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Development and Implementation of a NGSS Curriculum Unit for Astronomy in Ninth-Grade Earth and Space Science

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Abstract

Since the release of the NGSS in 2013, there has been a gap in available curricula that is aligned with the new standards. To fill this gap, I created and implemented a unit of study aligned to the Next Generation Science Standards (NGSS) on the topic of astronomy for a ninth grade earth and space science course. Much of the available curriculum is above the level of ninth grade students. This curriculum approaches the astronomy standards at the level of ninth grade students.

The research questions were "how well does the curriculum prepare students for the disciplinary core ideas (DCIs) of the standards" and "to what extent does the unit align to the NGSS?" To answer these questions, two concept inventories were used as pre and post tests, and the unit was evaluated against the EQuiP Rubric for Science. Based on the data from the concept inventories, student understanding of the DCIs increase, which indicates the success of the unit in regards to the DCIs. When compared to the EQuiP rubric, this unit shows adequate alignment to the NGSS, and areas of improvement were identified.

This project increased my understanding and ability of creating units that are aligned to the NGSS. By implementing the NGSS, students are actively participating in integrating the practices of science and increasing their abilities to think critically and apply the process of science.

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Acknowledgements

There are many people I would like to thank for their support during my graduate school process. First, I would like to express my sincere gratitude to my husband, Dalton, for encouraging me to finish my coursework and project when it was the last thing on my mind, for stepping up and taking care of every part of our lives as I finished this project, and for supporting me through everything. I would like to thank my kids for giving me the best reason to finish this project, my parents for supporting all of my educational decisions and pushing me to always do my best, and my sister for encouraging me and providing editing expertise to my work; my colleagues and principals for encouraging me through this process, providing educational insights, and challenging me to be a better teacher; my academic advisor, Dr. Jesse Wilcox, for taking me on as an advisee at the end of my grad school career and encouraging me to finish in a way that worked for me; outside reader, Dr. Kyle Gray, and UNI Science Education Coordinator, Dr. Dawn Del Carlo for being available to answer questions I had. Without these people, and many more, I would not have reached my goal.

Chapter 1- Introduction

This project creates a Next Generation Science Standards (NGSS) aligned unit in astronomy for my 9th grade Earth and Space Science course. The goal of creating a unit that is aligned to the NGSS, is to push students beyond rote learning and engage them in the practices of science and engineering. This unit will lay the foundation for students to gain the skills necessary to support claims with relevant evidence and data.

Iowa adopted The Next Generation Science Standards (NGSS) in 2015 (Iowa Department of Education, 2023; NGSS Lead States, 2013). Since then, there has been an emphasis on developing units of instruction that include all three dimensions of the NGSS, disciplinary core ideas, science and engineering practices, and crosscutting concepts. Past curricular initiatives fell short of ensuring that all students become lifelong learners of science, a science education priority in Iowa (Iowa Department of Education, 2023). Science education has often been criticized for being a “mile wide and inch deep” (L.A. Times Archives, 1996). This leads to students knowing discrete facts, but not understanding how science works, or engaging in science processes. There is now a focus on a few ideas to allow students to explore the content and natural phenomena in greater depth, while integrating science practices in the classroom (NGSS Lead States, 2013). This shift provides time within the school day for students to experience science (National Research Council, 2012). All students are now exposed to the skills they will need to meet the new science education goals which are to provide students the ability to make informed decisions about the world they live in, engage in discussions on issues related to their everyday lives, and have a level of curiosity to always learn more (National Research Council, 2012; Iowa Department of Education, 2023).

The NGSS includes three important components that together encompass the performance expectations (PE), which are the skills and knowledge that all students should have when they graduate (National Research Council, 2012; NGSS Lead States, 2013). The first component of the PE is the disciplinary core idea (DCI). The DCI is the content that the student should learn, and is divided into three scientific fields: life science, physical science, and earth and space science (National Research Council, 2012; NGSS Lead States, 2013). The next component of the PE is the science and engineering practice (SEP). The SEP is the skill that students should use to meet the standard (National Research Council, 2012; NGSS Lead States, 2013). For example, students will develop or use models to explain their understanding of nuclear fusion (National Research Council, 2012; NGSS Lead States, 2013). Throughout their K-12 experience, students will have many experiences with all eight of the science and engineering practices. The last component is the crosscutting concept (CCC). The CCCs are ideas that cross content areas and are not specific to science, such as identifying patterns, and interpreting different scales or data sets (National Research Council, 2012; NGSS Lead States, 2013). Performance expectations are more than standards. They include what students are expected to know and be able to do by the time they graduate high school (National Research Council, 2012). Performance expectations require students to apply content knowledge and use skills to demonstrate understanding.

Across the nation, an emphasis has been placed on implementing curricula that comprises all three pieces of the NGSS (known as three-dimensional instruction), but a curriculum that includes all three dimensions is hard to find. In my district we have been working to find a curriculum that fits this need, but have fallen short. Because of this challenge I created a unit of study surrounding the astronomy standards. My district decided this unit of study would be the first unit of study in the freshman earth and space science course. Most existing curricula are above the 9th grade level for which this class is intended. They assume students have a background in physical and biological science. Ninth grade students have a limited background in these areas and will not receive that knowledge until later in their high school career.. It is important to me that the curriculum presented to students allows them to experience science and to grow as scientists, but it cannot be so far advanced that they cannot understand or engage with the material.

There are three performance expectations that have been assigned to this unit of study, HS-ESS1-1 thru HS-ESS1-3. The concepts covered in this unit are difficult for students to understand, as well as challenging to model and engage with because they are abstract. The PEs that are addressed in this unit are (NGSS Lead States, 2013; Iowa Department of Education, 2023):

HS-ESS 1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy as radiation.

HS-ESS 1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

HS-ESS 1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.

In order to determine the success of my unit, I intend on answering the following research questions:

A. To what extent do students learn the disciplinary core ideas from an NGSS-aligned unit on astronomy?
B. To what extent does the unit align to the NGSS based on a modified EQuiP rubric?

Why I Chose This Project

I chose this creative project for a variety of reasons. One reason is because my experience teaching this content is limited. I wanted to start my journey in the Earth Science curriculum with a solid understanding of the material. However, teaching is not only about understanding the material as it also has to be conveyed effectively to others. By choosing this project, I am building a unit that effectively and engagingly teaches students about astronomy and our place in the Universe. Another reason I chose this topic is because of the depth of the NGSS. It is important to ensure that all components of the NGSS are included and ensure that the curriculum is aligned with the performance expectations.

I chose the astronomy unit because it is the first unit of my curriculum and is abstract to many students. Students in my classes live in an urban area that makes it difficult to see the night sky. This is an important unit to the Earth and Space Science course because it sets the stage for understanding our own planet better.

Chapter 2- Literature Review

History of Science Education Standards in the United States

Over the last 60 years, science education has changed many times in response to the ever changing world. To better understand the need for the shift that the Next Generation Science Standards bring, I will explore the history of science standards in the United States.

National Science Foundation's "Alphabet Soup" of Science Reform

The first major and important movement of the 20th century in science education came about because of the "Space Race" of the 1960s. This era of science education led to an emphasis in hands-on science experiences, increased education for teachers of science and mathematics, and a more practical understanding of science rather than a theoretical understanding (Kahle, 2007; Welch, 1979). The National Science Foundation (NSF) focused on improving teaching and teacher education by providing workshops and professional development institutes that brought teachers up to date with current science developments, and pedological best practices, which allowed classrooms to be more enriched by current events in science (Kahle, 2007; Kyle et al., 1982; Welsh, 1979). After the push to improve science teachers came a push to improve science texts for the classroom and other curricular materials. The curricula that were created during this time were known as the "Alphabet soup" curricula. By 1975, the NSF had funded fifty-three new curriculum projects, including BSCS, CHEM Study, CBA, SCIS, ESC and many others, which were used in classrooms across the nation (Kahle, 2007; Kyle et al.,1982; Welch, 1979). Kyle et al. (1982) found that the "Alphabet Soup" curriculum projects led to improvements in student learning including hands-on activities, and inquiry based extensions, but there were still gaps in science education that needed to be addressed.

“A Nation at Risk”

The United States Secretary of Education of 1981, T. H. Bell, created the National Commission on Excellence in Education to evaluate the quality of education in the United States (National Commission on Excellence in Education, 1983). This committee reported that the United States was falling behind other countries in all education subjects and that the new generation was no longer surpassing the previous generations (National Commission on Excellence in Education, 1983). They wrote a letter to the nation, called “A Nation at Risk,” which pushed for changes in science and math education. One of the major changes that occurred in science education because of this letter was the addition of state education policies. Some policies that were introduced were graduation requirements, and high-stakes standardized tests (Guthrie & Springer, 2014; Kahle, 2007). These new policies led to greater consistency within a single state, but limited the amount of autonomy teachers and schools had in choosing science topics (Kahle, 2007). It limited the amount of electives that counted toward high school graduation, therefore limiting the number of interest-based courses students could take, which caused schools to re-look at the courses they were offering (Guthrie & Springer, 2014; Kahle, 2007). The new graduation requirements placed a larger emphasis on science and math education. This led to the need for new science education standards.

