United States

Katie Herz
Teresa Neidorf
Alka Arora
Charles Yeomans
American Institutes for Research

Introduction

Overview of Education System

Public education is decentralized in the United States, with each state governing its own school system. States oversee all levels of primary and secondary education[a] and direct (or delegate to local authorities) all the political, administrative, and fiscal aspects that would generally be directed by a ministry of education in a centralized system. The degree of a state's control, in comparison to that of local authorities, depends on state laws and regulations, but education is the largest budget item in every state.[1] State education departments distribute federal and state funding, establish graduation and teacher certification requirements, provide curriculum guidance, conduct student assessments, and are responsible for ensuring that efficient and effective school opportunities are made available to every eligible child in the state. In the 2016–2017 school year, an estimated $1.34 trillion was spent nationwide to fund all levels of education.[b,2]

States delegate the operation of elementary and secondary schools to local governments, which, in turn, have traditionally assigned the task of running schools to elected or appointed school boards. Local school boards raise funds, establish policy and operating regulations, and hire superintendents to manage and operate the school district. The school district is responsible for curriculum decisions, the implementation of standards, facilities construction and maintenance, and the operation of school programs. In the 2015–2016 school year, there were about 13,600 public school districts in the United States.[3]

Of students attending public and private elementary and secondary schools in the fall of 2015, approximately 90 percent attended public schools and approximately 10 percent attended private schools.[4] Parents also have the option to send their children to charter schools. Charter schools are public schools that operate with freedom from many of the local and state regulations that apply to traditional public schools. In the 2015–2016 school year, there were 6,855 charter schools in the

---

[a] States also have some oversight of postsecondary institutions, such as community colleges and state universities.

[b] Federal funding for public education includes funds not only from the U.S. Department of Education, but also from other federal agencies, such as the U.S. Department of Health and Human Services' Head Start program and the U.S. Department of Agriculture's School Lunch program.

United States.[5] If a student attends a school that the state has identified as needing comprehensive support and improvement, the district may offer the student the option to transfer to another public school in the district.[6]

In the United States, public education refers to the system by which federal, state, and local governments provide the funding and oversight for free public schools for all children from kindergarten through Grade 12 (when most students are age 18). Although the age at which students start school varies by state, children typically begin kindergarten at age 5. Kindergarten, although free, is not compulsory in most states. Most schools require attendance at ages 6 or 7 until ages 16 to 19. Publicly funded education ends when a student graduates from high school or finishes Grade 12. The maximum age at which students are offered free education also varies among states.[7]

The federal government also plays a role in state education systems. Since 1917, the federal government has offered states funding to support various programs, including vocational education as well as mathematics, science, and foreign language programs.[8] Since the 1960s, the federal government also has promoted equal educational opportunities, starting with the Elementary and Secondary Education Act (ESEA). The act made equal education requirements a condition for federal funding and provided aid to high-poverty schools to improve the learning of educationally disadvantaged children. In 1980, the federal Office of Education became the U.S. Department of Education, a Cabinet-level department with the additional responsibilities of promoting improvements in the quality and usefulness of education through federally supported research, evaluation, and sharing of information. In 2002, ESEA was reauthorized as the No Child Left Behind Act (NCLB), which made federal funding conditional on educational improvements. Specifically, NCLB required states to ensure that all students were proficient in reading, mathematics, and science by the 2013–2014 school year based on state academic content standards. In December 2015, NCLB was replaced by the Every Student Succeeds Act (ESSA). In comparison to NCLB, ESSA gives states more flexibility on the issue of school accountability, with competitive programs included to encourage innovation, evidence-building, and the replication of high-performing schools.[9]

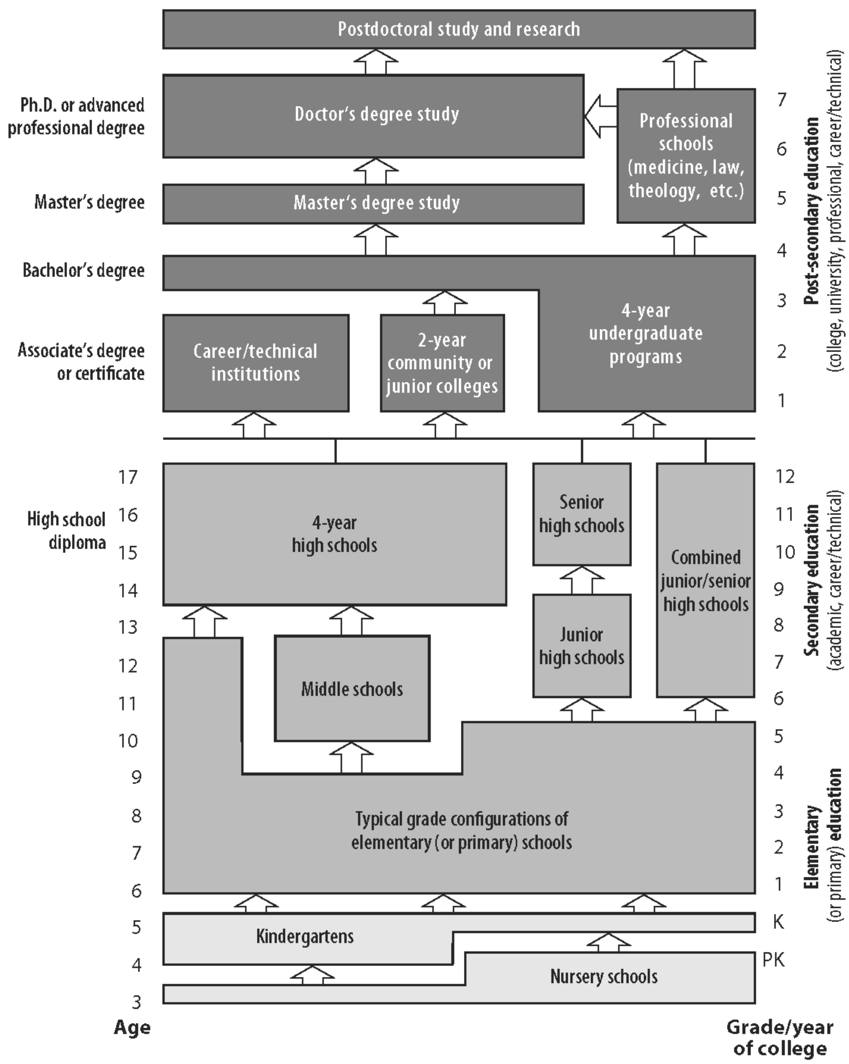
School districts organize grades into:

- Elementary schools (sometimes called primary schools)—generally including kindergarten and Grades 1 to 4, 1 to 5, or 1 to 6
- Middle schools (sometimes called intermediate or junior high schools)—commonly consisting of Grades 5 to 8, 6 to 8, 7 to 8, or 7 to 9
- High schools (sometimes called secondary schools)—typically Grades 9 to 12 or 10 to 12

Before the age of 5, children often attend preschool (sometimes called nursery school). The federal Preschool for All Initiative provides preschool access to low- and moderate-income 4-year-old children.[10] At age 5, a child typically enters kindergarten.

