

What are elementary and middle school students expected to learn about the sun and moon in Taiwan and the US?

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Abstract

The overarching goal of this study is to examine what is considered most important regarding the depth, breadth and content of space science concepts as reflected in current national science education standards and science curricula in Taiwan and the US. Major findings of this study conclude that many skills and concepts articulated in the standards in both countries are similar, although the structure of the standards is not the same; most space science content is addressed more specifically for a smaller grade span in Taiwan's standards than in the US standards; and 'Insights' (an elementary science curriculum in the US) exhibits greater learner self-direction but expects students to comprehend more concepts in about the same amount of time as does the Taiwanese curriculum. Differences in these two curricula could be attributed to the varied content expectations for different clusters of grade span in the science standards. While the US is developing the Next Generation Science Standards, the findings of this study shed light on students' performance expectations in science in different countries, which in turn helps direct focus to areas of science education requiring significant attention, such as science standards, curriculum, and textbook development through international benchmarking.

Key words: *science curriculum, science standards, comparative study, sun and moon concepts*

Introduction

Science Education Standards in Taiwan and the US

Reform documents in science education in the US emphasize the inclusion of inquiry, a 'less is more' philosophy, and the movement to standards-based education (National Research Council [NRC], 1996; American Association for the Advancement of Science, 1993). In spite of these reform efforts, Valverde and Schmidt (2000) found that American schools introduce three times as many science topics in grades 1-3 than do some foreign countries and thus tend to cover core science more superficially. The National Center for Education Statistics (NCES)

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also reported “wide variation among states in the rigor of their standards” when “mapping state standards for proficient performance on the NAEP [National Assessment of Educational Progress] scales” (NECS, 2011, p. 27). In an effort to satisfy different state standards, the US curriculum has been modified to its current form, which has been characterized as lacking both focus and coherence and being highly repetitive in comparison to average patterns derived from countries that participated in the Trends in International Mathematics and Science Study, or TIMSS (Schmidt et al., 1997).

More than 15 years ago, the American Federation of Teachers (1996) asserted that, “without honest international benchmarking, we will be captives of our own parochial notions of what students accomplish, and low standards might very well be the result” (p. 33). After years of debating the idea of national content standards, interest in a ‘common core’ of internationally benchmarked standards has increased and resulted in the development of the Common Core State Standards in mathematics and language arts as a state-led effort of 48 states, 2 territories and the District of Columbia coordinated by the National Governors Association and the Council of Chief State School Officers (Common Core State Standards Initiative, 2011). The Standards, which define the knowledge and skills that young people need for success in colleges and careers, were released in June 2010 (Cavanagh, 2010; Common Core State Standards Initiative). A similar effort in science standards has been observed. The National Research Council has recently released *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* that “is grounded in the most current research on science and science learning and identifies the science all K-12 students should know” (NRC, 2012, para. 2). Based on the *Framework*, 20 states are developing the *Next Generation Science Standards* that will be rigorous and internationally benchmarked and “prepare students for college and careers” (NRC, 2012, para. 3). One of the factors driving the renewed interest in standards is the concern regarding American students’ disappointing performance on U.S.-based exams like the National Assessment of Educational Progress, or NAEP, and on international tests like the TIMSS and the Program for International Student Assessment, or PISA (Cavanagh, 2010).

Other countries, such as Taiwan, have also begun reform efforts in science education that affect science curricula and the teaching of inquiry. Although Taiwan has been one of the top-performing countries on international assessments such as the TIMSS and PISA (National Center for Education Statistics, n.d.-a; Organization for Economic Co-operation and Development, n.d.), critics assert that Taiwan’s math and science courses are test driven, designed primarily for achieving high test scores rather than general comprehension (Chou & Ho, 2007; Stigler, Lee, & Stevenson, 1987). The difficulty comes when the students try to apply their skills to real-life enterprises. These concerns prompted the Taiwanese government in 1998 to begin phasing in new curriculum guidelines for grades 1-9 as well as other educational reforms, such as the revision of teacher training to include innovative teaching methods and the development of a school-based curriculum (Chen & Chung, 2000; Hwang, 2004; Ministry of Education [MOE], 2010a).

Taiwan’s Curriculum General Guidelines recognized seven major fields of study at the elementary and middle school levels and prompted in 2003 the development and implementation of specific guidelines for each field, such as Curriculum Guidelines of Science and Technology Learning Area (CGSTLA) (MOE, 2010a). Similar to science education reform efforts in the US, the goals of the CGSTLA are to reduce the amount of science content students are required to learn and to promote connections between science and students’ daily lives (Chang, Lee, & Yeh, 2006). Moreover, emphasis on scientific inquiry is evident in its “Implementation Guidelines” section, which states:

Teachers should design and create a learning environment for students to engage in which includes arranging time for them to devote themselves to extended exploration activities. ... Teaching should be focused on student-centered learning activities to guide them to do scientific exploration and to apply the problem-solving process to design and manufacture according to special themes. ... Teaching activity design should be centered on problem-solving strategies and follow the procedures of confirming questions, collecting related information, drawing up a plan for solution, choosing and administering the plan, and reviewing and improving on the plan. (MOE, 2010a, pp. 32-34)

Elementary Science Curricula in Taiwan and the US

In the US, the local board of education plays the pivotal role in making decisions about curriculum. In a study on the third TIMSS results, Peak et al. (1996) reported that “most of the nearly 16,000 districts design their own curriculum or standards, usually within broad guidelines issued by each of the 50 states” (p. 37). Another study on the third TIMSS results also noted that “Because responsibility for curriculum decisions rests with states and localities, there is variation among the curricula used within U.S. borders” (Beatty, 1997, p. 9).

To improve elementary level science instruction in American schools, the National Science Foundation in the 1960s funded a few inquiry-based science curriculum projects, including the Science Curriculum Improvement Study (SCIS), Science-A Process Approach (SAPA), and the Elementary Science Study (ESS) (Laurence Hall of Science [LHS], 2001, p. 2). NSF funded another round of K-8 curriculum development in 1988, partly due to the fact that the textbook industry continually produced science and math curricula of poor quality (LHS, p. 4). The following curriculum projects were sponsored by the second round of NSF funding: the K-8 Science for Life and Living program by Biological Science Curriculum Study (BSCS); the Insights K-6 science curriculum by Educational Development Center (EDC); the K-8 Full Option Science System (FOSS) program by the LHS; the K-6 Life-Lab Science Program by the University of California at Santa Cruz; and the K-8 Science and Technology for Children (STC) program by the Smithsonian Institution (LHS, p. 6).

Taiwan centralized the compilation of textbooks prior to 1996, when it started to adopt the review system (Fu, 2004; MOE, 2007). There are currently eight approved elementary science curricula that were developed by the following publishers: National Academy for Educational Research, National Institute for Compilation and Translation, Hanlin, Kang Hsuan, Nani, Newton, Senseio, and Uchen (National Academy for Educational Research, 2012).