Project 2061

From “A Nation At Risk” came a new curriculum project that focused on finding the skills needed for the next generation of learners to compete in the ever changing fields of science. “Project 2061” was a long-term look at the goals and needs of science education, identifying what was important to know and do for the next generation and making science accessible for all students (American Association for the Advancement of Science, 1989; Collins, 2001). Project 2061 called for a complete change in how science was taught in public schools. Schools now needed to place an emphasis on science by either blocking out time specifically for science education or to find an integrated approach that included science literacy in existing reading, writing, and mathematics programs (American Association for the Advancement of Science, 1997; Collins, 2001). Project 2061 introduced a new set of standards and benchmarks that were broad but had the clear goal of increasing science literacy for all Americans (American Association for the Advancement of Science, 1993; American Association for the Advancement of Science, 2001; Collins, 2001). The standards were broken down into grade bands that included K-2, 3-5, 6-8, and 9-12 (American Association for the Advancement of Science, 1993). These grade level groupings allowed teachers to focus on the needs and academic levels of their students, which allowed student knowledge to grow appropriately, and provided the threshold at which all students should become science-literate (American Association for the Advancement of Science, 1993). The Benchmarks text provided a guide for what students should know, focusing on science literacy and student collaboration to solve problems with the lens of scientific inquiry (American Association for the Advancement of Science, 1993; American Association for the Advancement of Science, 2001). Many of the benchmarks provided in this document spiral information from one grade to the next understanding that it takes many years and iterations of the material for students to understand the material in much depth (American Association for the Advancement of Science, 1993). This is a current feature of the Next Generation Science Standards that allows students to create in-depth knowledge of just a few important concepts.

National Science Education Standards

The National Science Education Standards (NSES) of 1996 addressed the systemic issues in science education (Collins, 2001; Kahle, 2007). These standards would have ensured all students would walk away from their K-12 science experience with the ability to make informed decisions about the world around them; to use scientific processes and thinking to solve problems (American Association for the Advancement of Science, 1989; American Association for the Advancement of Science, 1997). The NSES emphasized scientific literacy and inquiry as a way of learning and problem solving (American Association for the Advancement of Science, 1989; American Association for the Advancement of Science, 1993; American Association for the Advancement of Science, 1997; Collins, 2001; National Research Council, 1996). This movement also changed the depth at which students learned the content. Instead of learning many topics at a superficial level, the curriculum went deeper into fewer topics (American Association for the Advancement of Science, 1997; National Research Council, 1996). This change allowed more time for hands-on investigations to occur in the classroom because less content had to be covered. There was more time for students to learn and practice the skills that are used in scientific investigations. Even with this emphasis on inquiry and problem solving, there were still connections missing between what students needed to know and what they needed to do. Inquiry was being taught as its own separate set of standards that were not connected to the content being taught in the classroom (National Research Council, 1996; American Association for the Advancement of Science, 1997). Studies showed improvements in student learning that resulted from inquiry based learning were only sustained if inquiry learning continued throughout a child's education (Kahle, J. B. 2007). This led to the Next Generation Science Standards. (National Research Council, 1996).

History of NGSS Standards

In July 2011, the National Research Council released the *Framework for K-12 Science Education*. This was the first step in identifying what all K-12 students should know and be able to do in the modern science classroom. There were many stakeholders involved in creating this *Framework* that ranged from scientists working in the field, Nobel Laureates, cognitive scientists, education researchers, and policy experts (National Research Council, 2012). "The Framework", as it has become known, was the driving force for a state-led movement to create a set of science standards that would provide students with an "internationally benchmarked science education" (National Research Council, 2012; NGSS Lead States, 2013). Named "The Next Generation Science Standards" (NGSS), these science standards were written to prepare students for college and careers in science (NGSS Lead States, 2013). There were additional stakeholders in the writing and review process of the NGSS that included teachers and other professionals in education (NGSS Lead States, 2013). These standards were officially published and ready for states to adopt in April 2013 (NGSS Lead States, 2013).

The state of Iowa, which took part in creating the NGSS, adopted a portion of the NGSS in 2015 and named them the Iowa Core Standards in Science (Iowa Department of Education, 2023). However, Iowa adopted only the performance expectations and excluded the NGSS provided supporting documents that clarified the information and processes that were contained within them (NGSS Lead States, 2013, Iowa Department of Education, 2023). It is assumed that the Iowa Core Standards in Science include all three dimensions of the NGSS; therefore those all three dimensions will be taught and assessed, even without the supporting documents (Loewus, 2022). The support materials add depth and understanding for the teacher around the three-dimensions, which leads to coherence and integration, and three-dimensional teaching (NGSS Lead States, 2013).

Components of the NGSS

The NGSS begins with a performance expectation (PE), which is the complete descriptive explanation of what the student is expected to know and be able to do (NGSS Lead States, 2013). The performance expectation is divided into three additional components which include the Disciplinary Core Idea (DCI), the Science and Engineering Practice (SEP), and Crosscutting Concepts (CCC) (NGSS Lead States, 2013).

Performance Expectations

Performance expectations are the integrated representation of what students know and can do and set the bar for students and teachers (NGSS Lead States, 2013). They include the DCIs, SEPs, and CCCs. The statements are not intended to be daily learning goals, but are outcomes for learning for the course or grade-band (NGSS Lead States, 2013). Performance expectations do not prescribe a specific way for students to learn the material (NGSS Lead States, 2013); instead, PEs are written so that students can demonstrate learning and to accommodate the learning needs of all students (NGSS Lead States, 2013). The PEs provide a foundational understanding of science and engineering that all students should be able to understand and apply after instruction (NGSS Lead States, 2013). PEs are broken down by grade-band to ensure that they are developmentally appropriate to the students (NGSS Lead States, 2013).

Disciplinary Core Ideas

The Disciplinary Core Idea (DCI) is the scientific concept that is included within each performance expectation (NGSS Lead States, 2013). The goal of the DCI is to provide a connection from the content in science courses to the real world or student interests, and to create lifelong learners by giving students the foundation they will need for future learning (NGSS Lead States, 2013). DCIs lay the foundation students need to understand the world around them and make informed decisions (NGSS Lead States, 2013). There are four major domains of DCIs for science that include physical science, life science, earth and space science, and engineering, technology and science application (NGSS Lead States, 2013). The topics that were chosen as DCIs have a broad importance to understanding science (NGSS Lead States, 2013; National Research Council, 2012). They are considered the fundamental ideas that can build more complex ideas in future science work. There were many scientific ideas that were left out of the DCIs because it was believed that if students have a better understanding of a smaller number of topics, they will be more interested in further investigating scientific concepts (National Research Council, 2012, pp. 30-33). The DCIs are interconnected and may be included across multiple disciplines. One example of an interconnected topic is human impact, which can be found in both earth and space science and biology courses (NGSS Lead States, 2013; National Research Council, 2012). By showing the connectedness of the content, students are more likely to be interested in furthering their knowledge and understanding of the topic if they see the relevance.

Science and Engineering Practices

The Science and Engineering Practices (SEPs) are the skills that scientists use to investigate phenomena about the world around them (NGSS Lead States, 2013; National Research Council, 2012). From these investigations, scientists can build models that lead to theories about our world (NGSS Lead States, 2013; National Research Council, 2012). The expectation of the NGSS is that students will practice the SEPs through their learning experiences and will use them daily (NGSS Lead States, 2013; National Research Council, 2012). This approach allows students to engage in inquiry in the classroom and increase the use of cognitive, social, and physical practices formally (NGSS Lead States, 2013; National Research Council, 2012; Duschl & Bybee, 2014). According to “The Framework for K-12 Science Education” (2013) “students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves” (p. 30). The practices are asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information (NGSS Lead States, 2013; National Research Council, 2012; Bybee, 2011). Throughout scientific investigations each of these practices plays an important part to furthering our understanding of a concept. These are skills that students learn even before they enter the classroom (National Research Council, 2012). The goal of incorporating the practices is to develop logical explanations or solutions supported by evidence (National Research Council, 2012). When used repeatedly, they become second nature (National Research Council, 2012). The SEPs are similar to the inquiry standards of the past, but the shift from inquiry to practices meant all students are routinely incorporating the skills necessary for scientific inquiry (NGSS Lead States, 2013; National Research Council, 2012; Bybee, 2011).

Crosscutting Concepts

The last component of the performance expectation is the crosscutting concept (CCC). The CCCs are "concepts that hold true across the natural and engineered world" (Duschl, 2012; Cooper, 2020). The seven CCCs are patterns; cause and effect; scale, proportion and quantity; systems and system models; energy and matter; structure and function; and stability and change (Duschl, 2012; NGSS Lead States, 2013). These help build connections between the diverse subjects in science and even between other content areas, such as math and language arts courses (Cooper 2020). They also provide the tools, lenses, and bridges necessary for students and teachers to connect phenomena to prior knowledge (Cooper, 2020). By using CCCs as tools or lenses, teachers can focus student learning in a particular direction (Cooper, 2020). For example, if a teacher wants students to identify which elements are most common in a set of stars, the teacher may ask students to find patterns in a data set, a skill that is transportable beyond the classroom (Cooper, 2020).

One important factor that separates the NGSS from all other iterations of science curricula and standards is that the NGSS are not a set of discrete facts that students need to know (NGSS Lead States, 2013). The skills and content that students are exposed to in each grade band of the NGSS are cycled between the different grade bands, and progress as student knowledge and cognitive abilities progress (NGSS Lead States, 2013). Students will be exposed to the same DCIs, CCCs, and SEPs, which are interwoven in different ways, as they progress through their science education (NGSS Lead States, 2013).

Instruments

I used three assessment instruments to measure the project goals and the answers to the research questions. The three instruments are: the Light and Spectroscopy Concept Inventory, the Star Properties Concept Inventory, and a modified EQuiP Rubric for Science.

Concept Inventories

I used two concept inventories in this project. Both instruments were based on in-depth student interviews, and instructor syllabi, and were created for introductory college level astronomy courses (American Association of Physics Teachers, 2023a;American Association of Physics Teachers, 2023b). These assessments are multiple choice assessments that have between three and five potential answers, with the wrong answers being based on common misconceptions that students have (Garvin-Doxas et al., 2007). Concept inventories are used to evaluate student understanding and effectiveness of instructional methods surrounding specific concepts (Bardar et al., 2007; Bailey et al., 2012). The benefit of using concept inventories is that they have been tested for validity and reliability, and the questions have been developed from in-depth research (Bailey et al., 2012).