Academic grades are recorded in student transcripts, which are used to document the completion of graduation requirements and for competitive admission to higher education. After graduation from high school, students may continue their education by enrolling in public or private universities or colleges, community colleges, or vocational or technical schools (see Exhibit 1).

Exhibit 1: The Structure of Education in the United States[11]



Note: The grade configurations shown are not the only possible routes of educational attainment. For example, some areas of study permit entering a doctoral program directly out of an undergraduate program, which generally takes four years or more to complete.

Source: Snyder, T.D., & Dillow, S.A. (2017). *Digest of education statistics 2017 (NCES 2017-011)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

There is no national curriculum in the United States. State education agencies and local school districts are responsible for subject area curriculum frameworks. States are also responsible for implementing accountability systems tied to curriculum standards. Local school districts, and sometimes individual schools, determine how to implement the curriculum standards. For all states and districts, the curricula for mathematics and science prescribe a series of topics, content standards, and indicators of student achievement.

Over the last 10 years, national collaborations have given way to shared mathematics and science standards across states, and a common approach to curriculum priorities and frameworks. Started in 2009, the Common Core State Standards (CCSS) initiative is a state-led effort sponsored by the National Governors Association and the Council of Chief State School Officers. The initiative aims to bring diverse state curricula into alignment by establishing a set of educational standards for English language arts and mathematics that states can voluntarily adopt. As of summer 2019, 39 states, the District of Columbia, four U.S. territories, and the Department of Defense Education Activity[c] had either voluntarily adopted the CCSS Initiative's mathematics standards, or their state standards are largely based on or influenced by them.[12] The CCSS calls for several key shifts in mathematics including (1) a greater focus on fewer topics, (2) establishing coherence by linking topics and thinking across grades, and (3) pursuing three aspects of rigor in the major work of each grade: conceptual understanding, procedural skills and fluency, and application.[13]

In 2012, the National Research Council (NRC) published "A Framework for K-12 Science Education," which provided a vision for science education in the United States.[14] Based on the recommendations in the NRC framework, new science standards for kindergarten through Grade 12 (known as K–12), called Next Generation Science Standards (NGSS), were published in 2013.[15] The NGSS were developed through a collaborative, state-led effort (managed by Achieve, Inc.). In addition to states, the NRC, National Science Teachers Association, and American Association for the Advancement of Science were critical partners in the development and review of the NGSS. As of summer 2019, 20 states and the District of Columbia had formally adopted the NGSS, and another 24 states had recently revised their state science standards based on recommendations in the NRC framework.[16]

The NGSS focus on a limited set of core ideas in the natural sciences and in engineering, technology, and applications of science that build coherently across the grade levels. The NGSS also emphasize the importance of crosscutting concepts that apply across disciplines, as well as the practices used by scientists and engineers that K–12 students should develop. The intent is a set of standards that provides a coherent, internationally benchmarked science education program for all K–12 students.[17]

Use and Impact of TIMSS

Since the late 1990s, TIMSS has played a role in U.S. education policy discussions, informed curricular reform efforts in the states, and been the principal vehicle for international

[c] The Department of Defense Education Activity is a federally operated school system (prekindergarten through Grade 12) for children of servicemen and servicewomen stationed in Europe, the Pacific, and the Americas.

benchmarking by the states. Moreover, public interest in TIMSS has remained high, as measured by requests for TIMSS data from the National Center for Education Statistics (NCES). Another way to assess public interest in TIMSS is by the number of people looking for TIMSS information on the NCES website, the primary U.S. Department of Education internet source for information on TIMSS. In 2018, the number of visits to the NCES website for information about TIMSS averaged 13,000 per month.[18]

In the late 1990s, when the results from the first TIMSS assessment were released, TIMSS became a standard policy citation to emphasize that U.S. student performance in mathematics and science was not leading the world. Between 1999 and 2002, state and national educational reformers across the country regularly used the results of TIMSS 1995 and TIMSS 1999 to make this point in editorials and articles.[d] During these years, more than three dozen congressional statements, debates, and bills cited TIMSS results to justify passing specific education bills or to call for reforms in education to keep the United States internationally competitive.[e] In 2002, the U.S. Congress passed two major reforms of U.S. education legislation—the No Child Left Behind Act and the Education Sciences Reform Act—both of which referred to TIMSS and made exceptions in the law to ensure continued national and state participation in TIMSS.[f]

Advocates have used TIMSS results to improve education in science, technology, engineering, and mathematics (STEM) subjects. For example, a 2008 report to the U.S. Congress on promoting STEM education relied on comparisons of U.S. achievement in TIMSS with that of other nations as a basis for understanding the current state of mathematics and science education. The report served as a justification to promote further investment in STEM programs.[19]

TIMSS data on curricula in top-performing nations have informed curricular reform efforts in various states. TIMSS curricular data have played a role in the CCSS Initiative's successful effort to develop a clear and consistent framework to guide teaching practices for mathematics in every state. Experts who guided the development of the CCSS cited conclusions from TIMSS in their research, especially focusing on the curriculum of high-performing countries.[20] TIMSS also has served as a resource for development of the science framework for the National Assessment of Educational Progress (NAEP) [21] and the NGSS.[22] In addition, the NGSS developed its international benchmarking standard from analysis of the top-performing countries in TIMSS.

---

d See the results of searches for "TIMSS" on LexisNexis and the Education Resources Information Center (ERIC) for 1999 to 2002.

e See the results of searches for "TIMSS" under legislative sessions 106 through 109 at http://thomas.loc.gov/home/LegislativeData.php.

f The No Child Left Behind Act of 2002 (P.L. 107-110) refers to TIMSS in Sec. 2202 (Grants For Mathematics and Science Partnerships) when it permits states seeking specific grants to use the results from "an International Mathematics and Science Study assessment" as a substitute for state mathematics and science assessment results for measuring "improved student academic achievement" and makes an exception for federal funding of TIMSS in Sec. 9529 (Prohibition on Federally Sponsored Testing) (www2.ed.gov/legislation/esea02/107-110.pdf). The Education Sciences Reform Act (20 USC Sec. 9543, P.L. 107-279) refers in Part C, Sec. 153 to TIMSS as a specific example of the type of data on educational activities and student achievement that NCES is mandated to collect to compare the achievement of U.S. students with their peers in foreign nations (https://www2.ed.gov/policy/rschstat/leg/PL107-279.pdf).