The relationship between standards, curriculum, and learning has been clearly identified in the literature. Standards help to ensure that we are clearly communicating “content goals, performance expectations and attitudes” to students, parents and teachers (Valverde & Schmidt, 2000, p. 654). Valverde and Schmidt compared expectations about student performance in the United States and 21 other high-achieving countries using data from the third TIMSS and found that “substantial differences in educational standards are related to different levels of student attainment in science and mathematics” (p. 685). Schmidt et al. (2001) also claimed that “through the curriculum they [schools] provide a systematic opportunity for students to learn and master the subject matter contents and processes necessary for their successful living” (p. 354). The findings from their study on cross-national comparison of curriculum and learning strongly support that “curriculum mattered to learning in mathematics and the sciences” (p. 355).

Given the prominent relationship of the standards and curriculum to students' learning, the research objective of our overall study is to answer the following questions:

1. What do Taiwan and the US consider most important regarding the depth, breadth and content of science concepts as articulated in their standards and curricula?
2. How well do the science education standards inform the development of elementary science curriculum materials in these two countries?

The following findings from the aforementioned studies support our selection of Taiwan and the US for this comparison study:

1. “The average U.S. fourth-grade science score was higher than those in 25 of the 35 other countries, lower than in 4 countries (all of them in Asia), and not measurably different from 6 countries. The average U.S. eighth-grade science score was higher than those in 35 of the 47 other countries, lower than in 9 countries (all of them in Asia or Europe), and not measurably different from 3 countries” (National Center for Education Statistics, n.d.-b). Why does Taiwan, being one of those Asian countries, outperform the US on the international assessments, such as the TIMSS? Past studies have examined many factors that may be related to patterns of students’ achievement in different countries, and the prominent relationship of the standards and curriculum to students’ learning has been confirmed. Thus, this study compares the science standards/curriculum in these two countries.

2. Though Taiwan and the US took different reform paths in 1990s and early 2000s, the resulting standards documents (National Science Education Standards, or NSES, in the US and CGSTLA in Taiwan) share some similar goals, such as “changing emphases to promote inquiry” and developing understanding of “a few fundamental science concepts” (NRC, 1996, p. 113). How well do these standards with similar visions guide the development of science curricula in the two countries with different levels of curriculum control (Beatty, 1997; MOE, 2007)? The findings from this comparison study of the currently used science standards and curricula will provide additional insight as the US is developing the *Next Generation Science Standards* that are internationally benchmarked.

Method

As a first step to this cross-national comparative study on science education standards and curricula materials, we conducted an in-depth comparative analysis of the science content related to the Moon and Sun topics presented in one commonly used elementary science curriculum from the US and one from Taiwan, taking into consideration the space science content standards in both countries. The Moon and Sun concepts were chosen, as they are two of the commonly addressed topics for the same grade span in both countries’ science curricula.

For our comparative examination and analysis, we chose the US Insights curriculum and the Taiwanese Elementary Science and Technology Curriculum (ESTC) by Hanlin Publisher. This choice is based on the following factors:

1. Insights and ESTC are widely adopted in each country, respectively. Insights, FOSS and STC, the three NSF-supported science curriculum projects, “have spread across the country” (Jerome et al., 2006, p. 469). “There are over 100 district materials centers to support the curricula in large districts, and many additional districts are using the materials” (Jerome et al., p. 469). Similarly, as one of the eight approved Taiwanese elementary science curricula, the ESTC by Hanlin Publisher is used in many schools.

2. The hands-on inquiry science featured or claimed in the elementary NSF programs and ESTC echoes the standards' emphasis on scientific inquiry in each country, *respectively*.
3. Many studies have been conducted to evaluate the elementary NSF programs, particularly the FOSS program. Insights curriculum has not received as much attention as the other programs (LHS, 2001).

We conducted a comparative analysis of the science content standards organization, identified similar and different space science content in each country's science education standards document (NSES and CGSTLA) and curricula (Insights' *Sun, Earth, and Moon* module and ESTC's *Moon* and *Sun* units), and organized the findings into charts. In addition, we analyzed how inquiry features are exhibited in the teacher's guides of the chosen curricula. A coding system based on the variations of the Five Essential Features of Inquiry Teaching and Learning Across All Grade Levels (NRC, 2000) was used to code every Sun- and Moon-related learning experience in both Insights and ESTC. Using a two-digit code (e.g., 1-1), the first digit identifies five essential features of inquiry:

1. Learner engages in scientifically oriented question.
2. Learner gives priority to evidence in responding to questions.
3. Learner formulates explanations from evidence.
4. Learner connects explanations to scientific knowledge.
5. Learner communicates and justifies explanations. (NRC, 2000, p. 29)

Each essential feature of inquiry is accompanied by four variations that differ based on "the amount of structure, guidance, and coaching the teacher provides for students engaged in inquiry" (NRC, 2000, p. 28). The second digit of the code indicates the variation associated with the identified essential feature, with 1 being most learner self-directed and 4 being most teacher-guided. For example, the four variations associated with the first essential features of inquiry from most learner self-directed to most teacher-guided are:

1. Learner poses a question.
2. Learner selects among questions, poses new questions.
3. Learner sharpens or clarifies question provided by teacher, materials, or other source.
4. Learner engages in question provided by teacher, materials, or other source. (NRC, 2000, p. 29)

Following the individual analysis of the standards and curricula, the researchers shared their preliminary analyses to triangulate the similar and different space science content identified and coding of inquiry features assigned. Finally, each researcher reviewed the triangulated comparison and coding as a final validation. To further examine the amount of learner self-direction vs. teacher guidance exhibited in Insights' *Sun, Earth, and Moon* module and ESTC's *Moon* and *Sun* units, the frequency of each identified variation of classroom inquiry was computed by dividing the number of learning experiences that exhibit a certain variation by the total number of learning experiences in each curriculum.

Results and Discussion

Comparison of science content standards organization between the NSES and CGSTLA

The science content standards in the NSES are divided into the following eight categories: unifying concepts and processes in science, science as inquiry, physical science, life science,

earth and space science, science and technology, science in personal and social perspectives, and history and nature of science (NRC, 1996). Each category of standards are clustered for grades K-4, 5-8, and 9-12 with the exception of the standard of unifying concepts and processes being presented for grades K-12 (NRC, 1996). Each category for each grade span contains a range of one to six standards. Essential aspects of the NSES of particular importance here are the content standards categorized as:

- I. Earth and Space
 - a. Levels K-4
 - i. Properties of Earth materials; objects in the sky; and, changes in Earth and sky.

After each content standard are two sections, Developing Student Understanding and Guide to the Content Standard (NRC, 1996). The ideas that are fundamental to each content standard are described in the latter section. One of the fundamental concepts and principles that underlie the standard ‘objects in the sky’ states that “The sun provides the light and heat necessary to maintain the temperature of the earth” (NRC, 1996, p. 134).