While both concept inventories were written for college students, the concepts that are covered are essential for student mastery of the NGSS DCIs used in this unit of study. Even with this limitation, these concept inventories provide an unbiased representation of student understanding of these concepts in the high school classroom.

The results obtained from these assessments can also provide insight into the effectiveness of the chosen instructional strategies used in this unit of study.

Light Spectroscopy Concept Inventory

The Light and Spectroscopy Concept Inventory (LSCI) is a 26-question assessment that focuses on light, the electromagnetic spectrum, the Doppler effect, and how these topics relate to astronomy (Bardar et al., 2005; Bardar et al., 2007). The LSCI was administered to 500 college students to determine the reliability and validity of the assessment when it was written in 2005 (Bardar, 2005).

The questions in the concept inventory were written to address the alternative conception of college level students. There were also questions though that aligned very well with the DCIs addressed in this unit. For example the questions in Figure 1 tested student knowledge of how light spectra can be used to determine the motion of stars, which can be used as evidence for the Big Bang Theory and the expansion of the Universe.

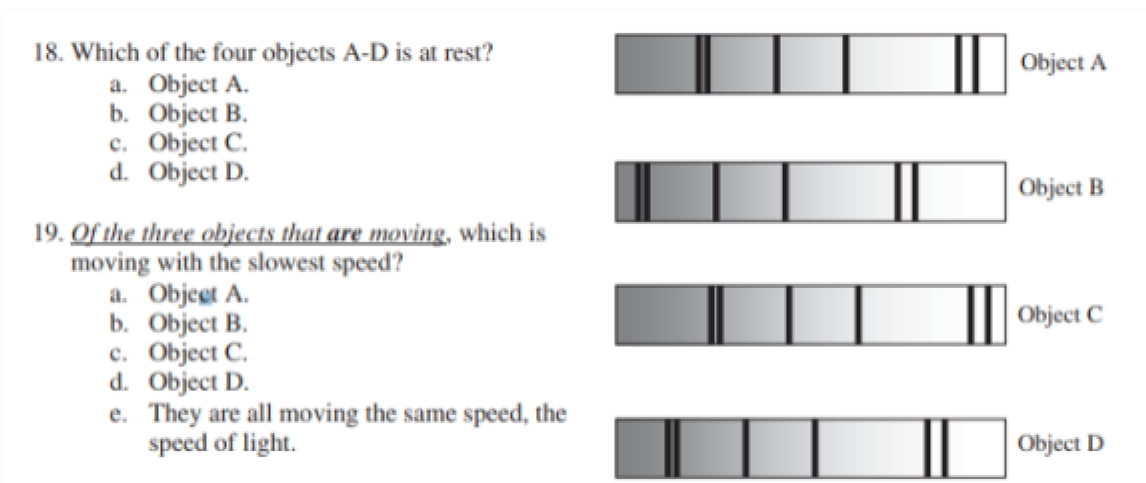

Figure 1. LSCI questions 18 and 19.

Star Properties Concept Inventory

The second assessment that was used was the Star Properties Concept Inventory (SPCI). The Star Properties Concept Inventory (SPCI) is a 24 question, multiple choice assessment over the concepts of star formation, star properties, star life cycle and nuclear fusion (Bailey et al., 2012). This assessment was written for college level astronomy courses but aligned closer to the requirements of the NGSS than the LSCI did. There were many questions from this assessment that aligned with the DCIs for this unit. Figure 2, Figure 3, and Figure 4 are examples of questions that were commonly missed by the students in this class on the pre-assessment, but after instruction, students were able to answer the questions correctly.

5. The force that dominates the formation of a star is
   a. static electricity.
   b. gravity.
   c. magnetism.
   d. pressure.
   e. nuclear fusion.

Figure 2. Example question from the SPCI.

10. What is the name given to a star as it is initially forming?
    a. protostar
    b. nebula
    c. supernova
    d. star cluster
    e. white dwarf

Figure 3. Example question from the SPCI.

16. How is the lifetime of a star related to its mass?
    a. More massive stars live considerably longer lives than less massive stars.
    b. More massive stars live considerably shorter lives than less massive stars.
    c. More massive stars live slightly shorter lives than less massive stars.
    d. More massive stars live slightly longer lives than less massive stars.
    e. All stars have the same lifetimes regardless of mass.

Figure 4. Example question from the SPCI.

EQuIP Rubric

The EQuIP Rubric for Science can be used to evaluate the level of alignment the lessons and units have to the NGSS (NGSS Lead States, 2013). This rubric can assess pre-existing units, as well as guide the development of new lessons and units (NGSS Lead States, 2013). The EQuIP Rubric for Science is broken down into three major categories: NGSS 3D Design, NGSS Instructional Supports, and Monitoring NGSS Student Progress (NGSS Lead States, 2013). In order to ensure alignment to the NGSS when planning a unit of study, some things that should be considered and incorporated are the phenomena to explain or problem to be solved, how each of the three dimensions are going to be integrated, how the lessons will build on each other, and links to other courses and the real world (Achieve, 2018; NGSS Lead States, 2013). This rubric is important in guiding the planning of the unit to ensure that the unit is aligned to the NGSS.

Theoretical Framework

Constructivism is the learning theory where learners are active participants in their own learning (Bächtold, 2013; Mcleod, 2023). Each student comes to the classroom with their own set of experiences and view of the world. From these experiences students build new knowledge, or change their current understandings (Agarkar,2019; Mcleod, 2023). Prior knowledge affects how the student will obtain new knowledge and shape new ideas (Agarkar, 2019; Mcleod, 2023). Students must be actively engaged in the learning process and meaningful connections need to be made between prior knowledge and the new learning in order for the student to retain and understand the new knowledge and build upon it (Agarkar, 2019; Mcleod, 2023). There are three types of constructivism: social constructivism, cognitive constructivism, and radical constructivism. This project focuses on a mix of social and cognitive constructivism. In both models the learner is an active participant in their learning, and the teacher is a facilitator of that learning. The teacher provides learning opportunities and situations for the student to build upon their prior knowledge. A constructivist classroom is very fluid and student driven, meaning there is not a strict lesson format or plan that the teacher will follow, but ideas of experiences and questions that will help facilitate student learning (Agarkar, 2019; Mcleod, 2023).

Relevance

Even though the Next Generation Science Standards have been implemented in Iowa since 2015, there is still much work to be done in terms of alignment. Teachers have been working every year to get closer and closer to being fully aligned to the three dimensions of the standards. This is the case for Davenport Community Schools.

The educators in the Davenport school district have spent many hours determining what standards should be grouped together to form units. There has also been work done to create summative assessments that are three dimensional. My school is still lacking an NGSS designed curriculum for Earth and Space Science. This study will create an engaging astronomy unit that meets the NGSS.

This project applies to the science teaching community because there is an all around lack of curricula designed for the NGSS that teachers can pull from. There has been a recent push to design curriculum to meet the earth and space science standards, but there is still a gap that needs to be filled.

Chapter 3 - Project Design

The purpose of this project is to create a unit of study for a 9th grade Earth and Space Science course that is aligned with the Next Generation Science Standards. I had two research questions I was trying to answer. The questions were: “how well do students learn the disciplinary core ideas from an NGSS-aligned unit on astronomy?” and “to what extent does the unit align to the NGSS based on the EQuiP rubric?”

Development of Instructional Unit

Phase 1- Planning for standards based assessment

At the beginning of the 2022-2023 school year, the Earth and Space Science teachers in my school set ourselves a goal that we would write standards based unit tests for each unit in our curriculum. We started with the first unit, astronomy (APPENDIX A). Creating unit tests that are three-dimensional and aligned to each component of the PEs is challenging because the three dimensions are meant to be intertwined, and the SEPs are meant to be experienced (NGSS Lead States, 2013). We wanted to ensure that our assessment allowed students to show their content knowledge, but also be able to apply that knowledge to a scenario.

The assessment writing process led us to realize that the assessment we wrote could not be the only summative assessment we gave for each standard because the SEP could not be fully met with a written assessment. With this understanding in mind, I had to find additional assessments that would meet all three dimensions of the PEs. The SEPs that are included in this unit can be found in Figure 5, highlighted in blue.

Figure 5. NGSS performance expectations used in this project.

HS-ESS 1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.
HS-ESS 1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.
HS-ESS 1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Key to color coding:
Science and Engineering Practices
Disciplinary Core Ideas
Crosscutting Concepts
*Based on the NGSS (NGSS Lead States 2013)

To further my understanding of the PEs, I considered the learning progressions for each component to determine what students should already know and be able to do coming into my classroom (NGSS Lead States, 2013). From this exploration (Figure 6), I found that, regarding the DCIs addressed by this project, students come to high school with a very limited understanding of anything beyond the Earth-Sun-Moon system (NGSS Lead States, 2013a). To show mastery of two of the PEs for this unit (Figure 1), students need to understand the electromagnetic spectrum, radiation, and how we use light waves to get knowledge about our Universe. I noticed students learn about waves and wave properties through the 3-5 and 6-8 grade band standards for DCI PS4, but they did not need to apply this knowledge until they entered high school courses (NGSS Lead States, 2013a). By looking at all the progressions, I was better able to anticipate any gaps and preconceptions students may have in their learning.

Figure 6. NGSS Earth and Space Science Progression for ESS1.A and ESS1.B

Earth Space Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
ESS1.A The universe and its stars	Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.	Stars range greatly in size and distance from Earth and this can explain their relative brightness.	The solar system is part of the Milky Way, which is one of many billions of galaxies.	Light spectra from stars are used to determine their characteristics, processes, and lifecycles. Solar activity creates the elements through nuclear fusion. The development of technologies has provided the astronomical data that provide the empirical evidence for the Big Bang theory.
ESS1.B Earth and the solar system		The Earth's orbit and rotation, and the orbit of the moon around the Earth cause observable patterns.	The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons.	Kepler's laws describe common features of the motions of orbiting objects. Observations from astronomy and space probes provide evidence for explanations of solar system formation. Changes in Earth's tilt and orbit cause climate changes such as Ice Ages.