TIMSS has been the principal vehicle for international benchmarking by the states. In the first administration of TIMSS in 1995, five U.S. states participated as benchmarking participants to gain insight into how their students compared with their peers around the world. Since then, 18 states have taken part in TIMSS as benchmarking participants, in one or more assessment years.[23] In 2011, the National Center for Education Statistics initiated a NAEP-TIMSS linking study that used data from NAEP and the nine participating states in TIMSS 2011 to predict TIMSS scores for an additional 43 U.S. states and entities. The report, published in 2013, enabled states to compare their students' performance with that of students internationally.[24]

The Mathematics Curriculum in Primary and Lower Secondary Grades

In the United States, the curriculum frameworks of individual states vary, although a more unified approach to mathematics education has taken place across states over the past decade. Mathematics standards across the states increasingly emphasize learning mathematical content in the context of real-world situations while also focusing on computational thinking and mathematical fluency to solve problems and foster a deeper understanding.[25]

In 2009–2010, a state-led effort coordinated by the National Governors Association and the Council of Chief State School Officers (CCSSO) developed the Common Core State Standards for Mathematics (CCSSM) to bring greater focus and coherence to the teaching of mathematics. The CCSSM provide recommendations for what mathematics students should understand and be able to do starting in kindergarten and continuing through high school. In addition, the CCSSO has developed a list of tools, resources, and practices to help states implement the Common Core State Standards.[26] Although not all states have adopted the CCSSM, which are only guidelines for states in the development of their curriculum frameworks, the CCSSM have widely influenced mathematics education in the United States. As of August 2019, about three-quarters of students lived in states with mathematics education standards influenced by the CCSSM.

The CCSSM describe two dimensions of mathematics education: (1) mathematical content to be taught at each grade within key areas (e.g., number, algebra, measurement, geometry, and data), and (2) mathematical practices that mathematics educators at all levels should seek to develop in their students. The mathematical practices are the processes and skills that students need to develop and draw upon to succeed in mathematics, including:

- Making sense of problems and persevering in solving them
- Reasoning abstractly and quantitatively
- Constructing viable arguments and critiquing the reasoning of others
- Modeling with mathematics
- Using appropriate tools strategically
- Attending to precision

- Looking for and making use of structure
- Looking for and expressing regularity in repeated reasoning

Exhibits 2 and 3 summarize the topics that were commonly included in states' mathematics curricula during the 2018–2019 school year. Exhibit 2 focuses on upper elementary school (Grades 3 to 5), and Exhibit 3 focuses on middle school (Grades 6 to 8). These grade bands were selected because the curriculum grade structure in the United States varies by state, and some topics are taught across grade levels. Thus, Exhibits 2 and 3 will reflect the mathematics topics that are generally included in the curriculum frameworks covering the two TIMSS grades (4 and 8), although some topics may not be covered in all states by these specific grade levels. The mathematics topics in the exhibits are based on the TIMSS 2019 Curriculum Questionnaire topics at the corresponding grade levels (4 and 8), the content standards in the CCSSM for upper elementary school (Grades 3 to 5) and middle school (Grades 6 to 8), and the upper elementary and middle school mathematics standards from five states with large populations of kindergarten to Grade 8 students (California, Texas, Florida, New York, and Massachusetts).[g] Additional topics not included in the exhibits appear in some states' curricula. Moreover, specific curriculum frameworks at the state and district levels may include detailed grade-level instructional benchmarks, approaches to learning, and instructional resource material.

Exhibit 2: Mathematics Curriculum Topics in Upper Elementary School*

Area of Mathematics	Topics
Number	▪ Concepts of whole numbers, including place value and ordering ▪ Adding, subtracting, multiplying, and/or dividing with whole numbers ▪ Concepts of multiples and factors; odd and even numbers ▪ Concepts of fractions (fractions as parts of a whole or of a collection, or as a location on a number line) ▪ Adding and subtracting with fractions; comparing and ordering fractions ▪ Concepts of decimals, including place value and ordering; adding and subtracting decimals ▪ Number sentences (finding the missing number, modeling simple situations with number sentences) ▪ Number patterns (extending number patterns, finding missing terms)
Geometry	▪ Parallel and perpendicular lines ▪ Comparing and drawing angles ▪ Elementary properties of common two-dimensional geometric shapes (e.g., triangles, rectangles) ▪ Recognizing and drawing lines of symmetry

[g] Curriculum frameworks for the five states include the California Common Core State Standards: Mathematics (https://www.cde.ca.gov/be/st/ss/documents/ccssmathstandardaug2013.pdf); Texas Essential Knowledge and Skills for Mathematics (http://ritter.tea.state.tx.us/rules/tac/chapter111/index.html); Mathematics Florida Standards (https://www.fldoe.org/core/fileparse.php/5390/urlt/0081015-mathfs.pdf); New York State Next Generation Mathematics Learning Standards (http://www.nysed.gov/curriculum-instruction/new-york-state-next-generation-mathematics-learning-standards); and Massachusetts Curriculum Framework for Mathematics (http://www.doe.mass.edu/frameworks/math/2017-06revisions.pdf).

Area of Mathematics	Topics
	▪ Graphing points on the coordinate plane to solve real-world and mathematical problems
Measurement and Data	▪ Solving problems involving measurement, estimation of intervals of time, money, and mass ▪ Converting like measurement units within a given measurement system ▪ Measurement using mathematical tools (e.g., ruler and protractor) ▪ Finding and estimating areas, perimeters, and volumes ▪ Organizing data in pictographs, bar graphs, and line plots ▪ Reading data from tables, pictographs, and bar graphs ▪ Drawing conclusions from data displays

*Upper elementary school refers to Grades 3 to 5. This grade band covers the mathematics topics that are generally included in state curriculum frameworks for upper elementary school, but states differ in their curricular structure and the topics included at each grade.

Note: Curriculum topics listed in this exhibit are based on the TIMSS 2019 Curriculum Questionnaire at Grade 4, the Common Core State Standards in Mathematics (CCSSM) for Grades 3 to 5, and the upper elementary state curriculum frameworks in California, Texas, Florida, New York, and Massachusetts in place during the 2018–2019 school year. The topics listed are not exhaustive, as curriculum frameworks vary by state.

