THE NEW CURRICULUM STANDARDS FOR FOR ASTRONOMY IN THE UNITED STATES

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Abstract: There is widespread interest in constraining the wide range and vast domain of the possible topics one might teach about astronomy into a manageable framework. Although there is no mandated national curriculum in the United States, an analysis of the three recent national efforts to create an age-appropriate sequence of astronomy concepts to be taught in primary and secondary schools reveals a considerable lack of consensus of which concepts are most age-appropriate and which topics should be covered. The most recent standardization framework for US science education, the *Next Generation Science Standards*, suggests that most astronomy concepts should be taught only in the last years of one's education; however, the framework has been met with considerable criticism. A comparison of astronomy learning frameworks in the United States, and a brief discussion of their criticisms, might provide international astronomy educators with comparison data in formulating recommendations in their own regions.

Keywords: Astronomy education research; Teaching didactics; United States Next Generation Science Standards.

NOVOS PARÂMETROS CURRICULARES PARA ASTRONOMIA NOS ESTADOS UNIDOS DA AMÉRICA

Resumo: Há um grande interesse em restringir a ampla gama e vasto domínio dos possíveis temas que poderiam ser ensinados sobre astronomia em uma estrutura gerenciável. Embora não haja nenhum currículo nacional obrigatório nos Estados Unidos, uma análise dos três esforços nacionais recentes para criar uma sequência apropriada de conceitos de astronomia por idade para serem ensinados nas escolas primárias e secundárias revela uma considerável falta de consenso a respeito de quais conceitos são mais apropriados para cada idade e quais tópicos devem ser cobertos. O esquema de padronização mais recente para a educação científica dos EUA, o Next Generation Science Standards (Padrões em Ciência: Nova Geração), sugere que a maioria dos conceitos de astronomia devem ser ensinados apenas nos últimos anos de educação do aluno; e no entanto foi recebido com críticas consideráveis. Uma comparação dos esquemas de aprendizagem da astronomia nos Estados Unidos e uma breve discussão das críticas levantadas podem proporcionar aos educadores de astronomia internacionais dados de comparação na formulação de recomendações em suas próprias regiões.

Palavras-chave: Pesquisa em educação em astronomia; Didática do ensino; United States Next Generation Science Standards.

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NUEVOS PARÁMETROS CURRICULARES PARA ASTRONOMIA EN LOS ESTADOS UNIDOS DE AMÉRICA

Resumen: Hay un gran interés en restringir la amplia gama y vasto campo de posibles temas que podrían ser enseñados en astronomía dentro de una estructura manejable. Aunque no existe un plan de estudios nacional obligatorio en los Estados Unidos, un análisis de los tres esfuerzos nacionales recientes para crear una secuencia apropiada para la edad de los conceptos de astronomía que se enseñan en las escuelas de primaria y secundaria revela una considerable falta de consenso en cuanto a qué conceptos son más adecuados para cada edad y qué temas deben ser cubiertos. El esquema de estandarización más reciente para la enseñanza de las ciencias de Estados Unidos, los *Next Generation Science Standards*, sugiere que la mayoría de los conceptos de astronomía se les debe enseñar sólo en los últimos años de la educación al estudiante; y sin embargo, fue recibida con muchas críticas. Una comparación entre los programas de aprendizaje de astronomía en los EE.UU., y una breve discusión de las críticas recibidas, pueden proporcionar a los educadores en astronomía internacionales datos importantes para la formulación de recomendaciones en sus propias regiones.

Palabras clave: Investigación em educación en astronomía; Didáctica de la enseñanza; United States Next Generation Science Standards.

1 Introduction

Both professional scientists and schoolteachers have a deeply vested interest in what school-aged children are learning in their science classes. Every country's successful economic and societal engines require an educated pipeline of children moving their way toward careers in science, technology, engineering, and mathematics. In support of this career pipeline, schooling systems and their teachers have the intellectual task of determining on a day-to-day basis which topics need to be taught to students, in what manner they are to be taught, in what sequence, and how they are to be assessed. As a whole, this is a momentous task carrying the upmost importance in nearly every country across the planet.