Phase 2- Developing the learning sequence

The assessment writing process led to discussions within the group about what ideas and experiences should be included in our instructional plans. This is the first unit students encounter in earth and space science. It is 20 days long with 80 minute classes. I began outlining the unit, while always keeping the goals in mind. To lay the foundation for the standards and to engage students in science at the start of the course, I began with wave properties and the electromagnetic spectrum to build on student prior knowledge and lay the important foundational knowledge they will need for later concepts. This decision provided students with some of the evidence they needed to construct their explanations of the Big Bang Theory, as well as use emission and absorption spectra to determine the composition of stars.

After deciding where to start, the challenge was determining which order would be the best to proceed with. We had many discussions within our team about this. For example, there was an argument to teach the Big Bang Theory first because starting with the beginning of the Universe would help students understand the chronology of the Universe. Other team members argued for staring with stars and star life cycles. Ultimately, I proceeded with stars and star life cycles for two reasons. First, the Big Bang theory is very abstract. This is a process that happened a very long time ago and has pieces of evidence that are difficult to explain and present or experience concretely. For example, students have a difficult time understanding cosmic background radiation because it is like air. We know it is there, but we don't see it or know that we are experiencing it. Stars are something that students can visualize on clear nights, and one phenomenon about which children wonder. The second reason is that by learning about stars first, students can use light spectra to determine the composition of stars, which can be used as evidence to discuss the abundance of light elements in the Universe (stars contain mostly light elements, how and why does this happen?). When I introduce the abundance of light elements as a piece of evidence for the Big Bang Theory, I typically talk about how the Universe will take the path of least resistance. By teaching stars first, it naturally leads to incorporating nuclear fusion, which students can then use to support the path of least resistance. Figure 3 contains the brief, topic outline of this unit.

Figure 7. Topic outline (The full set of unit materials can be found in APPENDIX B.)

Lesson 1: Wave properties and the Electromagnetic Spectrum.
Lesson 2: Life Cycle of Stars and Star Properties.
Lesson 3: Evidence of the Big Bang Theory.

Phase 3- Developing daily learning plans

After the goals of the unit were established and the learning progression determined, my next step was to find, adapt, or develop the daily lessons. As I was working through this process, my goal was to create lessons that were hands-on and minds-on, and allowed students to develop their understanding of space. I wanted the lessons to build upon each other instead of being stand-alone lessons. I started with the lessons I used in the past, and the lessons that were developed by my teammates. As I was evaluating these lessons for alignment to both the standards and my goal of having students take part in the scientific process, I felt that most of the lessons we were using fell into the “sit and get” style lesson category. Very few of our previous lessons were hands-on or minds-on. There were many reasons that lessons were written in this way, the biggest reason being that they were developed during the COVID-19 pandemic where students were doing a lot of learning online and independently. Our team had gotten away from group labs and collaboration. I wanted to add more collaboration and group work back into my daily lessons.

The first time I taught this course, I found a storyline that was built around the same standards (Erickson, 2020). I found that this storyline did not meet the needs of my students and not all the pieces made sense to me as the teacher. I did, however, find that certain parts of the storyline really helped students understand the material. I adapted these storyline pieces to meet the needs of my classroom and my students. The challenge with everything I found that was “aligned” to the standards was that these met the needs of some students, but rarely met the needs of my students or the curriculum my team and I decided upon.

After I found and adapted materials to meet the needs of my classroom and students, I determined what other assessment opportunities I wanted to provide my students to determine their level of mastery on the standards. By looking at the SEPs that were presented in the standards, I determined students needed to communicate their understanding of the material in multiple ways. To do this, I decided students needed to develop models of nuclear fusion and the star life cycle. Students needed to gather and organize their evidence to help them with this task. They also needed to communicate the evidence that is used to support the Big Bang Theory. These are the tasks that students needed to do in order to fully meet the PEs that I didn't feel our written assessment could fully assess.

Phase 4- Teaching and differentiating

The order of topics that was chosen was different than what I have done in the past. For this project, I started with the electromagnetic spectrum and light spectra because this was foundational knowledge that students needed to understand before they could apply it to star properties and evidence of the Big Bang Theory. I wanted to start the class with a few hands on experiences on which the students could build their understanding. The first thing students did was use snakeys to model transverse waves and visualize wave properties. I asked students to find ways that they could manipulate the waves to change those properties. As students were working in groups on this short challenge, they were showing the cause and effect relationships of different changes to the waves. This activity helped students get into a science mindset. One of the challenges students were having as they were changing the properties of the waves, was seeing what those changes were doing, or knowing how to describe the changes. After students gathered data, I held a class discussion to ensure that every student understood this foundational material. Visual representations of the waves were created so that students could refer back to them when we started discussing the electromagnetic spectrum and the differences in the types of light waves.

After students understood the foundational concepts of waves and the electromagnetic spectrum, I thought that the next logical step would be to discover how scientists use this information when they are studying stars. Students used emission and absorption spectra to analyze which elements existed in different stars. Some students had a very difficult time with this task because it required them to visually compare the spectra, and it had to be exact for the element to exist in the star. To differentiate this task, some students used the measurements on the spectra, while others lined the spectra up and compared them spatially. Students were able to identify which elements were found most commonly in stars and which elements were found rarely. This information allowed students to build the idea that there is an abundance of light elements, and why that may be, as well as older stars have heavier elements within them. We were able to put together pieces of the life cycle of stars based on this information. From here, we went into the process of nuclear fusion which is how elements are created in stars. In retrospect, this part of the unit seemed choppy and a little out of place because the transition was very abrupt. In the future, I would like to find a better transition or flow for life cycle of the star and nuclear fusion to help tell the story better. There are two performance assessments for this part of the unit. The students had to create models that showed the life cycle of the star and how nuclear fusion occurs within the star to get energy to the Earth. These assessments are still in development because much of this information can be found on the internet, which does not show student understanding.

The final topic that we covered was the Big Bang Theory. This topic is one that I have started with in the past, but I found that the topics were abstract and difficult for students to understand. Much of the student learning for this part of the unit came from readings and videos that provided evidence for the Big Bang Theory. Students were able to build their knowledge of the universe expanding and microwave background radiation through the balloon labs, but some of the students felt that these labs forced connections as opposed to leading them to understanding. The performance assessment that students were required to complete for this section of the unit asked them to write an essay about the evidence that supported the Big Bang Theory. It was required that students included relevant sources to support their writing, and build their understanding. In the future, I would like to find a way to help students communicate their findings to others in the course, or to break down the evidence in a way that would help others understand.

As I implemented this unit, I continually adapted my lesson plans based on the needs of my students and their formative assessment results. When I realized students were not meeting the standards, or were not providing evidence of understanding, I went on the search for activities and resources to improve learning outcomes. I found hands-on activities, reading sources, worksheets, and other resources that I could pull from to help individual students. Each resource that I found targeted certain aspects of the curriculum and allowed me to provide the needed interventions for each student to be successful. I would still like to find materials that will further the learning of students who understand the foundation and can show mastery of the standards.

Impact of the Curriculum

In order to determine the success of this unit, I used two concept inventories that helped me gauge to what degree students could understand the DCIs. I also used a modified version of the EQuiP Rubric for Science to evaluate my unit’s level of alignment to the PEs at hand.

Concept Inventory Results

The two concept inventories I used were the “Light Spectra Concept Inventory” (LSCI) (Bardar et al., 2007) and the “Star Properties Concept Inventory (SPCI) (Bailey et al., 2012). I used these inventories as pre and posttests for the DCIs associated with my unit. These inventories are pre-NGSS, and written for Introductory college astronomy courses. While some questions did not align to the DCIs in the unit, many of the questions did. To analyze the data collected, a paired sample t-test was used, because the same group of students took both the pre and post tests (Pallant, 2020). The results from a paired-sample t-test will show if there is a statistically significant difference in scores between the two times the test was given. The results of the t-test showed a statistically significant difference between the pre and post-test results for both assessments and the effect size for my unit was a large effect based on both the Eta squared score and Cohen's d score. Table 1 contains the results of the T-test.

Table 1

T-Test Results for Both Concept Inventories

	Pre-test		Post-test					Eta	Cohen's	95% Confidence
	M	*SD*	*M*	*SD*	Δ*M*	p	*N*	Squared	d	Intervals
SPCI	5.4	2.89	7.8	3.8	2.4	<.001	55	0.3	0.7	-3.38 to -1.38
LSCI	5.6	1.6	6.8	2.3	1.2	<.001	55	0.21	0.6	-1.84 to -0.56

EQuiP Rubric Evaluation

To evaluate this unit's level of alignment to the NGSS, a modified version of the EQuiP Rubric for Science was used by both myself, and my academic advisor, Jesse Wilcox. The completed rubric can be found in APPENDIX C. From evaluating my unit based on the modified EQuiP Rubric, I found I was aligned to the DCIs for the standards very well. The data from my pre/post assessments also supported this idea. When addressing the SEPs and CCCs, we found that these components were scattered throughout the unit. For example, students were asked about patterns in data a few times, and they were asked to use and develop models multiple times. We discussed that one one to improve in these categories is to have students reflect on their understanding and learning of SEPs and CCCs, and why they are using these skills to understand the content. As I look back on the unit, and look forward for how to improve it, I see many instances where I can add more depth, and build more scaffolds into the SEPs and CCCs to increase student competency with these skills.