Exhibit 3: Mathematics Curriculum Topics in Middle School*

Area of Mathematics	Topics
Number	▪ Understanding negative numbers in the context of real-world contexts (e.g., temperature, height below sea level), including absolute value ▪ Comparing and ordering rational numbers ▪ Computing with rational numbers (fractions, decimals, and integers) ▪ Concepts of irrational numbers ▪ Solving problems involving ratios, proportions, and percent
Algebra	▪ Simplifying and evaluating algebraic expressions ▪ Working with radicals and integer exponents ▪ Solving simple linear equations ▪ Solving simple linear inequalities ▪ Solving systems of simultaneous linear equations (in two variables) ▪ Concepts of numeric, algebraic, and geometric patterns or sequences (extension, missing terms, generalization of patterns) ▪ Representation of functions as ordered pairs, tables, graphs, words, or equations ▪ Qualitative understanding of properties of linear functions (slopes, intercepts)
Geometry	▪ Properties of two- and three-dimensional geometric shapes (circles, cubes, rectangular prisms, cubes, triangular prisms, cylinders, cones, and spheres) ▪ Relationships between three-dimensional shapes and their two-dimensional representations ▪ Basic understanding of congruent and similar figures ▪ Understanding and applying the Pythagorean theorem ▪ Using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes ▪ Translation, reflection, and rotation

Area of Mathematics	Topics
Data, Statistics, and Probability	▪ Characteristics of data sets including mean, median, range, and shape of distribution ▪ Interpreting data sets (drawing conclusions, making predictions, and estimating values between and beyond given data points) ▪ Investigating patterns of association in bivariate data ▪ Using random sampling to draw inferences about a population ▪ Investigating chance processes and developing, using, and evaluating probability models

*Middle school refers to Grades 6 to 8. This grade band covers the mathematics topics that are generally included in state curriculum frameworks for middle school, but states differ in their curricular structure and the topics included at each grade.

Note: Curriculum topics listed in this exhibit are based on the TIMSS 2019 Curriculum Questionnaire at Grade 8, the Common Core State Standards for Mathematics for Grades 6 to 8, and the middle school state curriculum frameworks in California, Texas, Florida, New York, and Massachusetts in place during the 2018–2019 school year. The topics listed are not exhaustive, as curriculum frameworks vary by state.

The Science Curriculum in Primary and Lower Secondary Grades

In the United States, the curriculum standards of individual states vary, and the specific science curriculum taught at each grade may be determined at the local level. Students begin studying inquiry-based science in lower elementary school, focusing on observations and explanations related to familiar natural phenomena. The focus on scientific investigation and explanation of phenomena that starts in elementary school increases in sophistication in the middle school grades. Science in elementary school covers core concepts in the life, physical, and Earth and space sciences, which build progressively across the grades. In middle school, students study science in more depth, and the specific science courses that are taught vary across states, districts, and schools. Many schools teach integrated science courses in middle school that cover core concepts from across the life, physical, and Earth and space sciences that progress across the grades, although some place more emphasis on certain content areas at different grade levels. Other schools teach separate courses in the content domains starting in middle school (e.g., life science, physical science, and Earth and space sciences), although the order of these courses varies.

In 2013, new science education standards for elementary, middle, and high school students, called Next Generation Science Standards (NGSS), were published. The NGSS were developed through a collaborative, state-led process involving teachers, scientists, and leaders in science education from around the country and are based on the recommendations in "A Framework for K–12 Science Education" published by the National Research Council (NRC) in 2012. These national documents have had a major impact on state science standards over the past several years. The NGSS provide goals (student performance expectations) for certain grade levels but leave curricular and instruction decisions to states, districts, and teachers. The NGSS also provide tools and resources for schools and teachers to implement their science curricula. As of August 2019, nearly three-quarters of U.S. students lived in states with new science curriculum standards influenced by the NRC framework and the NGSS.

The NGSS describe three dimensions that are intended to be integrated in science education at all grade levels:

- Disciplinary core ideas that reflect content to be learned at each grade level in the natural sciences (life, physical, and Earth and space sciences) as well as in engineering, technology, and applications of science
- Crosscutting concepts—such as energy, matter, and systems—that reflect key underlying concepts that apply across the domains of science and unify the study of science and engineering
- Scientific and engineering practices that elaborate the processes and habits of mind in science and engineering that students should develop and apply, including:
  - Asking questions (for science) and defining problems (for engineering)
  - Developing and using models
  - Planning and carrying out investigations
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Engaging in argument from evidence
  - Obtaining, evaluating, and communicating information

The NGSS give equal emphasis to scientific inquiry and engineering design practices, and students are expected not just to learn content but to understand and develop the methods of scientists and engineers. An important facet of the standards is the integration of science content and scientific and engineering practices. This integration is a change from traditional science teaching, which typically either dealt with these areas separately or did not attempt to teach scientific and engineering practices.

Exhibits 4 and 5 summarize the topics that were commonly included in states' science curricula during the 2018–2019 school year. Exhibit 4 focuses on upper elementary school (Grades 3 to 5), and Exhibit 5 focuses on middle school (Grades 6 to 8). These grade bands correspond to those used in the NRC framework and the NGSS for upper elementary and middle school and cover science topics that are generally included in state curriculum frameworks covering the two TIMSS grades (4 and 8), although some topics may not be covered in all states by these specific grade levels. The life sciences, physical sciences, and Earth and space sciences topics in the exhibits are based on the TIMSS 2019 Curriculum Questionnaire topics at the corresponding grade levels (4 and 8), the performance expectations in the NGSS for upper elementary school (Grades 3 to 5) and middle school (Grades 6 to 8), and the upper elementary and middle school science standards from five states with large populations of students in kindergarten to Grade 8 (California, Texas, Florida, New York, and Massachusetts).[h] The curriculum structure and the specific topics taught at each grade in the United States vary by state and district, and additional topics not included in the exhibits appear in some states' curricula. Moreover, specific curriculum frameworks at the state and district levels may include detailed grade-level instructional benchmarks, approaches to learning, and instructional resource material.