Taiwan’s CGSTLA recognizes the following eight aspects of important competence in science and technology learning areas: process skills, recognition of science and technology, essence of science, development of science and technology, scientific attitude, cognitive and thinking skills, scientific application, and design and manufacturing (MOE, 2010b). Each group of competence indicators are clustered for grades 1-2, 3-4, 5-6, and 7-9 (MOE, 2010b). The main and detailed contents of teaching materials suggested for each grade span are described in the CGSTLA’s Appendix 1 and 2 (MOE, 2010b). Unlike the NSES’s grouping of the subject matter standards “using three widely accepted divisions of the domain of science” (NRC, 1996, p. 106), the CGSTLA’s teaching content is grouped into 13 main trans-disciplinary subjects with each subject further divided into different numbers of minor subjects (MOE, 2010b). Detailed contents of teaching materials for each grade span are then spelled out for each minor subject. For example, ten minor subjects, including “day, night and the four seasons,” “animals’ internal constancy and regulation,” and “chemical reactions,” underlie the main subject “change and balance” (MOE, 2010b, p. 36). For the minor subject “day, night and the four seasons,” students in grades 1-2 are expected to “notice sunrise and sunset distinguish day and night”(MOE, 2010b, p. 43).

The comparative analysis of the two countries’ science content standards organization shows that one to three aspects of important competence in the CGSTLA correspond to each category of standards in the NSES (see Table 1). Many concepts and principles articulated in the NSES are similar to those in the CGSTLA; however, differences exist in the focuses and details of the standards. For example, science and technology standards in the NSES clearly indicate the constraints, tradeoffs, benefits, and consequences associated with technological designs or technological solutions, while the CGSTLA emphasizes the positive impact of technology on individuals, families, communities and societies.

Table 1. Comparison of Science Content Standards Categorization between the US National Science Education Standards (NSES) and Taiwan’s Curriculum Guidelines of Science and Technology Learning Area (CGSTLA)

| Categories of Science Content Standards in the NSES | Corresponding Aspects of Important Competence in the CGSTLA |
|---|--|
| Unifying Concepts and Processes | Recognition of Science and Technology |
| Science As inquiry | Process Skills Recognition of Science and Technology Cognitive and Thinking Skills |
| Physical Science | Recognition of Science and Technology Appendix 1 and 2 |
| Life Science | Recognition of Science and Technology Appendix 1 and 2 |
| Earth and Space Science | Recognition of Science and Technology Appendix 1 and 2 |
| Science and Technology | Recognition of Science and Technology Development of Science and Technology Design and Manufacturing |
| Science in Personal and Social Perspectives | Development of Science and Technology Scientific Application |
| History and Nature of Science | Essence of Science Development of Science and Technology Scientific Attitude |

Comparison of space science content standards for elementary and middle school grades between Taiwan and the US

In the NSES, space science content standards include ‘objects in the sky,’ and ‘changes in the earth and sky’ for grades K-4 and ‘earth in the solar system’ for grades 5-8. In contrast, the main and detailed contents of teaching materials for space science are spelled out in the following six minor subjects in the CGSTLA: earth and space; commonality of life; day, night and the four Seasons; temperature and calorific capacity; movement and force; and forms and transformation of energy. In general, space science content is similar in both countries’ standards documents but is addressed more specifically in the CGSTLA than in the NSES. For grades K-4, the NSES expects students to observe and describe the properties, locations and movements of the Sun, Moon, stars, clouds, birds and airplanes, while the CGSTLA suggests similar but more detailed content for each grade span, including the movements of the Sun from east to west throughout the day for Grades 1-2, lunar rising from the east and setting to the west for Grades 3-4, and recognizing important stars and constellations during different seasons for Grades 5-6. In addition, the CGSTLA expects grades 1-2 students to know how the regular pattern of the Sun’s movement, which accompanies the changes of its shadow, can be used to measure time, as well as to notice that sunrise and sunset distinguish day and night, and expects grades 3-4 students to notice the difference in the length of day and night and temperature in different seasons.

Furthermore, the space science standards for the upper elementary or middle school grades in both countries (one grade span of 5-8 in the NSES vs. two grade spans of 5-6 and 7-9) emphasize the following fundamental concepts:

- The Sun is a star
- The composition of the Solar system
- Causes of the day, the year, phases of the moon, eclipses, and seasons
- Gravity is the force that governs the motion of the objects in the Solar system

However, some space science content is recommended for different grade spans in these two countries' standards. While the CGSTLA expects grades 5-6 students to discover the different positions of sunrise and sunset in different seasons, a similar science content regarding the Sun's slow path change over the seasons underlies the NSES standard 'changes in the earth and sky' for grades K-4. Some other content is only clearly spelled out in one of the standard documents. The NSES space science content standards for grades 5-8 include the concept of the Sun being the major source of energy for phenomena on the Earth's surface (e.g., winds, ocean currents, and the water cycle), but the CGSTLA barely addresses the significant role that the Sun plays in such natural phenomena. On the other hand, the CGSTLA expects grades 7-9 students to understand the following content, which is not elaborated in the NSES:

- The Earth is very unique and can gestate life
- There are geologies and atmospheric activities on some planets and moons
- There are numberless galaxies in the Universe; Milky Way is one of them and the Sun is a star in this galaxy
- The meaning of light-year

A thorough comparison of space science content standards for elementary and middle school grades between Taiwan and the US is presented in Table 2.

Comparison between the two science curricula: Insights and ESTC

The Insights curriculum is an inquiry-based core curriculum of 21 six- to eight-week modules, which is "built directly on the work in science education of the 1960s, in particular the Elementary Science Study (ESS) developed at the Education Development Center, Inc (EDC)" (Worth, 2007, Development Process section, para. 1). Each Insights module, including a comprehensive teacher's guide with reproducible masters for student science notebook pages and sets of materials, is designed for use at grades K-1, 2-3, 4-5, or 6 and focuses on one topic in depth (EDC, 2010).

The ESTC by Hanlin is one of the elementary science and technology curricula reviewed and approved by Taiwan's Ministry of Education. It consists of eight sequenced volumes that are designed for use at grades 3 through 6. Each volume encompasses four four- to five-week units (three 40-minute sessions per week) for the first seven volumes and three units for the last volume, with each unit focusing on one topic. Similar to Insights, each volume of ESTC consists of a comprehensive teacher's guide and student science notebook; however, it also has the textbook in both student's and teacher's edition.

The Moon- and Sun-related concepts are presented in one of the Insights modules titled, "Sun, Earth, and Moon," for grades 4-5, while these concepts are addressed in two ESTC units titled, "Moon," and "Sun" for grades 4 and 5, respectively. With regard to the Moon-related concepts, students are expected to "observe and describe the moon over a period of time and

identify a pattern in the changes of the moon's appearance" in both curricula (EDC, 2007, p. 81). However, a few differences exist. In addition to completing the nighttime observations for a complete Moon cycle, the Insights curriculum specifically guides students in observing "the daytime moon for 10 days" and recording its position "in relationship to the sun" by counting the number of fists between them so as to "recognize a relationship between the sun's light and the moon's appearance" (EDC, 2007, p. 81). After making direct observations of the Moon, students who use Insights are required to "use spheres and flashlights" to "model the motion of the moon and earth relative to the sun" and explain what causes the phases of the Moon (EDC, 2007, p. 175). ESTC, on the other hand, asks students to observe the Moon's surface and to explain what causes its different levels of brightness. Students are then guided to observe and describe the Moon's position and appearance changes over time, but not expected to explain the causes of the Moon phases. A complete comparison of students' performance expectations for the Moon-related learning experiences in these two curricula is presented in Table 3.