Chapter 4 - Reflection

This project has taught me a lot about curriculum writing, the NGSS, and the content standards I use in my classroom. I started this project when I entered the Earth and Space Science classroom for the first time. I knew very little about the content and I was learning a lot on my own while leaning on my colleagues for help with activities and assignments. I was not happy with how the course went the first time I taught it and I knew I could do better to facilitate my students' learning. I wanted to create a science classroom where students were engaging with the material and learning how to use science every day. I thought I knew about the three dimensions of the NGSS and what they should look like in the classroom, but I learned so much more about each piece through this project. In order to improve my curriculum for future use, I will revisit my research questions, theoretical framework, alignment to three-dimensional instruction, how this unit will impact science education, and my plans for the future of this work.

Research Questions

When looking back at my research questions and goals for the unit, I can see where there were successes, and where there were challenges to improve upon in my unit of study. My first research question focused only on the DCI portion of the standards. I wanted to make sure that the students were learning the content that was set before them, as this was a new type of learning for them. To do this, I sought a vetted assessment that could determine the degree to which my students achieved the DCI goals. The two concept inventories I found and used as my pre/post tests were a good starting point to determine their level of content knowledge. One challenge I had while using these concept inventories was that they were written for introductory college astronomy courses where students have a much larger background in science to lean on. Some questions that were on the assessment contained the content of the DCIs but were at a much higher level than we needed. This caused confusion for students. In the future, I plan on narrowing the questions down to better align with the standards and the level of my students. I would also like to find something similar that discusses the Big Bang Theory; it was not included in the two inventories I used. The concept inventories were written pre-NGSS. This meant that they were not three-dimensional which was a limitation to the amount of data that I could collect from them. I plan to do more research to find if there are other concept inventories, or pre/post assessments that are aligned to the NGSS. If there are no assessments that fit this need, it would be very beneficial to science education for these to be created and vetted at the high school level. The concept inventories I used, showed me where my students grew in regards to the DCIs, even though not all of the questions aligned to our standards. If these assessments could be created to address all three dimensions of the NGSS, these would be invaluable tools for all educators that could lead to improved science education for all.

My second research question was “To what extent does the unit align to the NGSS based on a modified EQuiP rubric?” Going into this project, I knew that my focus would not be meeting every part of the EQuiP rubric. I knew there were going to be parts of my curriculum that needed to be improved, or things that would need to be added in order to be fully aligned. I used a modified EQuiP rubric for this reason. When choosing the pieces of the rubric to use, I chose pieces I knew I included so that I can see the level of alignment for the curriculum I had developed. I noticed in conversations with my academic advisor, that I was much harsher on myself in my reflections. I felt that there were many places that I could improve, but it was pointed out that my unit still met each of the chosen EQuiP components at the adequate level, which means that there are many parts of my unit that allowed students to build their understanding and mastery of each of the three dimensions. In the future, I would like to incorporate more phenomena into my unit of study to add relevancy to the unit. I feel by adding phenomena, students would see that there is a real-world application to what they are learning, and that it's not just for the “old dead guys” of science. By adding relevancy to the unit, it would help students make more connections to the learning and build more on their prior knowledge.

Theoretical Framework

One of my major goals of this project was that I wanted students to start the course in a hands-on, minds-on way, so that they could build their knowledge of the Universe. I wanted students to take part in actively learning science, as opposed to memorizing facts for a short time. And I wanted to build on their prior knowledge. This was a challenging unit to start with because the concepts are very abstract. I kept asking myself “how do students see/experience the properties of waves and light?” and “how do we apply this to our understanding of the Universe?” This is still a challenge for me, and something I feel I can continue to still improve upon. While I know my students learned about waves, the electromagnetic spectrum, and how this applies to stars, it was very challenging for me to find engaging ways to relate this material to the Big Bang Theory. Microwave background radiation is one of the more difficult concepts for me to understand because this piece of evidence reminds me of air; we know it is there, but how do you prove it, or demonstrate it? I could find one activity that provided a tangible demonstration of the concept, but there was still a lot of confusion why this would be evidence for the Big Bang Theory. This is one idea that I need to do more learning around so that I can better understand and relate to students.

Another challenge that arose when trying to build on students' prior knowledge was that many of my students this year had very limited exposure to the standards this unit built upon. There are a couple of obvious reasons for this. The first reason is that students are not required to "pass" middle school before they move on to high school. Many students had attendance issues in middle school and missed a lot of the content that they should have learned. Another reason students missed the content is that some standards they should have learned fell within their COVID year. In my district, this meant that the curriculum was rushed or limited because of a hybrid schedule. While students had work that they were required to do on their home days, there were many more limitations placed on what was accessible to the students. To combat these challenges, I tried to provide experiences for students in the classroom that allowed them to learn the content missed, while also building to new content. Some students had a much larger background than others, but to make sure every student was meeting the standards, I needed to include more background knowledge than I would normally have done. In the future, I plan on doing less of the background work that students should have already been exposed to, and going deeper into the standards at hand. I know that there will still be students that are lacking the background knowledge, but I will differentiate within the classroom to ensure all students meet or exceed the standards.

Three-Dimensional Instruction

In the past, I took part in many professional development opportunities that surrounded the components of the NGSS and three-dimensional instruction. As much as I thought I was using three-dimensional teaching, it wasn't until I began working on this project that I really understood what it takes to fully implement each component of the NGSS. By learning how each component progressed through the grade bands, I could build upon student prior knowledge. I could also better understand what my students should be able to do by the time they graduate, and begin their high school science journey appropriately.

Even though the components of the PEs are meant to be taught together as a whole, it was an educational experience for me to learn about each component individually. I learned that even though each PE has its own SPE and CCC, in order for students to truly gain the desired skills set forth by these two components, they must be repeatedly interwoven into the lessons. This is something that I intend to continue to improve on as I build lessons in the future, and as I improve upon this lesson. It is my goal that most my course is three-dimensional.

Impact on Science Education

As I continue to reach my goal of a curriculum that is three-dimensional and aligned to the NGSS, I plan to share my curriculum with others. By doing this, it may provide other teachers with ideas for how to implement three-dimensional teaching in their own classrooms. I would like to create a lesson or unit that is to have it vetted by the NSTA website and have it available as a high-quality lesson. The more high-quality lessons that are available to teachers, the more students that will become skilled in the scientific practices and be able to make informed decisions that will benefit our world.

I would also like to present my unit at a conference to introduce others to the process of creating high-quality units aligned to the NGSS and provide an example of a high-quality unit. I have been on the listening side of conferences and I have learned a lot to further my career. I would like to present to others to help new and experienced teachers improve their own careers. This project is just the beginning for improving my curriculum.

Future work

This project was the first step in improving my ability to plan effective lessons that are engaging and three-dimensional. In the coming school year, I would like to add phenomena or more real world connections to this unit. I would like to continue to improve the lessons that I created for this unit. I know that there are still areas for improvement, or ways that I can differentiate for students, that I have not found yet. I would also like to push all students past doing just the minimum and extend their knowledge and improve their scientific reasoning skills.

I would like to extend the ideas and processes I learned from this project to all the courses I teach, no matter the content. While the process to get to three-dimensional lessons takes time, it is important to continue to implement it in every science course I teach so that students will continue to improve on their skills. By encouraging students to continue to practice scientific skills, the students will become more analytical, and make more informed decisions for the future of our designed world and planet.

I believe that increasing the quality of science education is important to maintaining and improving our future. Right now, our world is facing some challenging problems that will continue to get worse unless solutions are found. We need to provide students with the tools they need to make informed decisions and find solutions to those problems in our ever changing world. Improving science education is one way to do this. And I believe that creating three-dimensional lessons where students are discovering answers and developing their own thinking and problem-solving abilities can only improve the world in which we live.

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APPENDIX A - Astronomy Unit Test

Unit 1 Exam Astronomy

1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

Beginning

1. What is the electromagnetic spectrum?
   a. All forms of matter
   b. All forms of light (radiation)
   c. All forms of electricity
   d. All forms of sound

2. The Big Bang theory explains how the ______ formed.
   a. Earth
   b. Solar system
   c. Sun
   d. Universe

Progressing

3. What color would a star be that is moving AWAY from the Earth:
   a. losing its color.
   b. shifted toward blue
   c. shifted toward red.
   d. Unchanged.

4. As stars are further away, what happens to their velocity?
   a. No change
   b. It increases
   c. It decreases

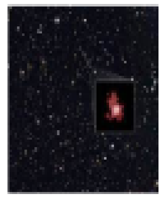
5. Immediately after the Big Bang expansion, which element formed first?
   a. Gold
   b. Oxygen
   c. Hydrogen
   d. Carbon

6. What happened to the energy from the Big Bang?
   a. It disappeared.
   b. It cooled and now exists as background radiation.
   c. It was heated up and converted into microwaves.
   d. More and more energy was formed and exists as solar flares now.

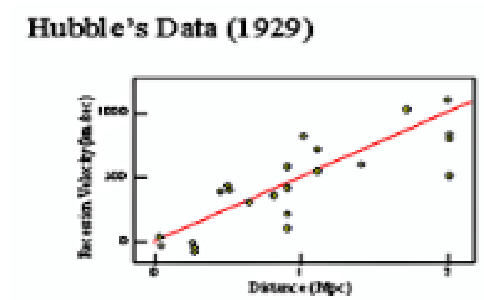
Meets/Proficient:

Construct an explanation of the Big Bang theory using the astronomical evidence below.

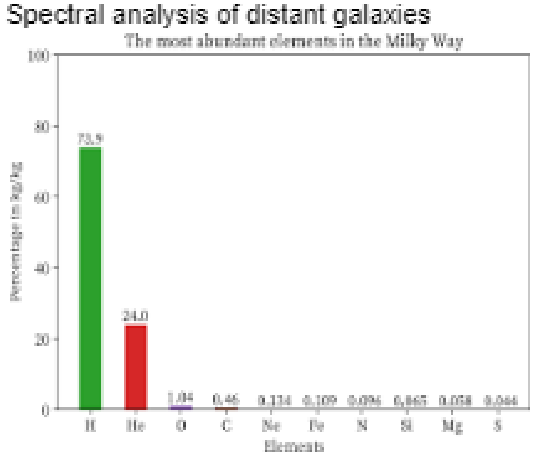
Most of the stars in the galaxy have the following spectral lines:



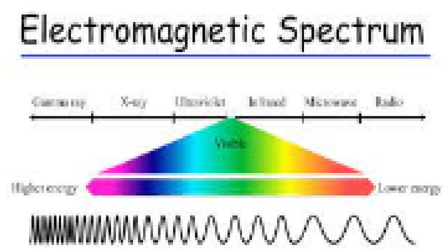
According to the diagram above what is the relationship between velocity and distance of galaxies.