Exhibit 4: Science Curriculum Topics in Upper Elementary School*

Area of Science	Topics
Life Sciences	▪ Characteristics of living things and the major groups of living things (e.g., mammals, birds, insects, fish, reptiles, flowering plants) ▪ Major body structures and their functions in animals and plants ▪ Life cycles of common plants and animals (e.g., mammals, birds, butterflies, frogs, flowering plants), including birth, growth, development, reproduction, and death ▪ How some characteristics of organisms are inherited from parents, some are the result of interactions with the environment, and some involve both inheritance and environment; examples of inherited versus acquired/learned traits ▪ How physical features and behaviors help living things survive in their environments; when environments change, some organisms survive, while others die or move to a different location ▪ How variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing** ▪ Relationships in ecosystems (e.g., simple food chains or food webs, predator-prey relationships); the role of the Sun, plants, animals, and decomposers in the transfer of matter and energy in ecosystems; effects of changes in ecosystems (e.g., populations, food sources)
Physical Sciences	▪ States of matter (solid, liquid, gas) and properties of the states of matter (volume, shape); how the state of matter changes by heating or cooling (melting, freezing, boiling, evaporation, and condensation) ▪ Common phenomena illustrating that matter is made up of particles too small to see (e.g., inflating a balloon, compressing a syringe, dissolving sugar in water, evaporating salt water)** ▪ Classifying materials based on physical properties (e.g., weight/mass, volume, color, texture, conducting heat, conducting electricity, magnetic attraction) ▪ Mixtures of two or more substances and their physical properties; materials dissolved in water (e.g., salt or sugar solutions) ▪ Chemical changes in everyday life (e.g., decaying, burning, rusting, cooking); how combining substances may result in new materials with different properties**

[h] Curriculum frameworks for the five states include the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (https://www.cde.ca.gov/ci/sc/cf/index.asp); the Texas Essential Knowledge and Skills for Science (http://ritter.tea.state.tx.us/rules/tac/chapter112/); Florida's Next Generation Sunshine State Standards for Science (https://www.fldoe.org/academics/standards/subject-areas/math-science/science); New York State P-12 Science Learning Standards (http://www.nysed.gov/common/nysed/files/programs/curriculum-instruction/nysscienceintro.pdf); and the Massachusetts Science and Technology/Engineering Curriculum Framework (http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf).

Area of Science	Topics
	▪ Conservation of matter (weight/mass) in physical and chemical changes** ▪ Common sources of energy (e.g., the Sun, flowing water, wind, coal, oil, gas); uses of different forms of energy (mechanical, light, sound, and thermal/heat) ▪ Energy transfer (e.g., by sound, light, heat, and electric current) and energy conversions (e.g., electrical energy converted to motion, sound, heat, or light; mechanical energy converted to heat or electrical energy) ▪ Basic properties and behavior of light: light travels in a straight line until it strikes an object and is reflected or absorbed or when it travels from one medium to another and is bent/refracted; formation of shadows; light reflected from objects and entering the eye allows objects to be seen ▪ Basic properties of sound (sound is produced by vibrating objects, and the pitch changes with the rate of vibration); waves (including sound) differ in amplitude (height/volume) and wavelength (spacing between wave peaks)** ▪ Electricity and simple circuits (e.g., concept of closed/complete circuits made of materials that are conductors); constructing simple circuits using wires, batteries, and bulbs ▪ Properties of magnets (e.g., like poles repel and opposite poles attract, magnets can attract some objects) ▪ Forces that cause objects to move (e.g., gravity, pushing/pulling); magnetic and electric forces acting at a distance; effects of balanced and unbalanced forces (including friction) on the motion of an object; observations and measurements of motion (e.g., direction and speed)
Earth and Space Sciences	▪ Physical makeup of Earth's surface (e.g., mountains, plains, deserts, oceans covering most of the surface); maps of the locations of mountains, continental boundaries, ocean trenches, volcanoes, and earthquakes ▪ Changes in Earth's surface over time (e.g., mountain building, weathering, erosion, earthquakes)** ▪ Water on Earth in liquid and solid form (e.g., oceans, lakes, rivers, groundwater, glaciers, polar ice caps); sources and relative amounts of fresh and salt water; water movement over land and in and out of the air (e.g., evaporation and precipitation) ▪ Examples of interactions between components of the geosphere (solid and molten rock, soil, and sediments), hydrosphere (water and ice), atmosphere (air), and biosphere (living things, including humans)** ▪ Human use of Earth's natural resources (e.g., land, water, wind, forests, fossil fuels) and its impact on the environment; renewable and non-renewable resources** ▪ Weather and climate (e.g., daily, seasonal, and locational variations versus long-term trends); describing and measuring common weather conditions (e.g., temperature, wind, precipitation, clouds); climates in different regions of the world

Area of Science	Topics
	▪ Patterns of rock formations and fossils as evidence of past conditions and living organisms on Earth ▪ Objects in the solar system (the Sun, Earth, the Moon, and other planets) and their movements (Earth and other planets revolve around the Sun, the Moon revolves around Earth); the Sun as the source of energy (heat and light) for the solar system ▪ Appearance of distant stars outside Earth's solar system (different stars seen at different times of the year); the Sun as a star ▪ Day and night as a result of Earth's rotation on its axis, and how shadows change throughout the day

*Upper elementary school refers to Grades 3 to 5. This grade band covers the science topics that are generally included in state curriculum frameworks for upper elementary school, but states differ in their curricular structure and the specific topics included at each grade.

**The NGSS introduce these topics in upper elementary school but in some states, they are not emphasized until middle school.

Note: Curriculum topics listed in this exhibit are based on the TIMSS 2019 Curriculum Questionnaire at Grade 4, the Next Generation Science Standards (NGSS) for Grades 3 to 5, and the upper elementary state curriculum frameworks in California, Texas, Florida, New York, and Massachusetts in place during the 2018–2019 school year. The topics listed are not exhaustive, as curriculum frameworks vary by state.

Exhibit 5: Science Curriculum Topics in Middle School*

Area of Science	Topics
Life Sciences (Biology)	▪ Differences among major taxonomic groups of organisms (e.g., plants, fungi, mammals, birds, reptiles, fish, amphibians, insects) ▪ Structure and function of major organs and organ systems in humans and other organisms (circulatory, respiratory, skeletal, muscular, digestive, excretory, reproductive, nervous, and endocrine systems) ▪ Cellular composition of organisms (unicellular and multicellular); groups of specialized cells forming tissues and organs; structure and functions of cells, including major organelles in plant and animal cells ▪ Basic processes, reactants, and products of photosynthesis (use of light energy, reaction of carbon dioxide and water to produce sugars and release oxygen) ▪ Basic processes, reactants, and products of cellular respiration (use of oxygen to break down sugars, form new molecules that support growth, and release carbon dioxide, water, and energy) ▪ Reproduction in plants and animals; differences between sexual and asexual reproduction in terms of the transfer of genetic information to offspring ▪ Heredity (the role of chromosomes and genes in the expression and passing on of traits from one generation to the next); how changes in genes (mutations) can affect traits in organisms** ▪ Diversity, adaptation, and natural selection (the role of genetic variation and adaptation in the survival and extinction of species in changing environments) ▪ The fossil record as evidence for changes in life forms throughout the history of life on Earth; anatomical similarities and differences between organisms living today and organisms in the fossil record to infer evolutionary relationships (common ancestry)** ▪ Interdependence of populations of organisms in ecosystems: food webs; the role of producers, consumers, and decomposers in the cycling of matter and energy flow; competitive, predatory, and mutually beneficial interactions; importance of biodiversity; environmental factors (biotic and abiotic) affecting population size