The comparative analysis of the Sun-related learning experiences in these two curricula indicates that the common expectations include making, changing and tracking shadows and describing the Sun's position in the sky in terms of its direction and angular height. However, Insights expects students to use the number of fists, angles made by the arms, a protractor with a straw, and a quadrant to measure the Sun's height above the horizon (i.e. angular height) during the day through using a peripheral view of the Sun, while ESTC has students utilize the shadow of an object to indirectly measure the Sun's angular height and its direction, in order to avoid the potential harm to eyes from direct observation of the Sun. The direct angular height measurement is introduced in the ESTC's "Moon" unit instead, where students are guided to practice different ways of measuring the angular height of both near and far objects before they observe and describe the Moon's position changes. After having students identify the pattern in the changes of the Sun's directions and angular heights within a day, ESTC extends students' thinking by prompting them to discover the relationship between the Sun's angular height and surface temperature measured at different times of the day.

Table 2. Comparison of Space Science Content Standards for Elementary and Middle School Grades between Taiwan and the US

| National Science Education Standards (NSES)– Fundamental Concepts and Principles that Underlie Content Standard D Grades K-8 | Corresponding Taiwanese Detailed Contents of Teaching Materials for Learning Areas in Science and Technology Stage 1 (Grades 1-2) | Corresponding Taiwanese Detailed Contents of Teaching Materials for Learning Areas in Science and Technology Stage 2 (Grades 3-4) | Corresponding Taiwanese Detailed Contents of Teaching Materials for Learning Areas in Science and Technology Stage 3 (Grades 5-6) | Corresponding Taiwanese Detailed Contents of Teaching Materials for Learning Areas in Science and Technology Stage 4 (Grades 7-9) |
|--|---|--|--|---|
| K-4: Objects in the Sky The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described. | 111-1a. ^a notice that the sun rises from the east at daytime and sets to the west 212-1a.^b notice that sunrise and sunset distinguish day and night | 111-2a. notice that the moon rises from the east and sets to the west | 111-3b. notice that there are numberless stars in the sky; some are bright and some are dark 111-3d. recognize important stars and constellations | |
| K-4: Objects in the Sky The sun provides the light and heat necessary to maintain the temperature of the earth. | 214-1a ^c . learn that heat can be generated from the sun, combustion, and friction; learn to use a thermometer 217-1a ^d . notice that exposure to the sun can warm up a body and the sun can provide heat | | | |
| K-4: Changes in the Earth and Sky 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. | 111-1a. notice that the sun rises from the east at daytime and sets to the west 215-1a ^e . notice that there is a regular pattern of the sun’s movement, which accompanies the changes of its shadow and can be used to measure time | 111-2a. notice that the moon rises from the east and sets to the west 111-2b. observe and discover the moon’s waxing and waning phenomena (change of the phase of the moon) 212-2a. notice the difference in the length of day and night and temperature in different seasons | 111-3a. discover the different positions of sunrise and sunset in different seasons 111-3c. observe and describe different stars (or constellations) at night during different seasons | |
| 5-8: Earth in the Solar System The earth is the third planet from the sun in a system that includes | | | 111-3e. learn that the sun is a star | 111-4d. learn the members in the solar system 111-4f. understand that the |

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|--|--|
| <p>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.</p> | <p>earth is very unique and can gestate life 111-4e. learn that there are geologies and atmospheric activities on some planets and moons 111-4h.^f understand that there are numberless galaxies in the universe; Milky Way is one of them and the sun is a star in this galaxy 111-4g. understand the meaning of light-year</p> |
| <p>5-8: Earth in the Solar System Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.</p> | <p>111-4a. utilize models to describe the relevant motion of the earth, sun, and moon; and to explain the phenomena of change of the phase of the moon, and solar and lunar eclipse 212-4a. recognize that day and night are caused by the rotation of the earth from observing earth and sun models 212-4c. learn that one rotation of the earth is one day and one revolution of the earth is one year</p> |
| <p>5-8: Earth in the Solar System 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.</p> | <p>111-4b. understand the phenomena of tides and their causes 111-4c. know that every member in the solar system is affected by gravitation</p> |
| <p>5-8: Earth in the Solar System The sun is the major source of energy for phenomena on the</p> | <p>212-4b. recognize from observing earth and sun models that the four seasons are caused</p> |

earth's surface, such as growth of plants, winds, ocean currents, and the water cycle.

Seasons result from variations in the 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.

by the revolution of the earth and the tilt of the earth's axis

Note. The content bolded in the table is the concepts/principles that are missing or not clearly described in the other country's standards.

^aCGSTLA's teaching content is grouped into five broad areas: components and characteristics of nature, effects of nature, evolution and continuance, life and environment, and sustainable development. Each broad area includes 2 or 3 main trans-disciplinary subjects with each subject further divided into different numbers of minor subjects. The 3-digit number before the dash for each code used in the table identifies the broad area, main subject and minor subject of a specific content. The number-letter combination after the dash indicates the grade level (1 is Grade 1-2, and 2 is Grade 3-4) and serial number (a, b, c...) for each teaching material. For example, 111-1a refers to the first broad area (components and characteristics of nature), first main subject (Earth environment), minor subject of Earth and Space, Stage 1 (Grade 1-2), and "a" item teaching materials.

^bMinor Subject 212 is Day, Night and the Four Seasons.

^cMinor Subject 214 is Temperature and Calorific Capacity.

^dMinor Subject 217 is Forms and Transformation of Energy.

^eMinor Subject 215 is Time Measurement.

^fSimilar concepts/principles are found in NSES Content Standard D for Grades 9-12, which states, "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."

Table 3. Comparing Moon-Related Concepts in Taiwan and United States Elementary Science Curricula

| United States – Insights | | | Taiwan – ESTC | | |
|--|---|---|---|---|---|
| Lesson Sequence and Length | Expectations | Variations of Classroom Inquiry Exhibited | Lesson Sequence and Length | Expectations | Variations of Classroom Inquiry Exhibited |
| <p>Moon Observations—</p> <p>Part I-Daytime: two 50-minute and five to six 15-20 minute sessions;</p> <p>Part II-Nighttime: Two 30-minute and one 50-minute sessions</p> | <p>Science Concepts—</p> <p>1. Observe and describe the moon over a period of time</p> <p>2. Identify a pattern in the changes of the moon's appearance</p> <p>3. Recognize a relationship between the sun's light and the moon's appearance</p> <p>Inquiry—</p> <p>1. Collect data on various aspects of the moon</p> <p>2. Recognize patterns</p> <p>3. Make predictions based on patterns</p> | <p>1-4; 2-2; 3-2; 4-3; 5-4</p> | <p>1. Observing the Moon's Surface—</p> <p>Three 40-minute sessions</p> | <p>1. Share the folktales about the moon.</p> <p>2. Cultivating students' imagination through observing the moon's surface</p> <p>3. Explain what causes different levels of brightness on the moon's surface.</p> | <p>1-4; 2-2; 3-3; 4-4; 5-2</p> |
| <p>3. Using Models to Understand the Moon Data—</p> <p>One 50-minute session</p> | <p>Science Concepts—</p> <p>1. Observe and describe the moon over a period of time</p> <p>2. Identify a pattern in the changes of the moon's appearance</p> <p>3. Recognize a relationship between the sun's light and the moon's appearance</p> <p>Inquiry—</p> <p>1. Collect data on various aspects of the moon</p> <p>2. Recognize patterns</p> <p>3. Make predictions based on patterns</p> <p>4. Model the motion of the moon and earth relative to the sun</p> | <p>1-4; 2-2; 3-4; 4-3; 5-3</p> | <p>2. Observing Moon's Position Changes in the Sky—</p> <p>Eight 40-minute sessions</p> | <p>1. Discuss what should be noted down while observing the moon's position in the sky</p> <p>2. Accurately describe and record the height of an object</p> <p>3. Construct a quadrant and explain how it works</p> <p>4. Measure the angular height of both near and far objects with a quadrant</p> <p>5. Use a compass and quadrant to observe and describe the moon's position change over time</p> | <p>1-4; 2-2; 3-3; 4-3; 5-3</p> |