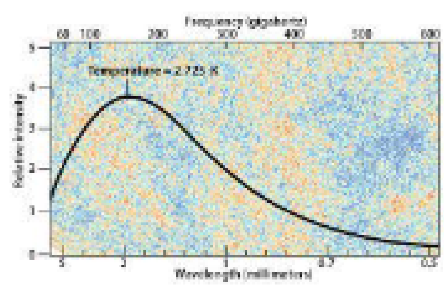


Spectral analysis of distant galaxies



Penzias and Wilson found microwave radiation everywhere present in the universe using radio telescopes. The data is shown below.





Exceeds:

Suppose a group of scientists discover more stars are displaying blue shifts. Explain how this would change the Big Bang Theory.

1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Beginning:

1. What are elements?
    a. The building blocks of matter identified by the number of protons
    b. Water, Earth, Wind, and/or Fire
    c. Tiny structures that make up all living things that have electrons in the center.
    d. Photons released from the Big Bang.

2. What is a star?
    a. Heavy metals that reflect the sun's light orbiting the earth
    b. Helium ball of gas that is splitting by nuclear fission to release light
    c. Luminous ball of heavy elements floating in space due to gravity
    d. Hydrogen held together by gravity so that nuclear fusion occurs

3. Match the part of the atom to its description:

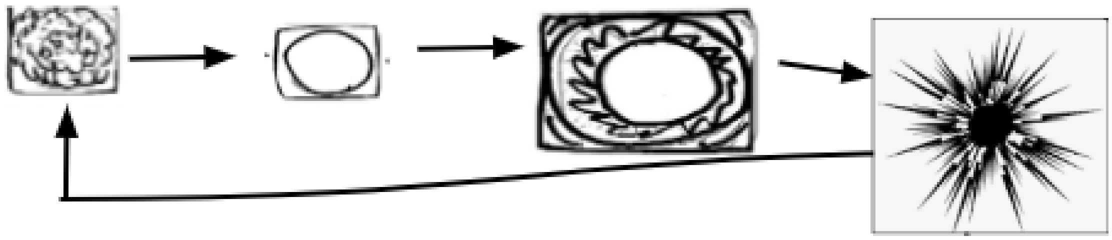
_____ electron	a) located in the nucleus with no charge
_____ neutron	b) located in the orbitals and has a negative charge
_____ proton	c) located in the nucleus with a positive charge

Progressing:

4. Where are elements created?
    a. The core of the earth
    b. The core of a blackhole
    c. The core of a nebula
    d. The core of a star

5. What happens to atoms during nuclear fusion?
    a. They split
    b. They combine
    c. They generate electricity
    d. They show redshift

Meets:



6. Label the life cycle of the star on the diagram using the following terms:

Supernova explosion	nebula	main sequence	red supergiant

7. Label the elements listed below where they are formed on the diagram of the star life cycle.

Carbon/Oxygen/Silica	Elements from previous star	Gold/Silver	Hydrogen/Helium

8. Construct an explanation for why you labeled each picture the way that you did. Be sure to include:
   i) The relationship between star mass and types of elements formed
   ii) How different elements are formed in stars

Exceeds:

9. How does a spectrometer tell scientists what elements are present in a star?

10. Explain why a LARGER star has a SHORTER lifespan than a small star.

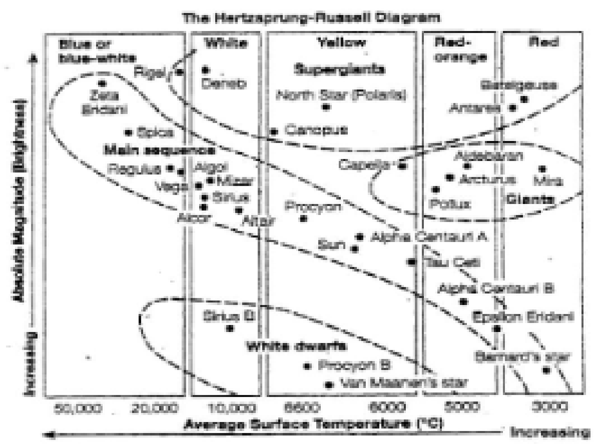
NON PRIORITY STANDARDS

1-1:Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.

Beginning: Match the following layers of the sun.

1. Radiative zone	a) Nuclear fusion occurs in this layer
2. Convective zone	b) Halo of energy surrounding the sun
3. Core	c) Convection currents
4. Corona	d) First visible layer of the sun
5. Chromosphere	e) Red layer of the sun solar flares occur
6. Photosphere	f) Energy released from nuclear fusion passes through this layer

Progressing: Interpreting Graphics



7. Which is the hottest star in the **Main Sequence** category?

8. Which is the dimmest star in the **White dwarf** category?

Meets:. Draw or describe nuclear fusion.
9. Show/describe where nuclear fusion is happening in the star and what is happening to the elements during nuclear fusion. Also, explain what conditions are needed for nuclear fusion to occur, and the results of this process.

Exceeds:
10. What types of radiation come from our sun? Explain which are beneficial and which are harmful.

APPENDIX B - Instructional Plans

Pre-Assessment:

<table>
<tr><td colspan="3">Lesson 1: Wave Properties and the Electromagnetic Spectrum</td></tr>
<tr><td>Objectives:</td><td colspan="2">1. Students will be able to describe the motion of waves on the electromagnetic spectrum (transverse wave).
2. Students will be able to identify the parts of a transverse wave.
3. Students will be able to identify the types of electromagnetic radiation and typical uses challenges with each type.
4. Students will understand the source of electromagnetic radiation is the Sun.</td></tr>
<tr><td>DCI:</td><td colspan="2">ESS1.A: The Universe and Its Stars
● The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3)</td></tr>
<tr><td>CCCs:</td><td colspan="2">Patterns
Energy and Matter</td></tr>
<tr><td>SEPs:</td><td colspan="2">Constructing Explanations and Designing Solutions
Developing and using models</td></tr>
<tr><td>Activity:</td><td>Procedure:</td><td>Possible Questions:</td></tr>
<tr><td>Activity 1:
Snakey Waves
Materials:
● One snakey per group
● Meter stick (optional)
● Stopwatch (optional)
Vocabulary:
● Transverse Wave
● Amplitude
● Wavelength
● Frequency
● Medium</td><td>1. “Wiggle” the snakey until a “wave” is created.
*Safety considerations:
● Make sure one end of the snakey is pinned to the ground the whole time.
● DO NOT let go of the snakey.
2. Change one variable at a time to experiment with what changes a wave.
3. Record all changes that are made
4. After students have had a chance to figure out what they can change in the wave, introduce the properties of waves and have students create a diagram of a transverse wave in their notes.</td><td>● What is the snakey doing?
● What did you do to make the snakey movement bigger?
● What did you do to make the snakey movement faster?
● What did you do to make more waves in the snakey?
● What patterns do you see as you change what the snakey is doing?
● What happens when you add more energy to the system?
● How did using the snakey as a model help you?
● How can you explain</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>the different types of EMR using the snakey?</td>
</tr>
<tr>
<td>Activity 2: Water Waves
Materials: (Per group)
Disposable pipette
Clear tray
Water
Demo Materials:
Disposable pipette
Clear Tray
Water
Overhead Projector
Vocabulary:
Source of the Wave
Frequency
Observer
Perspective
Frame of reference
Doppler effect</td>
<td>Stationary Source Waves:
Use the pipette to drop water into the container at regular intervals with the eyedropper remaining stationary.
Record (draw or write) your observations.
Moving Source Waves:<ol start="3">
Move the pipette in one direction along the tray while dropping the water at regular intervals.
Record (draw or write) your observations.
Demonstration:<ol start="5">
Demonstrate both of these wave movements to the class so that everyone is seeing the same thing.</td>
<td>When the source of the wave is stationary, what do the waves look like? Describe the distances between waves on all sides of the source.
When the source of the wave is moving, what does the wave look like? Describe the distances between the waves on all sides of the source.
What happens when you move the source faster?
How does this relate to the doppler effect?
How does this relate to planetary motion?</td>
</tr>
<tr>
<td rowspan="2">Conclusions from Activities 1 and 2:</td>
<td colspan="2">Activity 1:
Frequency and wavelength: Faster frequency = shorter wavelength
Distance between the two ends of the snakey and effects on wavelength: Farther distance between ends = longer wavelengths
Changing Amplitude: Doesn’t change the energy of the wave.</td>
</tr>
<tr>
<td colspan="2">Activity 2:
The distance between the waves is the same in every direction when the source of the wave is stationary.
When the waves hit the sides of the container, the “rebounded” or bounced back to the source of the wave.
As the source moves, the waves are being produced at the</td>
</tr>
</table>

	same rate and travel at the same speed. The distance between the waves will be shorter in the direction of the source's movement and longer as the wave gets further from the source.	
Activity 3: Spectroscope lab and comparing emission spectra Materials: ● Spectroscope ● Tubes of H, He, Ne, Xe ● Light sources ● Recording Sheet Vocabulary: ● Spectroscope ● Absorption Spectrum ● Emission Spectrum	Use spectroscopes to view the light spectra of ● Hydrogen ● Helium ● Neon ● Xenon ● Fluorescent lights ● Sunlight (through the window) ● White light Students should see the absorption spectra for each element with dark lines in it, and they should see the full light spectrum when they look at the other lights.	● What do you see? ● What do the black lines represent? ● Are all of the spectra the same? ● What would it mean if an astronomer was looking at a star and saw the same spectra that you see when you look at hydrogen? ● What would it mean if they did not see the same spectra you see when you look at hydrogen?
Activity 3 Conclusion	● Students should identify the patterns produced by all of the different light sources. ● Students should understand that light spectra can help astronomers determine the composition of stars.	
Activity 4: Notes	Use these notes to guide students to an understanding of the electromagnetic spectrum. Driving Question: What are the different forms of light that are found in the Universe? Assignment: EMS Webquest	