In the scientific discipline of astronomy, the question of which specific topics are to be taught to schoolchildren, and at what depth of understanding, is a particularly challenging issue to resolve. Astronomy is a subject that, by its definition, stretches across and encompasses the entire universe. Among many things, astronomers study the motion and position of objects observed in the sky; the nature of planets, dwarf planets, comets, and asteroids orbiting around our Sun; the nuclear energy processes and subatomic particles created inside aging stars; the origin, distribution, and evolution of entire galaxies of stars; as well as the beginning and fate of our universe. The field of astronomy engages engineers to build Earth-based telescopes and to launch spacecraft, mathematicians and computer scientists to convert enormous numerical datasets into images for analysis, physicists to understand interactions among the matter our universe is composed of, chemists to understand how elements combine and recombine across space, and astronomy educators to teach in schools, museums, and science education centers, just to name a few. Given such a wide swath across the sciences, it is not surprising that developing a consensus vision of which astronomy concepts should be taught to school children is a challenging question.

As a first step toward identifying a consensus of which astronomy topics should be taught to schoolchildren, one might naturally try to determine which concepts are taught in countries other than one's own. Many countries have clearly specified learning targets for astronomy concepts, as well as nationally used curriculum materials, common textbooks, consistent tests and examinations that further constrain which astronomy topics are deemed as being most important. However, if one were to look to the United States for a nationally accepted specific list of which astronomy concepts are taught in the United States, one would not find such a list. Most recently, the document known as the *Next Generation Science Standards* (NGSS, 2013) offered a guideline for concepts related to astronomy, that the authors felt would be appropriate for school aged children, with the anticipation that the guidelines would become nationally accepted; yet by no means has this guideline been universally accepted. This paper provides a brief overview of the attempts to reform science education; examines which astronomy concepts have historically been promoted to serve as a common core of concepts, specifically comparing those that are currently being promoted by leading science education organizations, in the United States; and identifies some of the reasons for the difficulty in coming to a consensus for a unified curriculum for astronomy in elementary and secondary public school classrooms in the United States.

2.1 Background and Context

Perhaps surprisingly, the United States does not have a unified national curriculum for any school subject. Historically, each community has taken on the responsibility themselves of determining which topics will be taught and to which aged students. For most of the United States' history, day-to-day decisions about what topics are taught have been left to individual teachers in individual classrooms. In the last four decades, decisions about which topics are taught has been more greatly influenced by regulations and policies at the state-level of government, because that is the governmental level where the licensing and legal certification of public school teachers occurs. It has only been in the last decade and a half that the US federal government has become deeply involved in education; and even then has not federally mandated a unified curriculum for schoolchildren.

Science education in the United States has undergone change in many ways, in terms of what was taught and how it was taught. The early science education for children first appeared in children's literature in which science was used as a vehicle for piety and moral lessons. The early science education approach in the United States emphasized participation and experiential learning. In the 1870's science education in the elementary schools often included the use of the Object Teaching curriculum which continued to involve experiential learning, focusing on observations and the use of senses, with the belief that elementary children were not capable of reasoning; but they could observe and memorize. Secondary science education emphasized reasoning and the use of reading and recitation for learning. During these time periods, the curriculum material was generated by individual teachers in many cases, and there was no consistency in what material was taught in terms of content or order (ATKIN; BLACK, 2007). The Committee of Ten, organized by the National Education Association (NEA) was one of the earliest attempts to develop a national move to reforming education, including science. The 1894 report claimed less than 1% of students in high school were adequately prepared for college, and only 3 % attended, requiring colleges to decrease their expectations for entrance (MACKENZIE, 1894). The report considered the state of science education in near chaos, calling for a common degree of order and standardization. The committee recognized that not all students would pursue college careers, but that all students should be educated with a higher degree of science and language than was previously expected, and recommended that only college career students should be offered astronomy and meteorology courses.

The National Society for the Study of Education (NSSE) took the lead in trying to develop curriculum that would address some of the concerns of the Committee of Ten, but there was no science in their curriculum until 1932. Movements to address the concerns of the lack of science proficiency for both entering college students and members of society continued but with little impact on developing a national program of science. For example, in 1959 the National Science Foundation (NSF), created by Congress in 1950 had two broad missions: to support basic scientific research and to improve American science education. NSF then supported the efforts of a group of research scientists and curriculum developers to develop science curriculum that would emphasize problem solving and inquiry in high school biology, chemistry and earth sciences, with similar efforts to involve scientists in elementary curriculum development through the 1970's. Text books written by experts were designed to place the teacher as the mouthpiece, following in some cases, a verbatim of the content they were to teach. The Educational Research Council of America (SHOWALTER, 1971) presented a report calling for the spiraling of content, suggesting that teachers in school districts work together to determine the stages of content for the spiral approach, rather than supporting a national unified curriculum. The report also argued against the use of nationally written text books suggesting that they were inappropriate for both teachers and students. This placed the teachers back toward the forefront of determining what should be taught and required teacher content expertise.