Area of Science	Topics
Physical Sciences (Chemistry and Physics)	▪ Classification and composition of matter; pure substances (elements and compounds) and mixtures (homogeneous solutions and heterogeneous mixtures) ▪ Particulate structure of matter (atoms and molecules) ▪ Characteristic physical and chemical properties used to identify substances (e.g., density, melting or boiling point, solubility, flammability, thermal and electrical conductivity, magnetic properties) ▪ Chemical changes (transformation of reactants to form products with new properties); evidence of chemical change; difference between chemical and physical changes; reactions that release or store energy (heat, light) ▪ Physical states and changes in matter (explained by the movement and distance between particles); changes in particle motion, temperature, and state of a substance when thermal energy is added or removed ▪ Conservation of atoms and mass in physical and chemical changes ▪ Forms of energy: kinetic energy; types of potential energy (gravitational, magnetic, electric, chemical); temperature as a measure of the average kinetic energy of particles of matter** ▪ Energy transfer and conservation: transformations between kinetic and potential energy; changes in kinetic energy producing heat; thermal energy transfer (heat) needed to raise the temperature of materials/objects ▪ Properties and behavior of light (reflection, refraction, absorption, and transmission through a vacuum and different media); phenomena explained by the wave model of light (e.g., brightness, color, frequency-dependent angle of refraction)** ▪ Wave properties (waves as repeating patterns with a specific wavelength, frequency, and amplitude); sound waves transmitted through different media** ▪ Types of forces (contact, electric, magnetic, gravitational, friction); additive forces and net force acting on objects; how gravitational force depends on mass and distance; force diagrams ▪ Electromagnetic forces acting at a distance explained by fields that extend through space** ▪ Applications of Newton's laws of motion (law of inertia; relationship between force, mass, and motion; action-reaction forces)**
Earth and Space Sciences	▪ Structure and composition of Earth's layers (crust, mantle, and core)** ▪ Earth's systems (geosphere, hydrosphere, atmosphere, and biosphere) and their interactions over short and long time scales ▪ Earth's processes and cycles (water cycle, rock cycle, weathering, erosion, ocean currents); the flow of energy driving these processes derived from the Sun and Earth's hot interior ▪ Plate tectonics; lithospheric plate movement resulting in major geological events (e.g., earthquakes, volcanic eruptions, mountain building, sea floor spreading) ▪ Earth's history: changes in Earth's surface over time; formation of fossils and fossil fuels; measurement of geologic time; maps of ancient land and water patterns based on rock and fossil evidence

Area of Science	Topics
	▪ Weather and climate: global weather patterns; role of atmospheric movement, the Sun, oceans, and landforms in driving weather systems; weather patterns predicted within probabilistic ranges; impact of latitude, altitude, and geographical features on climate ▪ Earth's resources, their use, and conservation: renewable and nonrenewable resources; uneven distributions of Earth's resources due to past and current geoscience processes; human use of land/soil, water, and energy resources; ▪ Human impact on the environment (e.g., deforestation, urbanization, desertification, erosion, air and water quality) ▪ Factors contributing to climate change (e.g., greenhouse gases, ash from volcanic eruptions, changes in solar radiation)** ▪ Model of the solar system to explain phenomena on Earth (day and night, year, phases of the moon, eclipses, tides, seasons); seasons in the northern and southern hemispheres caused by differences in the intensity of sunlight due to the tilt of Earth's axis; physical features of Earth compared to other bodies (e.g., the Sun, other planets, moons, asteroids, and comets) ▪ Stars, galaxies, and the universe: the Sun as one of billions of stars in the Milky Way galaxy (among billions of galaxies in the universe); hierarchical relationships in distance and size of bodies inside and outside the solar system ▪ The role of gravity in the formation and motion of objects in the solar system and galaxies

*Middle school refers to Grades 6 to 8. This grade band covers the science topics that are generally included in state curriculum frameworks for middle school, but states differ in their curricular structure and the specific topics included at each grade.

**The NGSS introduce these science topics in middle school, but in some states, they are not emphasized until high school.

Note: Curriculum topics listed in this exhibit are based on the TIMSS 2019 Curriculum Questionnaire at Grade 8, the Next Generation Science Standards (NGSS) for Grades 6 to 8, and the middle school state curriculum frameworks in California, Texas, Florida, New York, and Massachusetts in place during the 2018–2019 school year. The topics listed are not exhaustive, as curriculum frameworks vary by state.

Professional Development Requirements and Programs

There are no national policies that prescribe the content and methods of professional development programs, but most states require continuing professional development and education for the renewal of teacher licenses. Requirements for licensure for public school teachers include a degree from a four-year college or university and completion of a teacher education program, including a practicum of supervised teaching experience.[i] Under ESSA, states have the autonomy to determine the qualifications that teachers need to obtain certification to teach specific subject areas by grade level, and these qualifications vary by state, local community, and by school type (e.g. public, private, and parochial schools). Although some states may require certification in mathematics and science for elementary teachers, it is most common for states to require teachers to have specialized certification in their subject area (either through their undergraduate program or through state-specific programs) beginning in middle school. In addition to a specialized certification, states also commonly require these teachers to pass a state academic subject test.[27]

[i] For additional details about public school teacher certification, please see https://www.teachercertificationdegrees.com/#cert.

Some approaches to professional development implemented by states are:

- Short-term workshops
- Summer institutes where teachers receive specialized training and equipment
- Master teacher programs that provide specialized training and financial incentives to participating teachers
- Professional development opportunities specifically for teachers in high-needs districts
- Special training and support for teachers of advanced secondary school courses

Teachers also have opportunities for informal professional development, such as coaching, which includes observing lessons, providing feedback, and demonstrating teaching strategies. Often, opportunities for teachers to continue their education through professional development activities are organized by the school district. In the 2015–2016 school year, among the 59,600 public schools that had staff with specialist or academic coaching assignments, 33.5 percent had math specialists and 27.6 percent had math coaches, whereas 12.1 percent had science specialists and 9.8 had science coaches.[28]

As new curriculum standards are implemented in states, teachers are offered curriculum-specific professional development opportunities organized by the state or district. For mathematics, the National Council of Teachers of Mathematics has developed resources, lessons, journal articles, books, professional development, and online content (organized by level) to support teachers as they work to meet the challenges of the CCSS. For science, within states that have adopted the NGSS (or revised their science standards based on the NGSS), tools and resources are provided to teachers and school administrators for evaluation of their curriculum's alignment with the NGSS.[j] The National Science Teacher Association (NSTA) Next Generation Science Standards Hub also offers information, resources, news, professional learning opportunities, and expert advice in understanding and implementing the NGSS.[k]

Monitoring Student Progress in Mathematics and Science

All states require standardized tests to be administered to students in elementary, middle, and high school. Under ESSA, states are required to test students in mathematics once a year between Grades 3 and 8, as well as once in high school. States must test their students in science at least once in each of three grade bands: Grades 3 through 5, Grades 6 through 9, and Grades 10 through 12.