Lesson 2: Life Cycle of Stars and Star Properties	
Objectives:	1. Students will identify that Hydrogen and Helium are the most abundant elements in stars. 2. Students will be able to identify what type of star our Sun is and what its life span looks like. 3. Students will be able to identify how our Sun makes energy and how that energy reaches us. 4. Students will be able to create a model of nuclear fusion. 5. Students will be able to describe how stars produce new

	elements.	
DCI:	ESS1.A: The Universe and Its Stars ● The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) ● 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. (HS-ESS1-2),(HS-ESS1-3)	
CCCs:	● Scale, Proportion, and Quantity (Life Span) ● Energy and Matter	
SEPs:	● Develop and Use Models ● Constructing Explanations ● Obtaining, Evaluating, and Communicating Information	
Activity:	Procedure:	Possible Questions:
Activity 1: Determining the Elements in Stars Materials: ● Printed Star Spectra ● Printed Element Spectra ● Recording sheet Vocabulary: ● Absorption spectra ● Emission spectra ● Element ● star	Students will obtain a copy of each of the following pages: ● Star Spectra ● Element Spectra ● Recording Sheet Students will use these sheets to determine which elements can be found in the different stars. *This is a difficult task for some students. When they use the numbers to find the patterns, they get the most accurate answers. For those students that are unable to identify the patterns based on the numbers, they can use a light source to line up the star and element spectra sheets (one on top of the other). As long as the star and element spectra are the same size and they are lined up appropriately, this is an easy accommodation. *Students must understand that if there is even one line missing from the star spectrum, the element does not exist in	● What patterns do you see in the elements found in the stars? ● What elements showed up most frequently? ● Were there any elements that showed up in all of the stars? ● Were there any elements that showed up in very few of the stars? ● What do you predict these patterns mean for elements in stars?

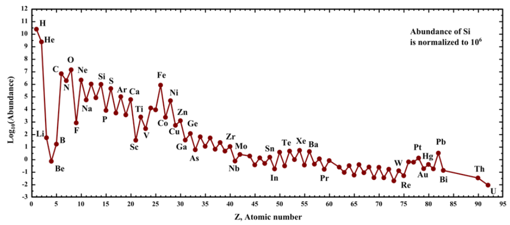
	the star. **Conclusion:** Students should conclude that stars are mostly made of hydrogen and helium.	
Activity 2: Nuclear Fusion Marshmallow/Play dough Demo and Notes Materials: • Mini Multi-colored Marshmallows or Play Doh • Uncooked Pasta • Nuclear Fusion Activity Instructions Vocabulary: • Proton • Neutron • Nucleus	Prerequisite/Review: To make this activity work well, it is important to review the parts of the atom and give a basic lesson on atomic structure and the periodic table. The goal of this activity is to introduce nuclear fusion and the release of energy to students. (Adapted from “Night Sky Network: Nuclear Fusion.) 1. Provide students with several marshmallows or balls of play doh. They will start with two in their hands 2. Tell students that each marshmallow represents a proton, and that generally fusion happens when with two nuclei at a time. 3. Students will put their hands together with the marshmallows inside and add heat and pressure. Tell students that tremendous amounts of heat and pressure are needed for nuclear fusion to happen. THe marshmallows should be joined together now. 4. Students should now have two marshmallows stuck together which represent helium. 5. Tell students that nuclear fusion doesn’t just generate new elements, but it also generates a lot of energy. Students should now take a pasta noodle out and place it on the table to represent the energy that is created in the form of gamma radiation. 6. Students should now create two additional helium atoms out of marshmallows, including the	• What does “fuse” mean? • What are the main elements in stars? • How many protons does Hydrogen have? Helium? • Describe the process of two hydrogen atoms coming together to make helium. • After creating 3 helium atoms, how many protons are there? • What is happening to the size of the atom after combining the nuclei? • What atom is created after combining two heliums? How do you know? How many protons does it have? What do you predict will happen when you add another helium atom? • How many protons does your final creation have? What element did you create? • How do you think the heavy elements are created, such as Iron? • Can you predict how the energy from our Sun reaches the Earth?

	energy. 7. Students will then smash two of their heliums together, making sure to include the energy released. 8. Tell students that the Beryllium atom they created is very unstable and will disintegrate unless another helium nucleus hits it. Quickly add your last helium nucleus! 9. After you have created your carbon atom, eat it. Marshmallows are made of Carbon atoms, you are eating stardust. Everything is created from the atoms made in stars. We are stardust. **Conclusion:** From this activity, students should be able to describe how new elements are made, and how the sun creates energy. **Assignment:** Have students create a drawing (visual model) of the process of nuclear fusion. This model should include the nuclei of two hydrogen atoms, the product of a helium atom and the release of energy in the form of electromagnetic radiation.	**Example of Nuclear Fusion Model:**
Activity 3:Types of Stars and HR Diagrams Materials: ● Star cards to print ● Types of Stars Worksheet ● Instructions	Students are given cards with a representation of a star on one side and some information about that star on the other side. The goal of this assignment is to find the patterns in the properties of the different types of stars and group them into the different types of stars. Students are to only use the information of the front of the stars to group them. They should not be turning them over	● What patterns do you first notice about the cards in front of you? ● Are there any cards that seem irregular to you?

for Students Vocabulary: • Density • Abundance • Fusion Reaction • Mass • Radius • Main Sequence Star • White Dwarf • Supergiant star • Giant	until they have their groups completed. *This can be a difficult assignment for some students because the patterns are not super obvious and some stars can go in more than one group. After students see the properties of the different types of stars, they can be introduced to HR diagrams. To do this tell students that astronomers group stars by temperature and luminosity (brightess). Blue stars are the hottest stars and red stars are the coolest stars. Given this knowledge, students should be able to place the stars from the card sort in order of temperature. **Conclusion**: Students should know the properties of stars, and how those properties can help determine what type of stars they are. **Assignment:** HR Diagram worksheet	
Activity 4: Life Cycle of a Star Materials: • Different colored balloons • Wooden beads • Marbles • Ball bearings • Something to pop balloons • Instructions for demo • Vocabulary: •	Start by having a discussion with students. Ask students: • Why is it important to understand the properties of stars and the differences between the types of stars? • Are the stars going to exist forever? (prerequisite knowledge question) • Do stars change or are they always one type? After this discussion, explain to students that just like living things stars will change and evolve over their life spans. They have a predictable sequence of events that happen in their lives, and this sequence of events has some very important milestones. After the discussion, students will do a demonstration (adapted from Adler Education "Life Cycle of Stars" Activity). All students in their lab groups will have	**Example of Star life cycle model**

	a different color balloon. Each balloon color will represent a different type of star. The stars will all start at about the same size. The teacher will be the moderator/narrator of this activity. This activity follows a specific set of instructions that are linked in the materials section. Students will then read this article and fill in the graphic organizer to define a minimum of two facts per star type. Students will do a card sort of the life cycle of stars. The card sort will lead to students creating a model of the star life cycle including what types of elements can be created in each type of star and the average lifetime of each star type. **Conclusions:** From the balloon activity, students will be able to describe that different types of stars will have different end results and different timelines.	

Lesson 3: Evidence of the Big Bang Theory		
Objectives:	1. Students will be able to identify the three pieces of evidence of the Big Bang Theory. 2. Students will be able to	
DCI:	ESS1.A: The Universe and Its Stars 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. (HS-ESS1-2)	
CCCs:	• Energy and Matter	
SEPs:	• Constructing explanations and designing solutions	
Activity:	Procedure:	Possible Questions:
Activity 1: Abundance of light elements Materials:	This activity is the same activity as Lesson 2, activity 1. The identification of the elements in the stars shows that all stars in our Universe include hydrogen	• What patterns did you see when we looked at the star spectra? • What patterns did you

Vocabulary: ● Element ● Lighter elements	and helium. We review this activity and then look at the graph included below to find patterns and interpret data.  By looking at this graph, students can see that there are larger amounts of the lighter elements. Students may notice that Lithium and Beryllium have smaller amounts, but this can be explained by saying that these elements are not very stable compared to other elements. During fusion, they do not last as long. Because the Universe takes the path of least resistance when creating new elements, the lightest elements were created first and therefore, there are the most of them. It takes many lighter elements to create heavier elements. Heavier elements are created from lighter elements.	notice about the graph presented? ● Why do you think some “light” elements have a low abundance?
Activity 2: Expanding Universe balloon lab Materials: ● Balloons ● Strings for measuring ● Rulers ● Markers ● Calculator ● [Worksheet] ● [Worksheet] Vocabulary: ● Expansion ● Speed ● Rate ● Stationary ● Hypothesis	For this lab, students will start by labeling a balloon with four dots. One dot will be placed by the mouth of the balloon and will represent the observer (the observer can be Earth, or can be the start of the Universe depending on the cognitive level of students). The next three dots will be placed in a line at different distances from the origin (I let the students choose how far they want them to be). These dots represent three different objects in space (planets or stars). Once the students have the dots placed, they measure the dots from the observer dot to get an initial distance for each object. After the initial data is recorded, students blow the balloon up a little bit.	● Predict what would happen to the distances between objects if the Universe was expanding? Shrinking? Stationary? ● What happened to the distance between dots each time you inflated the balloon? ● Which dot moved the greatest distance overall?

• Independent variable • Dependent Variable • Experimental Constant • Experimental Control • Circumference • Experimental error	They don't want to get the balloon too big because it will eventually pop, but they want to inflate it to a couple of inches in diameter. After inflation, they will measure the distance between dots again. They will inflate the balloon more after they get their measurements and get measurements again. They should do this three times total. Students should see that as the balloon is inflated, the distance between the balloons increases. This represents the universe expanding. In order to make a connection to Edwin Hubble's discoveries, we do the same activity, but inflate the balloon for 5 seconds. The data collected from this trial allows students to determine the speed of the movement of each dot. Students should conclude that the dots farther away from the center move at a faster speed than the objects closer to the center. Students will also graph this data and compare their graph to the graph of Hubble's data.	
Activity 3: Doppler effect and Redshift/blueshift Materials: • Doppler effect car example • The Doppler Effect: What does motion do to waves? Vocabulary: • Doppler effect • Redshift • Blueshift • Spectrograph	Because of how abstract this topic is, I use these notes to guide students through the understanding of the doppler effect and redshift/blueshift. This is a very difficult concept for students to understand.	Questions are built into the slide show.

Activity 4: Microwave Background Radiation	Because of how abstract this topic is, I use this activity with these questions.	Assignment: CK12 reading and questions on Cosmic background radiation.
Activity 5: Big Bang Theory Essay	For each piece of evidence for the Big Bang Theory, the students will write a paragraph to explain how that evidence supports the Big Bang Theory. To help students with their research and thought organization, students will use this worksheet.	
Unit assessment	The unit assessment is divided into priority and non-priority standards based on district definitions. And questions are written in a standards based format, with the idea that our district may be moving that direction in the next couple of years.	

APPENDIX C: Modified EQuiP Rubric

Category I: NGSS 3D Design (lessons and units): *The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions of the NGSS.*

Lesson *and* Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials** (what happened/where did it happen) **and reviewer's reasoning** (how/why is this evidence)		**Evidence of Quality?**	**Suggestions for improvement**
B. Three Dimensions: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) *that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.*	Document evidence and reasoning, and evaluate whether or not there is sufficient evidence of quality for each dimension separately	**Evidence of Quality?**	☐ None ☐ Inadequate ☒ Adequate ☐ Extensive **(All 3 dimensions must be rated at least "adequate" to mark "adequate" overall)**	
i. Provides opportunities to *develop and use* specific elements of the SEP(s).	i. Construct Explanations: - Lesson 3: Students create explanations about each piece of evidence for the Big Bang Theory. These explanations are based on evidence that they collect throughout the lessons. - Students construct explanations about stars and their life cycle throughout the unit. Develop Models: - In Lesson 1-Activity 1: students use the slinky as a model to understand the properties of waves and how those properties change. - Lesson 2-Activity 2: Students create a model of nuclear fusion to show how energy is produced in the star, and how that energy gets to the Earth. - Lesson 2-Activity 4: Students create a model of the life cycle of the star that includes different types of stars and shows what the life cycle of our star looks like. Obtain, evaluate, and communicate information: - Lesson 3: Students are gathering information about the Big Bang Theory throughout the lessons to create their explanation of the Big Bang Theory.	☐ None ☐ Inadequate ☒ Adequate ☐ Extensive		
ii. Provides opportunities to *develop and use* specific elements of the DCI(s).	ii. ESSS 1.A was addressed completely throughout the unit.	☐ None ☐ Inadequate ☐ Adequate ☒ Extensive		
iii. Provides opportunities to *develop and use* specific elements of the CCC(s). **Evidence needs to be at the *element level* of the dimensions (see rubric introduction for a description of what is meant by "element")**	iii. - During this unit of study students identify patterns in each lesson. - There are many instances where students are discussing energy and matter because of the creation of new elements in the Sun. - Students learn about time scales when we talk about the creation of the Universe and life span of the stars.	☐ None ☐ Inadequate ☒ Adequate ☐ Extensive		
C. Integrating the Three Dimensions: Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.	One dimension that is lacking in the integration part of this unit is the SEPs because I use these as summative assessments instead of integrating them into the learning. To improve this, I need to incorporate the model building into the learning of the lesson. It would be helpful to build the models based off phenomena.		☐ None ☐ Inadequate ☒ Adequate ☐ Extensive	
Rating for Category I. NGSS 3D Design—*lessons* After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which there is enough evidence to support a claim that the lesson meets these criteria. ***If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria D-F and rate Category I overall below.***	***Lesson* Rating scale for Category I (Criteria A–C only)**: **3**: Extensive evidence to meet at least two criteria (and at least adequate evidence for the third) **2**: Adequate evidence to meet all three criteria in the category **1**: Adequate evidence to meet at least one criterion in the category, but insufficient evidence for at least one other criterion **0**: Inadequate (or no) evidence to meet any of the criteria in the category			**Circle Rating** **0 1 2 3** (2 highlighted) After rating the lesson, read below for next steps

Category I: NGSS 3D Design (additional criteria *for units only*):
If you are evaluating a lesson, it is not necessary to evaluate criteria D–F. Please enter your rating for a single lesson above (after C).

Unit Criteria A unit or longer lesson designed for the NGSS will also include clear and compelling evidence of the following:	**Specific evidence from materials and reviewers' reasoning**	**Evidence of Quality?**	**Suggestions for improvement**
D. **Unit Coherence**: Lessons fit together to target a set of performance expectations. i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences. ii. The lessons help students develop toward proficiency in a targeted set of performance expectations.	This is one of those areas that no matter what order I teach this unit in, I feel that I must make a jump somewhere. All lessons build on the ideas of the electromagnetic spectrum. Everything refers to ideas that can be introduced through the electromagnetic spectrum.	☐ None ☐ Inadequate ☒ Adequate ☐ Extensive	
Rating for Category I. NGSS 3D Designed—*units* After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the criteria are met across the unit.	**Unit Rating Scale for Category I (Criteria A–F):** 3: At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C 2: At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C 1: Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C 0: Inadequate (or no) evidence to meet any criteria in Category I (A–F)		**Circle Rating** 0 1 2 3

*If the rubric is being used to approve or vet resources and the unit does not score at least a "2" overall in **Category I: NGSS 3D Design**, the review should stop here and feedback should be provided to the unit developer(s) to guide revisions. If the rubric is being used locally for revising and building units, professional judgment should be used on whether or not to continue reviewing the unit. For example, a unit that is weak in one aspect of criterion A, but that the reviewers think is easy to fix, might warrant continued review to provide more complete feedback to the unit developer(s).*

Category II: NGSS Instructional Supports (lessons and units): *The lesson/unit supports three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students.*

Lesson *and* Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials and reviewers' reasoning**	**Evidence of Quality?**	**Suggestions for improvement**
C. Building Progressions: Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers: iv. Explicitly identifying prior student learning expected for all three dimensions v. Clearly explaining how the prior learning will be built upon.	DCI: Started with waves and the electromagnetic spectrum to ensure students had the proper background for understanding star composition, and the evidence for the Big Bang Theory. SEP: Some evidence provided of building SEP Progression. Students build evidence over the course of the unit. CCC: Some evidence provided of building CCC Progression	☐ None ☐ Inadequate ☒ Adequate ☐ Extensive	There could be more places of explicitly including the SEPs and CCCs, and building upon what students already know in this aspects of the curriculum. Some CCCs are built into the unit. Next step for this unit is to increase student independence in identifying and applying CCCs.
D. **Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.	This curriculum was based on a lot of research into the DCIs. Developmental appropriateness for 9th graders is questionable. This course was assigned to 9th grade by the district.	☐ None ☐ Inadequate ☒ Adequate ☐ Extensive	No evidence specifically in the written curriculum.
Rating for Category II: Instructional Supports—lessons After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category. ***If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria F–G and rate Category II overall below.***	**Lesson Rating scale for Category II (Criteria A-E only):** 3: At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion 2: Some evidence for all criteria in the category and adequate evidence for at least four criteria, including A 1: Adequate evidence of quality for at least two criteria in the category 0: Adequate evidence of quality for no more than one criterion in the category		**Circle Rating** 0 1 2 3

APPENDIX D - IRB Approval Letter

UNI University of Northern Iowa

Jessica Hughes <jonesjaj@uni.edu>

Classroom research exemption form

Rebecca Rinehart <rebecca.rinehart@uni.edu> Fri, Dec 10, 2021 at 2:42 PM
To: Jessica Hughes <jonesjaj@uni.edu>, Jesse Wilcox <jesse.wilcox@uni.edu>
Cc: Sean Parrish <sean.parrish@uni.edu>

Dear Investigator(s):

Your study has been determined by the UNI IRB to meet the criteria for Exempt status, category 1. You may begin recruitment, data collection, and/or analysis for your project.

You are required to adhere to the study procedures reported in your IRB form, and to monitor the project to ensure that the rights and privacy of the participants in your study are protected.

If you need to make any changes to the study, you must request approval of the changes before continuing with the research. Requests for modifications should be emailed to Interim IRB Administrator Rebecca Rinehart at rebecca.rinehart@uni.edu, cc sean.parrish@uni.edu.

Your study will not require annual review or closure.

If during the study you observe any problems or events pertaining to participation in your study that are serious and unexpected, you must pause data collection and report this to the IRB immediately (at least within 10 days) to receive guidance on next steps. Examples include unexpected injury or emotional stress, missteps in the parental notification process, or breaches of confidentiality.

Best wishes for your project success.

Best,
Rebecca

Rebecca Weaver Rinehart, CRA
Preaward Specialist & Interim IRB Administrator

University of Northern Iowa
Office of Research and Sponsored Programs
319-273-6482 / rebecca.rinehart@uni.edu

[Quoted text hidden]