences increases, more pre-service science teachers may opt for an Earth science endorsement or select Earth science courses as part of their training.

It is worth noting that students who do not receive a commensurate education in the Earth and space sciences are less prepared for the challenges and opportunities that await them in adult life, whether in competing in the global job market or making informed personal and voting decisions on such vital issues as resource use, climate change, natural hazards, space exploration and Earth stewardship. As stated in the preface to the Earth Science Literacy Principles:

Earth Science Literacy is especially important at this time in history. There are many challenges facing humanity—dwindling energy and mineral resources, changing climates, water shortages—directly relating to the Earth sciences. There are many difficult decisions that governments, local and national, will have to make concerning these issues, and how well humans survive the twenty-first century will depend upon the success of these decisions. We need governments that are Earth science literate.

Human history is a record of the creativity and ingenuity of people solving difficult problems. The solutions to the current Earth-science-related challenges will also come from human creativity, as individuals or corporate businesses. However, as our modern society and its needs have become increasingly complex, so have the solutions. It will take a deep and subtle understanding of Earth's systems for future generations to be able to feed, clothe, house, and provide a meaningful existence for all humans. We need citizens and businesses that are Earth science literate.²⁷

²⁷ Wysesession, M. E., D. A. Budd, K. Campbell, M. Conklin, E. Kappel, J. Karsten, N. LaDue, G. Lewis, L. Patino, R. Reynolds, R. W. Ridky, R. M. Ross, J. Taber, B. Tewksbury, and P. Tuddenham, Developing and Applying a Set of Earth Science Literacy Principles, *Journal of Geoscience Education*, Vol. 60, No. 2, 95-99, 2012.

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Winning photo of Earth Science Week's 2017 Photo Contest, themed "Earth and Human Activity."
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