Some monumental attempts have been made since the 1970's to provide national consensus guidelines - but not legal mandates - for curriculum. In the context of science education, two of the most widely recognized efforts were conducted almost simultaneously. One was coordinated by the American Association for the Advancement of Science in a document known as *Benchmarks for Science Literacy* (AAAS, 1993). The other was the National Research Council's *National Science Education Standards* (NRC, 1996). Each of these efforts engaged hundreds of scientists, teachers, and education researchers; and had far reaching influence on helping individual states develop their own curriculum frameworks for which scientific concepts should be taught. Although overlaps between the two documents existed, they were certainly not identical. As a result of the United States' pervasive social history of the importance of local control of schools and curricula, neither of these was established as a national curriculum. Nonetheless, these documents have profoundly influenced commercial curriculum materials and assessment instruments, and continue to do so.

2.2 Astronomy Concepts in the *Benchmarks for Scientific Literacy*

Turning first to the American Association for the Advancement of Science's (AAAS) effort, the *Benchmarks for Scientific Literacy* (1993) contains hundreds of carefully worded statements about what all schoolchildren − not just those destined for science careers - should know related to science, the nature of science, and the history of science and technology. Recognizing the innate difficulty in what AAAS was trying to do, their effort was named *Project 2061*. It was so named because a recognized science education reform started around the time of the 1986 appearance of Halley's Comet, and it was hoped to be accomplished by the next time Halley's Comet appeared, in 2061. The astronomy concepts included in the AAAS Benchmarks document were summarized by Slater (2000) and shown in Table 1, condensed into 27 statements. This document, written mostly by educational leaders, provided justification for why topics should be taught at each of the stages. The document is still in current use by many school districts, states and teacher education programs.

Table 1 - Abridged Summary of Astronomy Concepts in the AAAS *Benchmarks* (1993).

Summary of Astronomy Concepts in the AAAS *Benchmarks* (1993)

Grades K-2 (Ages 5-7 Years)

- There are more stars in the sky than anyone can easily count.
- The Sun can be seen only in the daytime, but the Moon can be seen sometimes at night and sometimes during the day. The Sun, Moon, and stars all appear to move slowly across the sky. The Moon looks a little different every day, but looks the same again about every four weeks.
- The Sun warms the land, air, and water.

Grades 3-5 (Ages 8-11 Years)

- The patterns of stars in the sky stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons. Planets change their positions against the background of stars.
- Telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets and increase the number of stars visible. Stars are like the Sun, some being smaller and some larger, but so far away that they look like points of light.
- The Earth is one of several planets that orbit the Sun, and the Moon orbits around the Earth. Like all planets and stars, the Earth is approximately spherical in shape. The rotation of the Earth on its axis every 24 hours produces the night-and-day cycle.

Grades 6-8 (Ages 12-14 Years)

- The Sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars. The universe contains many billions of galaxies, and each galaxy contains many billions of stars.
- The Sun is many thousands of times closer to the Earth than any other star. Light from the Sun takes a few minutes to reach the Earth, but light from the next nearest star takes a few years to arrive. Some distant galaxies are so far away that their light takes several billion years to reach the Earth. People on Earth, therefore, see them as they were that long ago in the past.
- Nine planets of very different size, composition, and surface features move around the Sun in nearly circular orbits. Some planets have a great variety of Moons, some showing evidence of geological activity.
- Large numbers of chunks of rock orbit the Sun. Some of those that the Earth meets in its yearly orbit around the Sun [meteors] while others are mixed with ice and have orbits that carry them close to the Sun [comets], where the Sun's radiation boils off frozen material from their surfaces and pushes it into a long, illuminated tail.
- The Earth is a relatively small planet, third from the Sun, and composed of mostly rock. The other planets have compositions and conditions very different from the Earth's.
- Everything on or anywhere near the Earth is pulled toward the Earth's center by gravitational force.
- Because the Earth turns daily on an axis that is tilted relative to the plane of the Earth's yearly orbit around the Sun, sunlight falls more intensely on different parts of the Earth during the year. The difference in heating of the Earth's surface produces the planet's seasons and weather patterns.
- The Moon's orbit around the Earth once in about 28 days changes what part of the Moon is lighted by the Sun and how much of that part can be seen from the Earth - the phases of the Moon.
- Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation -- visible light. Differences of wavelength within that range are perceived as differences in color.
- The Sun's gravitational pull holds the Earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them.
- Telescopes reveal that there are many more stars in the night sky than are evident to the unaided eye, the surface of the Moon has many craters and mountains, the Sun has dark spots, and Jupiter and some other planets have their own moons.