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|---|--|----------------------------|---|--|----------------------------|
| 4. Scale Model of the Earth, Sun, and the Moon-- | Science Concepts— 1. Realize the shortcomings of an earth/sun/moon scale model | 1-4; 2-3; 3-2; 4-3; 5-4 | 3. Observing Moon's Appearance Changes— | 1. Identify changes in the moon's appearance over time; make a chart to record the moon's appearance 2. Observe and describe the moon's appearance changes over a period of time 3. Identify a pattern in the changes of the moon's appearance through observation records | 1-4; 2-4; 3-3; 4-4; 5-4 |
| Two 50-minute sessions | Inquiry— 1. Measure how far away the moon would need to be from a 1-cm earth | | Four 40-minute session | | |
| 5. More About Earth, Sun, and Moon Interactions (Optional Exploration)— | Science Concepts 1. Explain and draw the situation that will result in a lunar eclipse being seen from earth | 1-4; 2-4; 3-2;4-3; 5-4 | | | |
| Part I- Lunar Eclipse: one 30+ minute session | Inquiry— 1. Manipulate models to show how eclipses can occur | | | | |

Note. The content bolded in the table is the concepts/principles that are missing or barely addressed in the other country's science curriculum. A coding system based on the variations of the Five Essential Features of Inquiry Teaching and Learning Across All Grade Levels (NRC, 2000, p. 29) was used to code each learning experience. Each essential feature of inquiry is accompanied by four variations that differ based on the amount of learner self-direction and teacher guidance incorporated into the lesson (NRC, 2000). Using a two-digit code (e.g., 1-1) the first digit identifies five essential features of inquiry:

1. Learner engages in scientifically oriented question.
2. Learner gives priority to EVIDENCE in responding to questions.
3. Learner formulates EXPLANATIONS from evidence.
4. Learner connects explanations to scientific knowledge.
5. Learner communicates and justifies explanations.

The second digit of the code indicates the variation associated with the identified essential feature, with 1 being most learner self-directed and 4 being most teacher-guided.

Some Sun-related concepts are more thoroughly addressed in one of these two curricula. While Insights includes an optional session to explore and discuss how direct/indirect Sun rays affect our lives, ESTC devotes four 40-minute sessions to address how the Sun affects our lives and the survival of living organisms on the Earth. It also prompts students to critically think about how human beings have used the light, heat and shadow of the Sun by taking its direction and angular height into consideration, such as ancient time-measuring devices (i.e. sundials), the configuration of solar panels, and planting different plants that are tolerant or intolerant of shade. The emphasis of these four ESTC sessions on the Sun's impact reflects one of the goals of Taiwan's new curriculum guidelines to promote connections between science and students' daily lives (Chang, Lee, & Yeh, 2006).

The use of modeling as a learning strategy and inclusion of the concepts regarding the Sun-Earth-Moon interactions distinguishes Insights from ESTC. Among Insights' 13 learning experiences, six require students to explore and explain the Sun-Earth-Moon interactions, including Moon phases, day and night, different daylight hours at different locations on Earth, and solar and lunar eclipses, through making and manipulating models. Insights also has students create a scale model of the Earth, Sun and Moon to illustrate their size and distance relationships and realize the shortcomings of a scale model. A complete comparison of students' performance expectations for the Sun-related learning experiences in these two curricula is presented in Table 4.

In addition, the analysis of the learning experiences in both curricula according to the five essential features of classroom inquiry and their variations reveals that the Insights curriculum exhibits greater learner self-direction than ESTC (see Table 5). As for the first essential feature of classroom inquiry, Insights scaffolds students' ability to ask scientifically oriented questions by having students engage in provided questions to activate prior knowledge and transition to new concepts in most learning experiences. Students then sharpen/clarify provided questions and pose their own questions in the final experience. ESTC also provides questions in the beginning of each lesson to arouse students' interest and/or activate their prior knowledge; however, students' responses might be discouraged, as answers to some of these questions (e.g., chart of recorded position of the Moon in the sky) are provided in its student edition textbook.

Table 4. Comparing Sun-Related Concepts in Taiwan and United States Elementary Science Curricula

| United States - Insights | | | Taiwan - ESTC | | |
|---|--|---|--|--|---|
| Lesson Sequence and Length | Expectations | Variations of Classroom Inquiry Exhibited | Lesson Sequence and Length | Expectations | Variations of Classroom Inquiry Exhibited |
| Observing and Making Shadows— Two to three 50-minute sessions | Science Concepts— Draw differences in the shadow of an object – first by moving the object , then by moving the light source Summarize how shadows can change in length, direction, and /or shape Inquiry— Find ways to change the length, direction, and/or shape of a shadow Record findings Develop vocabulary for talking about shadows Use notebooks as tools in science learning | 1-4; 2-2; 3-3; 4-2; 5-3 | 1. Sun Makes Light and Heat— Four 40-minute sessions | Discover that the sun is a star that makes light and heat. Understand how shadows are formed. Understand that different positions of the light source relative to an object will change the length and direction of its shadow through an experiment. | 1-4; 2-2; 3-2; 4-3; 5-4 |
| 2. Tracking Shadows— One 45+ minute session and one 60 minute session (split between two days) | Science Concepts— Track shadows of a peg over the course of a day. State that the shadows caused by the sun’s light are longer in the morning and late afternoon, and shorter in the middle of the day because the relationship between the sun and the object casting the shadow changes Inquiry— Complete a science investigation with group Observe and describe how outside shadows change during the day Predict how a shadow might change based on earlier observations | 1-4; 2-2; 3-2; 4-2; 5-3 | 2. Position of the Sun in the Sky— Eight 40-minute sessions | Describe the position of the sun in the sky in terms of its direction and angular height. Identify the pattern in the changes of the sun’s directions and angular heights within a day. Discover the relationship between the sun’s angular height and surface temperature measured at different times of the day. Identify the pattern in the changes of the directions and angular heights of sunrises over a year. Understand that the seasonal changes in temperature are related to the pattern in the changes of the sun’s angular heights. | 1-4; 2-2 or 2-3; 3-3; 4-3; 5-3 |
| 3. The Sun’s Position in the Sky – Measurements | Science Concepts— State that the angular height of the sun changes during the day | 1-4; 2-2; 3-2; 4-2; 5-3 | 3. Sun and Our Life— | Understand how important the sun is to the earth. Know various time-measuring | 1-4; 2-4; 3-4; 4-4; 5-4 |