Shortly after the CCSS were released, several state-led consortia developed assessments in mathematics and English language arts that aim to measure whether students are on track to be successful in college and their careers through material aligned with the CCSS. States may choose

[j] For additional details about resources, visit http://www.nextgenscience.org/resources and http://www.nextgenscience.org/sites/ngss/files/EQuIP%20Rubric%20for%20Science%20v2.pdf.

[k] For additional details about NSTA resources, visit https://ngss.nsta.org/.

their own assessments, which can be those developed by the state-led consortia or other assessments. In the 2018–2019 school year, one-third of states used tests aligned to the CCCSM, such as the Partnership for Assessment of Readiness for College and Careers (PARCC) or Smarter Balanced. The remaining states either designed their own tests or administered a hybrid assessment with items designed by the state, PARCC, and Smarter Balanced.[29]

Although no comparable state-led consortia have developed science assessments based on the NGSS, a number of NGSS resources and tools are available to assist educators in developing their curriculum materials and assessments.[30,31] States that have adopted the NGSS are developing and field testing operational tests aligned to the standards.[32] Science tests are not required under ESSA for accountability purposes, but many states choose to make them part of their school rating systems, as an indicator of school quality or student success or to gauge schools academically.[33]

ESSA replaced the one-size-fits-all federal interventions under NCLB with intervention systems developed by individual states. Under ESSA, states have the flexibility to set their own student performance targets and measures of achievement. Funding incentives are provided to those states demonstrating the highest level of initiative and innovation. Under ESSA guidelines, state and local education agencies have the autonomy to determine whether evidence-based interventions are necessary for schools that fail to meet their criteria for academic achievement.

Although there is no nationally required examination that has consequences for individual students, the congressionally mandated NAEP conducts regular assessments in mathematics, science, and other subjects administered to representative samples of students at Grades 4, 8, and 12.[34] Results from NAEP are separate from other accountability systems used in states and schools but can be used to monitor progress at the national and state level. Under ESEA (2001) and continuing with ESSA (2015), states are required to participate in and report results from the biennial NAEP mathematics and reading assessments at Grades 4 and 8 to receive federal funds. Participation in the mathematics assessment at Grade 12 and the science assessments at all three grades is optional.

Some notable forms of standardized testing that take place throughout the United States include the SAT (originally called the Scholastic Aptitude Test), the ACT (originally called American College Testing), and the Advanced Placement (AP) tests, all of which are commercial tests developed and administered by private organizations, taken primarily by upper secondary school students, and used in the admission process for postsecondary education. However, admission to institutions of postsecondary education is not solely dependent on test scores; rather, most schools' admissions offices look at several factors, including students' class rank, grade point average (GPA), and extracurricular activities. Some postsecondary institutions, including most two-year community colleges, do not require these test scores for admission.[35,36,37]

There is no nationally mandated grading system across the United States. The most commonly used grading system entails the assignment of "letter grades," in which letters represent the possible range of achievement categories (e.g., "A" representing the top category, and "F" representing the bottom category). Decisions regarding which grading system to use are generally left up to individual institutions or individual faculty members.[38] High schools generally calculate an average of the letter grades earned in school—called a grade point average, or GPA—using a scale of 0 to 4.0 or 0 to 5.0. Grade reports typically are issued each quarter, or approximately every nine weeks. Semester grades and yearly grades are also given in most districts. Usually, only final grades, representing students' overall performance in courses for the entire school year, appear on a middle school or high school transcript. In cases in which students are identified as having special needs, schools are responsible for providing regular educational progress reports to parents.[39]

Special Initiatives in Mathematics and Science Education

National leaders regularly discuss the importance of improving and funding STEM programs at state and local levels to promote college and career readiness for studying and working in STEM fields. The Committee on Science, Technology, Engineering, and Mathematics Education (CoSTEM) was established in 2011 by the National Science and Technology Council in accordance with statutory requirements of the America COMPETES Reauthorization Act of 2010 (P.S. 111-358). The purpose of CoSTEM is to review and coordinate STEM education programs and initiatives across the federal agencies to ensure they are effective. CoSTEM is responsible for developing and implementing a STEM education strategic plan that is updated every five years.[40]

The most recent five-year strategic plan for STEM education was released in December 2018. The goals of the plan are to build strong foundations for STEM literacy; increase diversity, equity, and inclusion in STEM; and prepare the STEM workforce for the future. The plan's Pathways to Success strategy aims to close the STEM academic achievement gap between high- and low-achieving students. The initiative involves developing relationships between education entities and communities, encouraging students to interweave their STEM knowledge into non-STEM disciplines, building computational literacy through STEM education, and ensuring federal agencies are operating with transparency and accountability.[41]

Suggested Readings

U.S. Department of Education. (n.d.). *Data & statistics.* Retrieved from https://www.ed.gov/rschstat/landing.jhtml?src=rt

U.S. Department of Education. (n.d.). *Laws & guidance.* Retrieved from https://www2.ed.gov/policy/landing.jhtml?src=pn

U.S. Department of Education. (2013). *ED initiatives.* Retrieved from https://www.ed.gov/about/inits/ed/index.html?src=ln

References

[1] U.S. Department of Education, U.S. Network for Education Information. (2008). *Organization of U.S. education. State role I—Primary and secondary education.* Retrieved from https://www2.ed.gov/about/offices/list/ous/international/usnei/us/edlite-org-us.html

[2] Snyder, T.D., & Dillow, S.A. (2017). *Digest of education statistics 2017* (NCES 2017-011), (table 106.10). Retrieved from https://nces.ed.gov/programs/digest/d17/tables/dt17_106.10.asp

[3] Snyder, T.D., & Dillow, S.A. (2017). *Digest of education statistics 2017* (NCES 2017-011), (table 214.10). Retrieved from https://nces.ed.gov/programs/digest/d17/tables/dt17_214.10.asp