Grades 9-12 (Ages15-18 Years)

- The stars differ from each other in size, temperature, and age, and behave according to the same physical principles observed on earth. Unlike the Sun, most stars are in systems of two or more stars orbiting around one another.
- On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense in a process that is still ongoing today.
- Increasingly sophisticated technology and mathematical modeling is used to learn about the universe. Telescopes and space probes collect information from the EM spectrum; computers interpret data using increasingly complicated procedures, and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe.
- Various accelerating electric charges produce a large variety of electromagnetic waves around them. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed - the "speed of light."
- The observed wavelength of a wave depends upon the relative motion of the source and the observer. Because the light seen from almost all distant galaxies has longer wavelengths than comparable light here on earth, astronomers believe that the whole universe is expanding.
- Ptolemy devised a powerful mathematical model of the universe based on constant motion in perfect circles, and circles on circles which was consistent with the perception that the earth is large and stationary and that all other objects in the sky orbit around it.
- Copernicus made the unpopular suggestion that all sky motions could be explained by a daily spinning earth orbiting around the sun once a year.
- Johannes Kepler, showed mathematically that Copernicus' idea of a Sun-centered system worked well if uniform circular orbits were replaced with elliptical orbits.
- Galileo made many discoveries using a telescope that supported the ideas of Copernicus. It was Galileo who found the moons of Jupiter, sunspots, craters and mountains on the moon, and many more stars than were visible to the unaided eye. Galileo brought the issue of Earth's motion around the Sun to the educated people of his time and created political, religious, and scientific controversy.

- Isaac Newton created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. His mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Kepler had proposed two generations earlier.

NOTE: Abridged and summarized from the AAAS Project 2061 _Benchmarks for Science Literacy_ available on the WWW at URL: <http://www.project2061.org/tools/benchol/bolintro.html>.

2.3 Astronomy Concepts in the *National Science Education Standards*

Turning to the second parallel effort to guide schools for framing the nature of contemporary science teaching, the United States' National Research Council published the *National Science Education Standards* (NSES, 1996), which described "effective classroom instruction, age-appropriate guidelines for curriculum materials development, authentic assessment procedures, and professional development programs for teachers. Science education leaders, teachers and scientists were involved in the development of this document. As summarized in Table 2 by Adams and Slater (2000), the NRC NSES astronomy concepts described were much more holistic in nature than those specified in more detail by the AAAS Benchmarks (1993). Teachers could be more selective about what was specifically being taught. This made it easier for schoolteachers in the United States, who often lack formal college-level training in astronomy, to implement. These NSES astronomy concepts include describing the objects and motions of the sky (grades K-4), the characteristics of gravity and the solar system (grades 5-8), and the origin and evolution of stars, galaxies, and the Universe (grades 9-12).

Table 2 - NRC NSES Astronomy Objectives.

NRC NSES Astronomy Objectives (NRC, 1996)

Grades K-4 (Ages 5-10 Years)

- Sky objects have properties, locations, and movements that can be observed and described.
- The Sun provides the light and heat necessary to maintain the temperature of the earth.
- Objects in the sky have patterns of movement. The Sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The Moon moves across the sky on a daily basis much like the sun. The observable shape of the Moon changes from day to day in a cycle that lasts about a month.

Grades 5-8 (Ages 11-14 Years)

- The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest body in the solar system.
- Most objects in the solar systems are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.
- Gravity is the force that keeps planets in orbit around the Sun and governs the rest of the motion in the solar system. Gravity alone holds us to the Earth's surface and explains the phenomena of the tides.
- The Sun is the major source of energy for phenomena on the Earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of Sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

Grades 9-12 (Ages 15-18 Years)

- The Sun, the Earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early Earth was very different from the planet we live on today.
- The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since.
- Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.
- Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

For the earliest school years, the NSES reflects a notion that abstract astronomy developmentally is difficult for students in K-4. NSES focuses on the underlying processes and themes of science instead of facts. In grades K-4 they describe the properties, locations, and motions of the Sun, Moon, stars, clouds, birds, and airplanes from a geocentric perspective. Adams and Slater (2000) noted "constellation names can be, and should be, learned in the same way as the names of farm animals, the multiplication tables, and the months of the year." Memorizing these names should not be the emphasis; objectives should lead the students to participate in the process of science. K-4 students can observe and diagram the phases of the Moon; whereas asking a K-4 student to describe the abstract geometry of the Sun-Earth-Moon connection would be developmentally inappropriate.

In the United States, the last chance most students reliably encounter astronomy concepts is often during the middle grades. At this point, the NSES recommends moving students from the geocentric perspective to describing the solar system from a heliocentric or Sun-centered perspective. At this level, students are to go beyond observing and charting to describing the causes of day/night, seasons, eclipses, and lunar phases. They can examine the characteristics of the objects in the solar system, such as their satellite systems, rotation/revolution, size/mass, and composition. At this level they also begin to explore gravity and understand that gravity causes planets to orbit in nearly circular orbits as described by Kepler's laws.

The inclusion of the four highest grade band-level astronomy objectives seen in Table 2 focus on the observation, origin, evolution, and characteristics of the Universe beyond the solar system. The NSES document calls for secondary students to comprehend complex and abstract scientific phenomena and explanations such as nebular hypothesis, nucleosynthesis and the Big Bang Theory. Unfortunately, as an indirect effect of the No Child left behind (NCLB) laws, very little astronomy is taught to students past the age of 15 in the United States, even though there are astronomy concepts for this age group in the NSES document. Science teachers in the United States report that the practice of tracking students into the three traditional sciences (biology, physics and chemistry) and the emphasis of remediation courses to meet NCLB, have interfered with offering astronomy courses, leaving astronomy concepts taught by astronomy enthusiasts as embedded material in the traditional science (KRUMEMAKER, 2009).

2.4 Astronomy Concepts in the *Next Generation Science Standards*

Over the last few years, there has been tremendous pressure in the United States to revise the national science education guidelines to reflect a more modern era. With world globalization, advances in the sciences and cognitive learning, and a political climate of accountability in 2010, the National Academy of Science (NAS), and the National Science Teachers Association (NSTA) came together to write an updated form of science standards. The Carnegie Corporation supported this in two steps. The first report, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (SCHWEINGRUBER; KELLER; QUINN, 2012), was developed by the NAS, serving as the foundation for a new set of guidelines or standards for teaching science. In 2013, the second publication, *Next Generation Science Standards* (NGSS) was published (NGSS, 2013) with the hopes of serving as the new (and nationally accepted) science standard.

NGSS tried to go beyond the first generation curriculum standards and frameworks documents by more explicitly aligning science processes and practices with science content. It is built upon three dimensions; *Science and Engineering Practices*, *Cross Cutting Concepts*, and *Disciplinary Core Ideas* (DCI). In comparison to the previous standards, which were predominantly content oriented, the NGSS attempts to focus more toward the interaction between performance expectations and content. It is in the DCIs that the astronomy concepts, advocated by the NGSS, are illustrated. Table 3 summarizes the astronomy content covered by NGSS according to grade and age level.

Table 3 - Summary NGSS Astronomy-related DCIs.

Grades	**Ages**	**Summary NGSS Astronomy-related DCIs (NGSS, 2013)** Content/Concepts
1st	6-7 years	* Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted.
		* Seasonal patterns of sunrise and sunset can be observed, described, and predicted.
2nd	7-8 years	* Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe.
5th	10-11 years	* The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.
		* The orbits of Earth around the Sun, and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun, Moon, and stars at different times of the day, month, and year.
6th - 8th (middle school)	12-14 years	* The solar system consists of the Sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the Sun by its gravitational pull on them.
		* The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.
		* Patterns of the apparent motion of the Sun, the Moon, and stars in the sky can be observed, described, predicted, and explained with models.
		* Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
		* The solar system consists of the Sun and a collection of objects, including planets, their Moons, and asteroids that are held in orbit around the Sun by its gravitational pull on them.
		* This model of the solar system can explain eclipses of the Sun and the Moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

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		* Patterns of the apparent motion of the Sun, the Moon, and stars in the sky can be observed, described, predicted, and explained with models.
		* This model of the solar system can explain eclipses of the Sun and the Moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.
9th - 12th (high school)	14-18 years	* Kepler’s laws describe common features of the motions of orbiting objects, including their elliptical paths around the Sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.
		* Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.
		* The star called the Sun is changing and will burn out over a lifespan of approximately 10 billion years.
		* The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
		* The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
		* Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
		* Nuclear Fusion processes in the center of the Sun release the energy that ultimately reaches Earth as radiation.
		* The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

The United States’ new frameworks for teaching astronomy in the NGSS (provided in Table 3) are arranged by the *Disciplinary Core Ideas*. The DCI’s are separated into traditional science topics, and then listed by grade level, individually for grades K-5, and collectively for each middle school and high school. Topics in astronomy are found in the Earth and Space Science section with a few applicable standards in the physical science section.

Students first encounter the concepts of astronomy in the first grade with the study of the Sun, Moon, and the stars in terms of directly observable patterns of movement in the sky. They observe and describe seasonal patterns, stopping short of explaining the cause of this movement. In second grade, students are not exposed to traditional astronomy concepts; they do however look at events on the earth that happen very fast or very slowly. In this age band, astronomy concepts are limited to just these few, based on the notion that young students lack experiences, which allow them to think about the often-abstract astronomical concepts and construct new knowledge.

In the NGSS, intermediate Grades 3-5 (ages 8-10 years), students are expected to have their first real experience with learning about the solar system. They study stars, of which the Sun is one, and learn about distance and brightness. These students should begin to understand the orbital movements of Earth and Moon based on observable patterns. Forming a mental model of the causes of the seasons is very difficult; therefore, at this level students are not expected to describe the causes of the seasons.

Early secondary school (Ages 11-14) students being taught under the framework of the NGSS should build upon the skills they developed in elementary school. It is anticipated that this age group will be ready to use models to explain patterns of motion of the Sun, Moon, and stars. They will view the solar system as one of the billions of galaxies within the Milky Way. Their studies will include their first exposure to gravity as the force holding the solar system together and they will use mental and physical models to explain eclipses, seasons and lunar phases.

In the NGSS, the majority of astronomy concepts have been specified to be taught at the upper secondary levels (Ages 15-18) due to the abstract nature of the concepts and the need for higher-level thinking. For the first time, these students are to learn about the electromagnetic energy spectra and brightness of stars as it determines the composition of stars, their movements, and measurement of their distance from Earth. They are expected to understand how matter was formed during the Big Bang. Students will also explore fusion within stars and supernova in the formation of light and heavy elements. Finally, the document prescribes that high school students will build upon their novice observations of motion in support of learning Kepler's Laws.

Although newer than its AAAS *Benchmarks* and NRC *National Science Education Standards* predecessors, the NGSS has not escaped significant intellectual criticism. The most common criticisms levied are that none of the common core standardization efforts were able to fulfill two critical specifications of their design: being internationally benchmarked or being based on education research (*viz*., Porter, McMaken, Hwang & Yang, 2011). Moreover, they have been criticized by the cognitive science and learning sciences community for failing to take into account the vertical nature of student learning as it develops over time (*viz*., Slater & Slater, 2015). These go above and beyond the basic problem that most of the astronomy concepts are postponed until the high school years, where students do not take courses covering astronomy (KRUMENAKER, 2009).

3 Discussion

Any organization's success is contingent upon clear, commonly defined goals and clearly communicated objectives. As a nation, the United States' goal has been to improve student achievement in science and to develop a scientifically literate society. At various times throughout the history of the United States, different groups, including scientists, politicians, curriculum developers, teacher education leaders and industry have laid claim to identifying the need for science education reform, defining practices, curriculum and teaching approaches that they thought would improve the status of science education for both entering college students and everyday members of society. The documents currently in use, designed to address the reform in science education in the United States (the standards, frameworks and benchmarks) have been developed with this in mind, each building on the current status of student achievement and on current research in science education. Even with these clear goals in mind, the documents designed to meet these goals have not yet been accepted as a unified national standard. There are several reasons that this may be the case. Two important reasons are related to the debates on how people learn and what they should be learning. These are the recurring debates in science education reform. In addition to these major points is the question of who should be involved in making decisions about science education reform and who should be responsible to lead the reform.

In terms of how people learn, ideas about age appropriateness and what students know prior to being taught have changed dramatically. For example, it is no longer believed that students are blank slates or empty vessels; rather they come to the classroom with prior ideas and often strongly held misconceptions that may interfere with learning what is being taught (SCHNEPS; SADLER, 1988). Their ability to develop coherent theories is not necessarily age dependent, but is influenced by other factors such as maturation, experience and instruction (CLARK; D'ANGELO; SCHLEIGH, 2011; SCHLEIGH; CLARK; MENESKE, 2015). While it was once believed that age or grade determined developmentally appropriate topics, many now believe that developmentally appropriate topics are largely contingent on students' prior opportunities (NRC, 2007).

As these ideas about how people learn have progressed, educators at every grade level, have expressed dissatisfaction with the expectations and objectives that they are asked to teach. They often report frustration, describe the amount of objectives in their grade levels as daunting and perceive the objectives as disconnected from the classroom instruction and the assessments that were designed for the standards. They have claimed both that there is too much to teach, and that the standards are either too specific or not general enough to meet their classroom instructional needs; and there is a sense of chaos or no sense of coherence. Schmidt, McKnight, and Raizen (1996) argued that even the science text books written to help guide teachers in each grade level, to address the standards in the United States classrooms, covered significantly much more material than competitive countries that were out achieving and out performing United States students. Ironically, the rationale for developing the standards, and for the changes in each new standards document, was to address this chaos and unify objectives to facilitate the movement toward the common goals. The fact that the documents have yet to be accepted as a national curriculum indicates that they are not serving their purpose and indicates that they may even be contributing to the problem they were intended to solve.

Astronomy educators in the United States are often familiar with the variety of science standards and benchmarks as they have been influential for the past three decades, spanning most of the teaching careers of the currently in-service teachers. However, it is not only educators that have a stake in the content that is being taught. Higher education institutions, professional scientists and society as a whole has a stake in what it is that students are learning. From their perspective, what grades students are learning a topic is not necessarily as important as what topics are being covered in the US public school classrooms. Table 4 provides a comparison of the alignment between the three standards documents, of the overarching topics related to astronomy.

Whether or not teachers agree with either the concept of standards or the specific disciplinary core ideas prescribed, the existence of standards impacts schools across the United States. As Slater reported in 2000, “Even if [the United States’ various and optional] national standards are only with us temporarily, it behooves science teachers to take a close look at what is there regarding astronomy.” It seems that with the emphasis on accountability and assessment, standards, benchmarks, and frameworks are likely to be a permanent residence on the public education landscape. In addition, standards provide other stake holders a means of being able to rely on knowing what it is that students will have experienced and what they have learned during their education.

Table 4 - Alignment Among US National Standards Documents.

NSES (1996) Astronomy Related Standards	AAAS (1993) Astronomy Related Standards	NGSS (2013) Astronomy Related Documents
Ideas related to gravity: ** Gravity is the force that keeps planets in orbit around the Sun and governs the rest of the motion in the Solar System. Gravity alone holds us to the Earth's surface ** Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.	**Ideas related to gravity:** ** The Sun's gravitational pull holds the Earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them. ** Everything on or anywhere near Earth is pulled toward the planet's center by gravitational force.	**Ideas related to gravity:** ** The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. ** The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.
Ideas related to EMR production: ** Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object--emitted by or scattered from it--must enter the eye. ** Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include the electromagnetic spectrum from radio waves to gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength. ** Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.	**Ideas related to EMR production:** ** Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation - visible light. Differences of wavelength within that range are perceived as differences in color. ** Various accelerating electric charges produce a large variety of electromagnetic waves. These vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed - the "speed of light." The observed wavelength of a wave depends upon the relative motion of the source and the observer (Doppler Effect). Because the light seen from almost all distant galaxies has longer wavelengths than comparable light on Earth, astronomers believe that the whole universe is expanding.	**Ideas related to EMR production:** ** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. ** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. ** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. ** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ** The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
Ideas related to fusion: ** Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements. ** Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.	**Ideas related to fusion:** ** Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur.	**Ideas related to fusion:** ** Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy.

NSES (1996) Astronomy Related Standards	AAAS (1993) Astronomy Related Standards	NGSS (2013) Astronomy Related Documents
		Heavier elements are produced when certain massive stars achieve a supernova stage and explode. ** Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.
The evolution of the universe ** The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since. ** Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. **Stars and stellar evolution** ** Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe. **The evolution and structure of the solar system** ** The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today. ** The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest body in the Solar System. **The Sun and Earth's seasons** ** The Sun provides the light and heat necessary to maintain the temperature of the Earth. ** The Sun is the major source of energy for phenomena on the Earth's surface. Seasons result from variations in the	**The evolution of the universe** ** On the basis of scientific evidence, the universe is estimated to be over 10 billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense in a process that is ongoing. ** Because the light seen from almost all distant galaxies has longer wavelengths than comparable light on Earth, astronomers believe the whole universe is expanding. **Stars and stellar evolution** ** There are more stars in the sky than anyone can ** easily count. ** Stars differ from each other in size, temperature, and age, and behave according to the same physical principles observed on Earth. Unlike the Sun, most stars are in systems of two or more stars orbiting around one another. ** Stars are like the Sun, some being smaller and some larger, but they are so far away that they look like points of light. ** The Sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars. The universe contains many billions of galaxies, and each galaxy contains many billions of stars. ** The Sun is many thousands of times closer to Earth than any other star. Light from the Sun takes only a few minutes to reach Earth, but light from the next nearest star takes a few years to	**The evolution of the universe** **: Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. ** The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. **Stars and stellar evolution** ** The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. ** Patterns of the apparent motion of the sun, moon, and stars in the sky can be observed, described, predicted, and explained with models. ** Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. **The evolution and structure of the solar system** ** The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. ** This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of

NSES (1996) Astronomy Related Standards	AAAS (1993) Astronomy Related Standards	NGSS (2013) Astronomy Related Documents
amount of the Sun's energy hitting the surface due to the tilt of the Earth's rotation on its axis and the length of the day.	arrive. Some distant galaxies are so far away that their light takes several billion years to reach Earth. People on Earth, therefore, see the stars as they were that long ago in the past. **The evolution and structure of the solar system** ** Nine planets of very different sizes, composition, and surface features move around the Sun in nearly circular orbits. Several planets have a great variety of moons, some of which show evidence of geological activity. ** Many chunks of rock orbit the Sun. Some meet the Earth in its yearly orbit around the Sun [meteors] while others are mixed with ice and have orbits that carry them close to the Sun [comets], where the Sun's radiation boils off frozen material from their surfaces and pushes it into a long, illuminated tail. ** Earth is a relatively small planet, third from the Sun, and composed mostly of rock. Other planets have compositions and conditions very different from Earth's. ** The Earth is one of several planets that orbit the Sun, and the Moon orbits around the Earth. Like all planets and stars, the Earth is approximately spherical in shape. **The Sun and Earth's seasons** ** The Sun warms the land, air, and water. ** Because the Earth turns daily on an axis that is tilted relative to the plane of its yearly orbit around the Sun, sunlight falls more intensely on different parts of the planet during the year. The difference in heating of the Earth's surface produces the planet's seasons and weather patterns.	sunlight on different areas of Earth across the year. **The Sun and Earth's seasons** ** **Earth and the Solar System** The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. ** This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

NSES (1996) Astronomy Related Standards	AAAS (1993) Astronomy Related Standards	NGSS (2013) Astronomy Related Documents
Yearly patterns, daily patterns and moon phases ** The Sun, Moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described. ** Objects in the sky have patterns of movement. The Sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The Moon moves across the sky on a daily basis much like the Sun. The observable shape of the Moon changes from day to day in a cycle that lasts about a month. ** Most objects in the Solar System are in regular and predictable motion. Those motions explain such phenomena as the day, the year, the phases of the Moon, and eclipses.	**Yearly patterns, daily patterns and moon phases** ** The patterns of stars stay the same although they appear to move across the sky nightly, and different stars can be seen during different seasons. Planets change their positions against the background of stars. ** The rotation of the Earth on its axis every 24 hours produces the night-and-day cycle. ** The Moon's orbit around Earth (once about every 28 days) determines what part of the Moon is lit by the Sun and how much of that part can be seen from Earth. We see these changes as phases of the Moon. ** The Sun can be seen only in the daytime, but the Moon can be seen sometimes at night and sometimes during the day. All sky objects appear to move slowly across the sky. The Moon looks a little different every day, but looks the same again about every four weeks.	**Yearly patterns, daily patterns and moon phases** ** 1- Patterns of the motion of the sun, moon, and starts in the sky can be observed, described, and predicted. ** 1 Seasonal patterns of sunrise and sunset can be observed, described, and predicted. ** Earth and the Solar System The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. ** Patterns of the apparent motion of the sun, The moon, and stars in the sky can be observed, described, predicted, and explained with models. ** This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

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