What are elementary and middle school students expected to learn about the sun and moon in Taiwan and the US?

| | | | |
|---|---|------------------------------------|--|
| <p>One 30-minute session; one 30-60 minute session; and 30-90 minute session</p> | <p>Express that the angle is less in the morning and late afternoon and greater in the middle of the day Inquiry— Measure the angle of the sun’s height from the horizon with fists and a quadrant Construct a quadrant and explain how it works</p> | <p>Four 40-minute sessions</p> | <p>devices, such as the sun dial. Know the impact of the sun’s angular height on our life through research and discussions.</p> |
| <p>4. The Sun’s Position in the Sky – A Visual One 40-minute session; one 30-minute session; and one 30-40-minute session</p> | <p>Science Concepts— State that the angular height of the sun changes during the day Express that the angle is less in the morning and late afternoon and greater in the middle of the day Explain that the sun’s position changes from a more easterly position in the sky to a westerly position in the sky as the day progresses Inquiry— 1. Plot the sun’s path across the sky by means of marking a shadow on a plastic hemisphere</p> | <p>1-4; 2-2; 3-2; 4-2; 5-3</p> | |
| <p>5. Use of a Model for Understanding Day and Night— One 50-minute session and one 50+ minute session</p> | <p>Science Concepts— Explain that day and night occur because the earth rotates, or spins, on its axis Demonstrate how a model can be used to explain day and night on earth Inquiry— Use styrene balls and flashlights to model day and night on earth</p> | <p>1-4; 2-2; 3-2; 4-3; 5-3</p> | |
| <p>The Tilted Earth Rotates One to two 50-minute sessions</p> | <p>Science Concepts— Determine that the daylight hours at different locations on earth can vary greatly Explain that a tilted axis model explains the graph of daylight hours at different locations on earth Inquiry—</p> | <p>1-4; 2-2; 3-2; 4-2; 5-4</p> | |

| | | |
|--|---|---|
| | <p>Find the sunrise and sunset times of a particular location Mark the corresponding times on strips Compile strips into a graph of sunlight data</p> | |
| <p>Model of a Tilted Earth Orbiting the Sun</p> <p>One 50-minute session and one 20+ minute session spread throughout a whole day.</p> | <p>Science Concepts— Show how the tilted earth revolves around the sun using a model Explain differences in how sunlight hits the earth as the earth revolves around the sun Predict how the location of the sunset will change over time Inquiry— Investigate the relationship between the angle of light and the seasons Use a model to explore the light on a tilted sphere</p> | <p>1-4; 2-2; 3-2; 4-3; 5-4</p> |
| <p>Scale Model of the Earth, Sun, and the Moon</p> <p>One 50+ minute session and one 50 minute session</p> | <p>Science Concepts— Engage in a model that deals with the magnitude of the sun in comparison with the earth Realize the shortcomings of an earth/sun/moon scale model Inquiry— Make a scale model of the sun/earth size and distance relationships Measure how far away the earth would need to be from a 1-meter diameter sun Measure how far away the moon would need to be from a 1-cm earth</p> | <p>1-4; 2-3; 3-2; 4-3; 5-4</p> |
| <p>More About Earth, Sun, and Moon Interaction (Optional Exploration)</p> <p>One 50+ minute session (or split into</p> | <p>Science Concepts— Explain and draw the situation that will result in a lunar eclipse being seen from earth Explain and draw the situation that will result in a solar eclipse being seen from earth Inquiry—</p> | <p>1-4; 2-4; 3-2; 4-3; 5-4</p> |

What are elementary and middle school students expected to learn about the sun and moon in Taiwan and the US?

| | | |
|--|---|----------------------------|
| two parts) | Manipulate models to show how eclipses can occur | |
| Putting It All Together and Going Beyond | Science Concepts— Discuss and contribute to a group project modeling the interactions of the earth, sun, and moon | 1-3; 2-2; 3-3; 4-2; 5-2 |
| Two 50+ minute sessions | Inquiry— Work with a group to develop a model Critique models Research additional information | |

Note. The content bolded in the table is the concepts/principles that are missing or barely addressed in the other country's science curriculum. A coding system based on the variations of the Five Essential Features of Inquiry Teaching and Learning Across All Grade Levels (NRC, 2000, p. 29) was used to code each learning experience. Each essential feature of inquiry is accompanied by four variations that differ based on the amount of learner self-direction and teacher guidance incorporated into the lesson (NRC, 2000). Using a two-digit code (e.g., 1-1), the first digit identifies five essential features of inquiry:

Learner engages in scientifically oriented question; Learner gives priority to EVIDENCE in responding to questions; Learner formulates EXPLANATIONS from evidence; Learner connects explanations to scientific knowledge; and Learner communicates and justifies explanations.

The second digit of the code indicates the variation associated with the identified essential feature, with 1 being most learner self-directed and 4 being most teacher-guided.

Table 5. Frequency of Variations of Classroom Inquiry Exhibited in the Sun- and Moon-Related Learning Experiences^a in Insights and ESTC

| Essential Features | Insights (13 learning experiences in the <i>Sun, Earth, and Moon</i> module) | | ESTC (6 learning experiences in the <i>Moon and Sun</i> units) | |
|---|--|------------------------|--|-----------|
| | Variations ^b | Frequency ^c | Variations | Frequency |
| Learner engages in scientifically oriented questions | 1-3 | 1/13 | 1-4 | 6/6 |
| | 1-4 | 12/13 | | |
| Learner gives priority to evidence in responding to questions | 2-2 | 11/13 | 2-2 | 4/6 |
| | 2-3 | 1/13 | 2-3 | 1/6 |
| | 2-4 | 1/13 | 2-4 | 2/6 |
| Learner formulates explanations from evidence | 3-2 | 10/13 | 3-2 | 1/6 |
| | 3-3 | 2/13 | 3-3 | 4/6 |
| | 3-4 | 1/13 | 3-4 | 1/6 |
| Learner connects explanations to scientific knowledge | 4-2 | 6/13 | 4-3 | 3/6 |
| | 4-3 | 7/13 | 4-4 | 3/6 |
| Learner communicates and justifies explanations | 5-2 | 1/13 | 5-2 | 1/6 |
| | 5-3 | 6/13 | 5-3 | 2/6 |
| | 5-4 | 6/13 | 5-4 | 3/6 |

^aLearning experiences are science activities that the learners engage in to explore and discover science concepts.

^bA coding system based on the variations of the Five Essential Features of Inquiry Teaching and Learning Across All Grade Levels (NRC, 2000, p. 29) was used to code each learning experience. Each essential feature of inquiry is accompanied by four variations that differ based on the amount of learner self-direction and teacher guidance incorporated into the lesson (NRC, 2000). Using a two-digit code (e.g., 1-1), the first digit identifies five essential features of inquiry:

1. Learner engages in scientifically oriented question.
2. Learner gives priority to EVIDENCE in responding to questions.
3. Learner formulates EXPLANATIONS from evidence.
4. Learner connects explanations to scientific knowledge.
5. Learner communicates and justifies explanations.

The second digit of the code indicates the variation associated with the identified essential feature, with 1 being most learner self-directed and 4 being most teacher-guided.

^cFrequency is expressed as a ratio of the number of learning experiences that exhibit a certain variation of classroom inquiry divided by the total number of learning experiences in Insights' *Sun, Earth, and Moon* module or ESTC's *Moon and Sun* units.

The analysis of the variation associated with the second, third and fourth essential feature of classroom inquiry reveals that 11 of 13 learning experiences in Insights vs. four of six in ESTC exhibit the variation of inquiry 2-2; 10 of 13 in Insights vs. one of six in ESTC exhibit the variation 3-2; and 6 of 13 in Insights vs. none in ESTC exhibit the variation 4-2 (see Table 5). That is, Insights provides more guided experiences for students to “collect certain data,” to “formulate explanations from evidence,” and to examine suggested “areas and sources of scientific knowledge” and “form the links to explanations” (NRC, 2000, p. 29). These inquiry variation differences are exemplified in these two curricula's learning experiences exploring shadows and the Sun's positions in the sky. In the Insights learning experiences about shadows, students are expected to find ways to change the length, direction, and/or shape of shadows of various objects by moving either the object or light source. Students then complete a follow-up investigation of tracking shadows of a peg over the course of a day, and explain how outside shadows change in length and direction during the day due to the changes in the relationship between the Sun and the object by linking their thinking to the findings from the previous learning experience. The ESTC, on the other hand, does not provide the opportunity for students to fully explore different ways to change the length, direction, and/or shape of a shadow. Students are only guided to investigate how different positions of the light source (a flashlight) relative to an object (e.g., a pen) change the length

and direction of its shadow without exploring other ways to change shadows (e.g., moving the object) and paying attention to the change in the shadow's shape. In addition, the limited discussion suggested during and following the investigation neither guides students in articulating and recording how they are changing the shadow nor makes explicit links between their findings and the cause of changes in outside shadows during the day.

With regard to the learning experiences about the Sun's position in the sky, both curricula involve students in measuring the Sun's position in the sky at different times of the day. However, to provide students with "a visual representation of the path" to enhance their making sense of the observations, a follow-up learning experience in Insights lets students "plot the sun's path across the sky by means of marking a shadow on a plastic hemisphere" (EDC, 2007, p. 103). Furthermore, students compare the Sun's paths plotted on the dome at different times of the year and explain how angled sunlight contributes to seasonal changes. In contrast, ESTC provides students with a data table and a chart showing the Sun's angular heights measured monthly over the course of a year and a diagram of the Sun's seasonal moving paths. Students are not expected to collect any data about the Sun's position in the sky at different times of the year but are prompted to analyze the information presented in the table, chart and diagram and explain how the seasonal changes in temperature are related to the pattern in the changes of the Sun's angular height.

As to the fifth essential feature of classroom inquiry, more learning experiences in Insights enable students to use "broad guidelines" to "sharpen communication" (6 of 13 learning experiences), while in ESTC students are more frequently "given steps and procedures for communication" (3 of 6 learning experiences) (NRC, 2000, p. 29). Level of learner self-direction associated with these essential features of classroom inquiry is most evident in the Insights' final learning experience where students are asked to "complete a project in their groups to show the movements of the sun, earth, and moon," and to discuss how they might be able to find answers to their questions that come up during this process (EDC, 2007, p. 212).

The content bolded in Table 3 and 4 is the Sun- and Moon-related concepts/principles that are missing or barely addressed in the other country's science curriculum. It is apparent that more science concepts are included in Insights. However, the suggested time to complete the Insights' 13 learning experiences (one is optional and two are part of the Moon Observations) is 21 hours and 40 minutes, while the suggested time for the ESTC *Moon* and *Sun* units is 31 40-minute sessions (20 hours and 40 minutes in total). In contrast with ESTC, Insights expects students to comprehend more concepts in about the same amount of time.

Conclusions/Implications

Major findings of this study include that many skills and concepts articulated in the standards in both countries are similar, though the structure of the standards is not the same (e.g., NSES's grouping of the subject matter standards into three domains of science vs. 13 main trans-disciplinary subjects in the CGSTLA); most space science content is addressed more specifically for a smaller grade span in Taiwan's standards than in the US standards; and Insights exhibits greater learner self-direction but expects students to comprehend more concepts in about the same amount of time than does Taiwan's curriculum. Rather than a broad integrated approach like Insights that groups together all the Sun, Earth, and Moon concepts into one module, each of the ESTC's units is designed around a more focused topic, such as the Sun. In addition, ESTC makes explicit connection between the concepts and their life applications, such as determining the best growing site for a shade-tolerant plant.

The structure difference in these two countries may influence the ways in which users of the standards, such as science teachers or curriculum developers, perceive how science is to be taught across grade levels and disciplines. NSES groups the subject matter standards into three domains of science. Each domain includes one to six broad standards for each grade span, while the fundamental concepts and principles that underlie each standard are discussed in individual sections specific to different domains and grade spans. In contrast, the CGSTLA identifies 13 main trans-disciplinary subjects with each main subject further divided into a number of minor subjects. Detailed content of teaching materials for each minor subject is then spelled out for each of the applied grade spans. For example, ‘day, night and the four seasons’ is one of the minor subjects under the main subject ‘change and balance.’ The recommended science content associated with this minor subject is described in the following progression:

- notice that sunrise and sunset distinguish day and night (grades 1-2);
- notice the difference in the length of day and night and temperature in different seasons (grades 3-4);
- recognize that day and night are caused by the rotation of the earth from observing earth and sun models; recognize that the four seasons are caused by the revolution of the earth and the tilt of the earth’s axis from observing earth and sun models; and learn that one rotation of the earth is one day and one revolution of the earth is one year (grades 7-9). (MOE, 2010b, p. 43)

The trans-disciplinary nature and longitudinal arrangement of the science content for different grade spans presented in the CGSTLA may enable the users to better see how students can develop their understanding about a science concept across all years of schooling. The enhanced understanding of the developmental continuity of the main science subjects may in turn help the development of a more focused and coherent science curriculum that can bridge the gaps in students' learning between the current and next grade levels. Consistent with our position about the structure of the standards, the newly released *A Framework for K-12 Science Education* identifies three dimensions of science framework but suggests that:

In order to facilitate students’ learning, the dimensions must be woven together in standards, curricula, instruction, and assessments. When they explore particular disciplinary ideas from Dimension 3 [core ideas in the science disciplines], students will do so by engaging in practices articulated in Dimension 1 [scientific and engineering practices] and should be helped to make connections to the crosscutting concepts in Dimension 2. (NRC, 2012, pp. 29-30)

The analysis of both countries’ science standards and curricula revealed that standards play a significant role in guiding the development of curricula. CGSTLA’s specification of details for the teaching content prescribes what needs to be included in a science curriculum for a grade span of two (e.g., grades 1-2). Thus, the curriculum developed under the guidance of CGSTLA, such as ESTC, tends to focus on fewer concepts in each unit of study. In contrast, the NSES’s content standard statements are relatively general and broad for a grade span of four or five (e.g., K-4). As a result, a wide array of relevant concepts might be included in the curriculum for the study of a single science topic. For example, the Sun-Earth-Moon interaction concepts are included in the NSES’s Space Science Content Standards for grades 5-8, while these are not articulated in Taiwan’s CGSTLA until grade seven. As a result, the Sun-Earth-Moon interaction concepts are explored in the Insights’ *Sun, Earth and Moon* module intended for grades 4 and 5, but not included in the ESTC’s *Moon* or *Sun* units intended for the same grade levels.

Thus, students in the US might be learning the Sun-Earth-Moon interaction concepts as early as grade 5, while Taiwanese students will not encounter these concepts until grade 7. An important question emerges from this comparison. That is, “At what stages of the curriculum should these concepts be taught?” In the Developing Student Understanding section, which follows the Earth and Space Science standards for grades 5-8, the NSES stresses that:

By grades 5-8, students have a clear notion about gravity, the shape of the earth, and the relative positions of the earth, sun, and moon. Nevertheless, more than half of the students will not be able to use these models to explain the phases of the moon, and correct explanations for the seasons will be even more difficult to achieve. (NRC, 1996, p. 159)

Literature also supports the above statement from the NSES. Many studies have identified the complexity and difficulty of the Sun-Earth-Moon interaction concepts not only among K-12 students but also within pre- and in-service teachers (e.g., Callison & Wright, 1993; Lelliott & Rollnick, 2010; Sun, Lin & Wang, 2010; Trundle, Atwood, & Christopher, 2007a, 2007b). Recognizing the challenges associated with learning the three-dimensional nature of the astronomy concepts, researchers have investigated different interventions, such as modeling (using both physical and virtual models), technology-based inquiry approaches and conceptual change oriented instruction, to enhance students' understanding of these concepts (Barnett & Morran, 2002; Barnett, Keating, Barab, & Hay, 2000; Callison & Wright; Çelikten, İpekçioğlu, Ertepinar, & Geban, 2012; Sharp & Kuerbis, 2005; Shen & Confrey, 2007; Stahly, Krockover, & Shepardson, 1999; Sun et al.; Taylor, Barker, & Jones, 2003; Trundle et al., 2007b; Turkmen, 2009). Many of these studies report that fourth-/fifth-grade students and pre-/in-service teachers were capable of learning about these concepts through carefully structured teaching activities (e.g., Barnett & Morran; Callison & Wright; Çelikten et al., Shen & Confrey; Trundle et al., 2007a); however, other studies have found that students in the third and seventh grade showed limited understanding of these concepts even after interventions (e.g., Stahly et al.; Taylor et al.). Stahly et al. suggested that third-grade students may not be cognitively developed enough to understand complex lunar phenomena. Lelliott and Rollnick made a similar conclusion after their review of astronomy education research from 1974 to 2008 by stating that “complex explanations (as opposed to descriptions) of phenomena involving the sun-earth-moon system (e.g., the moon phases and the seasons), gravity, and concepts of scale are unlikely to be understood by children before about age 10” (p. 1791).

Conversely, Sharp and Kuerbis (2005) suggested that children aged 9 and 11 year old in the upper primary years of schooling are not only “capable of learning about the solar system”, but “appear perfectly capable of learning about it very well,” “despite the counterintuitive and nonspontaneous nature of much of its content” (p. 142). However, they also cautioned that “the extent to which findings can be generalized or considered representative of children of this age should, of course, be treated with care” (p. 142). Thus, they recommended that:

Much additional work remains to be done before any sensible decisions can be reached about what should and should not be included within any astronomy unit and how that unit might be delivered in order to help guide even more effective provision. (p. 142)

Factors other than the age of the learners may have influenced the effectiveness of the instructional activities to address the Sun-Earth-Moon interaction concepts, such as alternative conception and visual-spatial abilities of the learners, range of astronomy concepts covered, Sun-Earth-Moon models used (scale or not-to-scale models), and length of intervention period (Lelliott & Rollnick, 2010). In addition, Driver (1981) suggested that science curriculum development should consider “the structure of thought of the child” in

addition to “the structure of the science to be taught,” as “the logical order of teaching a subject may not always coincide with the psychological order of learning it” (as cited in Sharp & Kuerbis, 2005, p. 131). The various research designs and inconclusive findings of the studies on students' learning about the Sun-Earth-Moon system reveal the complexity of student conceptions and reinforce the need for more studies that are conducted in more consistent and systemic approaches to better inform what developmentally appropriate space science content should be expected of students across the school years.

Despite the questionable appropriateness of introducing the Sun-Earth-Moon interaction concepts in the Insights' *Sun, Earth, and Moon* module intended for grades 4-5, the extensive use of modeling to explore and explain such concepts has been identified as an effective learning strategy in the literature (e.g., Callison & Wright, 1993; Sharp & Kuerbis, 2005; Shen & Confrey, 2007; Sun et al., 2010; Taylor et al., 2003). In addition, Insights has students create a scale model of the Earth, Sun and Moon to illustrate their size and distance relationships and to realize the shortcomings of a scale model. This learning approach has also received strong support from the researchers. Dunlop (2000) asserted that “any model which is not to scale can be confusing, even the traditional orrery which has been used for generations in the demonstration of astronomical relationships” (as cited in Lelliott & Rollnick, 2010, p. 1786). Furthermore, Callison and Wright suggest that “attention to scale might have assisted the development of more correct propositions.... most especially the eclipse and heliocentric alternate models” (p. 11).

In addition to the modeling approaches widely used in the Insights' *Sun, Earth, and Moon* module, our analysis of the classroom inquiry variations show that the Insights' learning experiences provide greater learner self-direction than ESTC's do. In a study about preservice teachers' perceived usefulness of teacher's guides, Forbes and Davis (2010) found that “the inquiry orientations of their planned lessons were in large part determined by how inquiry-oriented curriculum materials they used to plan their lessons were to begin with” (p. 820). In other words, inquiry-based curricula can be critical resources for teachers' learning to teach science through inquiry. Both Insights and ESTC are standards-informed science curricula with an emphasis on inquiry, but Insights has provided more explicit support in teachers' learning about helping children develop the abilities and understandings necessary to do scientific inquiry. As claimed by Lin, Chang, and Cheng (2010), “the development of educative curriculum materials should address the function of teacher thinking which would encourage teachers... to compare with the rationales of reform and to develop innovative teaching” (p. 1383). They further recommended that curriculum developers should “address some facets of PCK which support the goals of reform to awaken their [teachers'] ideas and to provide supports for reconstructing their thinking, such as scientific inquiry and nature of science” (p. 1383).

While the US is developing the *Next Generation Science Standards* that are internationally benchmarked, this cross-national study offers insightful perspectives through its in-depth comparative analysis of the space science content included in the science standards and curriculum in Taiwan and the US. The findings of this study shed light on students' performance expectations in science in different countries, which in turn helps direct focus to areas of science education requiring significant attention, such as science standards, curriculum, and textbook development through international benchmarking.

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