[4] Snyder, T.D., & Dillow, S.A. (2017). *Digest of education statistics 2017* (NCES 2017-011), (table 105.20). Retrieved from https://nces.ed.gov/programs/digest/d17/tables/dt17_105.20.asp

[5] Snyder, T.D., & Dillow, S.A. (2017). *Digest of education statistics 2017* (NCES 2017-011), (table 216.90). Retrieved from https://nces.ed.gov/programs/digest/d17/tables/dt17_216.90.asp

[6] U.S. Department of Education. (2018). *ESSA Flexibilities.* Retrieved from https://www2.ed.gov/policy/elsec/leg/essa/essa-flexibilities-document-for-publication.pdf

[7] National Center for Education Statistics. (2017). *Compulsory school attendance laws, minimum and maximum age limits for required free education, by state: 2017.* Retrieved from https://nces.ed.gov/programs/statereform/tab5_1.asp

[8] U.S. Department of Education. (2012). *The federal role in education.* Retrieved from https://www2.ed.gov/about/overview/fed/role.html

[9] U.S. Department of Education. (2015). *Every Student Succeeds Act (ESSA).* Retrieved from https://www.ed.gov/essa?src=rn

[10] Administration for Children and Families. (n.d.). *Preschool for All.* Retrieved from https://www.acf.hhs.gov/ecd/preschool-for-all

[11] Snyder, T.D., & Dillow, S.A. (2017). *Digest of education statistics 2017* (NCES 2017-011). Retrieved from https://nces.ed.gov/programs/digest/d17/figures/fig_01.asp?referrer=figures

[12] Common Core State Standards Initiative. (2015). *Standards in your state.* Retrieved from https://www.corestandards.org/standards-in-your-state/

[13] Common Core State Standards Initiative. (2015). *Key shifts in mathematics.* Retrieved from https://www.corestandards.org/other-resources/key-shifts-in-mathematics/

[14] National Research Council of the National Academies. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Retrieved from https://www.nap.edu/openbook.php?record_id=13165

[15] Next Generation Science Standards. (n.d.). Retrieved from https://www.nextgenscience.org/

[16] Next Generation Science Standards. (n.d.). *About.* Retrieved from https://ngss.nsta.org/About.aspx

[17] Next Generation Science Standards. (n.d.). Retrieved from https://www.nextgenscience.org/

[18] Xie, H., & Tsokodayi, Y. (2018). *International activities program assessment division: Web usage statistics through December 2018*. National Center for Education Statistics, U.S. Department of Education. Unpublished report.

[19] Kuenzi, J.J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action* (Congressional Research Service report for Congress). Retrieved from https://www.fas.org/sgp/crs/misc/RL33434.pdf

[20] Common Core State Standards Initiative. (n.d.). *Frequently asked questions.* Retrieved from https://www.corestandards.org/about-the-standards/frequently-asked-questions/

[21] U.S. Department of Education, National Assessment Governing Board. (2015). *Science framework for the 2015 National Assessment of Educational Progress.* Retrieved from https://www.nagb.gov/content/nagb/assets/documents/publications/frameworks/science/2015-science-framework.pdf

[22] Next Generation Science Standards. (n.d.). Retrieved from https://www.nextgenscience.org/

[23] U.S. Department of Education. (n.d.). *TIMSS participating countries.* Retrieved from https://nces.ed.gov/TIMSS/countries.asp

[24] U.S. Department of Education, National Center for Education Statistics. (2013). *U.S. states in a global context: Results from the 2011 NAEP-TIMSS linking study* (NCES 2013-460). Retrieved from https://nces.ed.gov/nationsreportcard/subject/publications/studies/pdf/2013460.pdf

[25] California Department of Education. (2015). *Overview of the standards chapters of the mathematics framework for California public schools: Kindergarten through grade twelve.* Retrieved from https://www.cde.ca.gov/ci/ma/cf/documents/mathfwoverview.pdf

[26] Common Core State Standards Initiative. (2015). *Standards in your state.* Retrieved from https://www.corestandards.org/standards-in-your-state/

[27] Teach. (n.d.). *Public schools.* Retrieved from https://teach.com/careers/become-a-teacher/where-can-i-teach/types-of-schools/public/

[28] National Center for Education Statistics. (2017). *Characteristics of public elementary and secondary schools in the United States: Results from the 2015-16 National Teacher and Principal Survey* (NCES 2017-071). Retrieved from https://nces.ed.gov/pubs2017/2017071.pdf

[29] Education Week. (2017). *What tests does each state require?* Retrieved from https://www.edweek.org/ew/section/multimedia/what-tests-does-each-state-require.html

[30] Next Generation Standards (n.d.). *Curriculum planning.* Retrieved from https://ngss.nsta.org/Curriculum-Planning.aspx

[31] Next Generation Standards (n.d.). *Instruction and assessment.* Retrieved from https://www.nextgenscience.org/instruction-and-assessment/instruction-and-assessment

[32] Education Week. (2017). *Next-Generation science tests slowly take shape.* Retrieved from https://www.edweek.org/ew/articles/2017/05/24/next-generation-science-tests-slowly-take-shape.html

[33] Education Week. (2018). *How does science testing work under ESSA?* Retrieved from https://blogs.edweek.org/edweek/campaign-k-12/2018/10/science-essa-testing-states-plans.html

[34] National Assessment of Educational Progress (NAEP) (n.d.). *About NAEP.* Retrieved from https://nces.ed.gov/nationsreportcard/about/

[35] The College Board. (2015). *About the SAT.* Retrieved from https://sat.collegeboard.org/about-tests/sat

[36] ACT, Inc. (2015). *About the ACT.* Retrieved from https://www.act.org/content/act/en/about-act.html

[37] The College Board. (2015). *AP courses and exams.* Retrieved from https://apcentral.collegeboard.com/apc/public/courses/index.html

[38] U.S. Department of Education, International Affairs Office. (2008). *Structure of the U.S. education system: U.S. grading systems.* Retrieved from https://www2.ed.gov/about/offices/list/ous/international/usnei/us/grading.doc

[39] U.S. Department of Education. (2007). *A guide to the individualized education program.* Retrieved from https://www2.ed.gov/parents/needs/speced/iepguide/index.html

[40] Congressional Research Service. (2018). *Science, Technology, Engineering, and Mathematics (STEM) Education: An overview.* Retrieved from https://fas.org/sgp/crs/misc/R45223.pdf

[41] The White House. (2018). *Charting a course for success: America's strategy for STEM education.* Retrieved from https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf