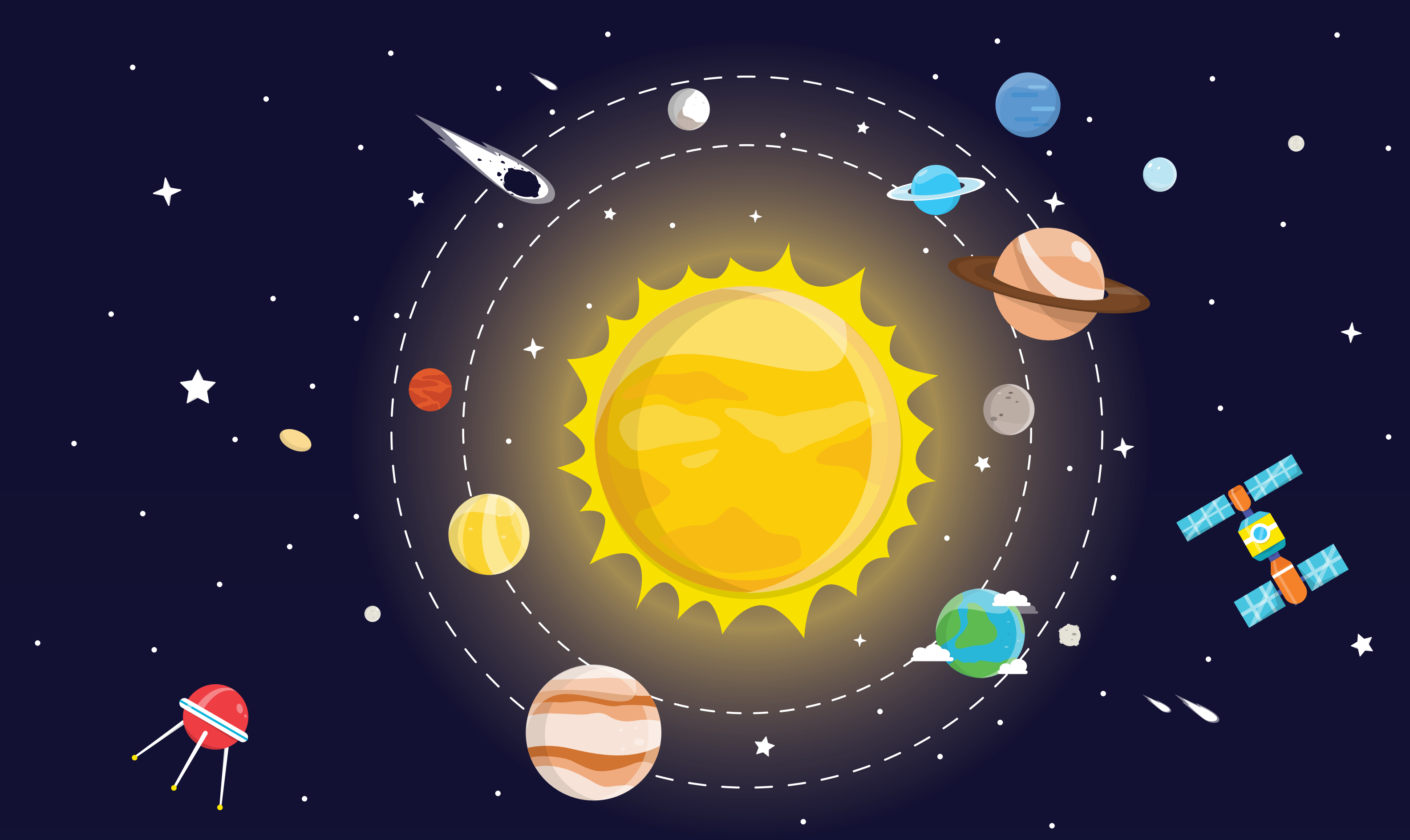


Comics in the Classroom

What's at the center of the solar system?

AMEE JEANETTE HENNIG, BROOKE A. WHITWORTH, AND ALLISON HUFF MACPHERSON

Teaching in today's classroom looks vastly different from 20 years ago. Today, many teachers have access to projectors, computers, smartboards, laptops and tablets, and have vast amounts of information and programs available at the click of a button. However, having access to all of these resources is not always beneficial, especially if we are not equipped to incorporate it into instruction. The 2015 Project Tomorrow Survey findings showed a number of aspects that support technology use in the classroom. Highlights of this data, related to the Center for Integrated Access Network's (CIAN) digital comic book, include the following results (Project Tomorrow, 2016):

- Thirty-eight percent (38%) of students find online videos to help with their homework and 27% regularly watch videos created by their teachers.
- Almost two-thirds of students want to use digital games for learning in school.
- Teachers are using more digital content in their classroom than ever before. This year's leader board: videos (68%), digital games (48%), online curriculum (36%), online textbooks (30%), and animations (27%).

When utilized effectively, the use of digital resources in the classroom can engage students in a way print resources may not.

At the Center for Integrated Access Networks (CIAN), an Engineering Research Center funded from 2008–2018 by the National Science Foundation, the education department worked to develop new and innovative digital resources to engage students in learning science content (Figure 1). One resource created, the CIAN Comic Book (see "On the web"), focuses on educating students about optics, technology, and scientific discovery, and is well-aligned with the *Next Generation Science Standards* (*NGSS*). This article suggests one way to utilize the CIAN digital comic book by incorporating it in an Argument Driven Inquiry (ADI) lesson.

Argument Driven Inquiry

Argument Driven Inquiry (ADI) involves students in the scientific process by including the development of scientific ways of thinking, considering evidence-driven examples, and always considering alternative ways of thinking (Sampson, Grooms, and Walker 2009). Sampson and colleagues (2009) suggest nine steps for completing the ADI process:

- *Identification of the task* that creates a need for students to make sense of a phenomenon or solve a problem
- *Generation and analysis of data* by small groups of students using a method of their own design
- *Production of a tentative argument* by each group that articulates and justifies an explanation in a medium that can be shared with others
- An *argumentation session* in which each group shares its argument and then critiques and refines its explanations
- An *investigation report* written by individual students that explains the goal of the work and the method used, and provides a well-reasoned argument
- A *double-blind peer review* of these reports to ensure quality and generate high-quality feedback for the individual authors
- The subsequent *revision of the report* based on the results of the peer review
- An *explicit and reflective discussion* about the inquiry

Implementing the lesson

Guiding question

The guiding question for the investigation in this lesson is: How can the phases of the moon, as well as pictures of Venus and Jupiter, help us understand if the Earth is at the center of the solar system? Using the ADI method, students are challenged to investigate and discover more about the Moon and the planets' phases and what those phases imply about the composition of our solar system as a whole. The alignment between objectives, lesson activities, and *NGSS* are more fully described on page 43 (See NGSS Connections).

Identification of the task

Students start this lesson by reading the CIAN Optics Adventures Comic Book. In the CIAN Optics Adventures Comic Book, two main characters are introduced: C.H.I.P. (Communication Highway Using Integrated Photonics), a robotic character who has the ability to time travel, and Professor Watt, a classic character portraying the inventor and scientist who has a robotic hand with the ability to project images and videos. After C.H.I.P. has been created, the two discuss the scientific discovery process and decide that the best way to learn about this process is to travel through time and meet a variety of important scientific figures to learn about their contributions. Scientists visited include Galileo Galilei, Christiaan Huygens, Isaac Newton, Henrietta Swan Leavitt, Thomas Young, and Albert Einstein.

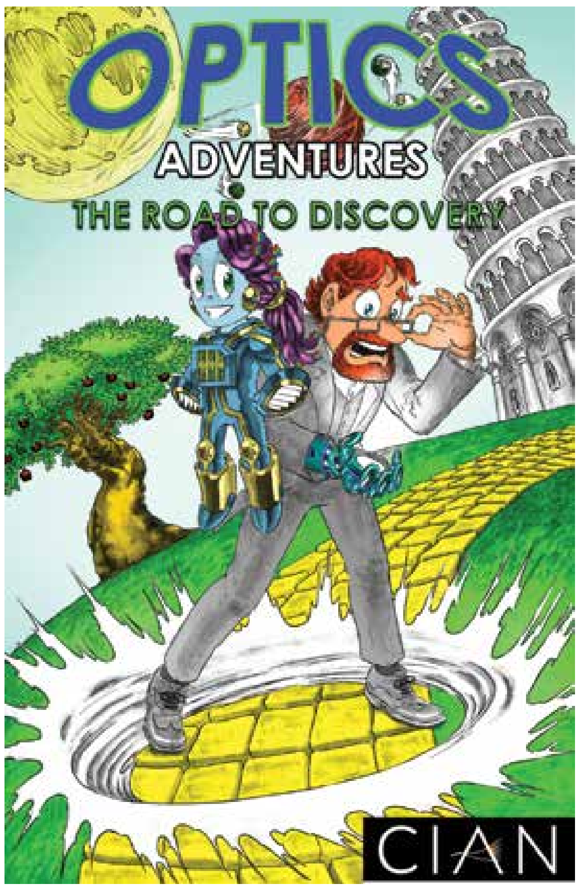
The focus of this lesson centers on the story of Galileo and his discovery of the moons of Jupiter (Figure 2). The comic book issue covers three topics: 1) the makeup of the Earth-Sun-Moon system as investigated through lunar phases, 2) the phases of Venus, and 3) Galileo's discovery of Jupiter's moons (Figure 3). This was a significant discovery in the scientific community because it implied that the Earth was not at the center of the universe. If other objects in space were orbited by other celestial bodies, how could the Earth be at the center of it all?

Students explore this historical discovery and its implications through the investigation of celestial bodies including the Moon, Venus, and the Jupiter system. As students read the comic, it may be appropriate to provide a note guide or graphic organizer for students to organize their thoughts as they read. Our students enjoyed reading the comic and were able to refer back to it often so we chose not to incorporate this into our lesson.

After reading the comic, students are given the ADI hand-

FIGURE 1

Cover for first issue of CIAN comic book.



out (Appendix A; see "On the web") and the task is introduced using the handout:

- **The task:** Investigate the phases of the moon. How do they work? What is their pattern? What causes them? And can the phases of the moon help us understand what the center of the universe is? Let's take a look at another planet! You will need to acquire images of the planet Venus at different times of the year taken with telescopes from planet Earth. Finally, you will take a look at Jupiter itself during different times of the year for comparison.
- **The guiding question of this investigation is:** *How can the phases of the moon as well as pictures of Venus and Jupiter help us understand if the Earth is or is not at the center of the universe?*

The handout was created using the ADI template provided freely (see "On the web"). After students read the comic and handout, have an informal class discussion to assess their understanding of what they have read. We make sure to ask simple review questions about the comic content, what question they are trying to answer in the investigation, and if students have any clarifying questions they need answered about the comic or task.

Students are then placed in groups of 3–4. We chose to group students heterogeneously based on their past performance on labs in class; however, teachers can choose to group their students in a variety of different ways that would be equally appropriate for accomplishing this task. In their groups, students are asked to investigate the phases of the moon and then consider observations of Venus and Jupiter at different times of the year. This is an open-ended assignment that challenges students to determine 1) what they want to find out about phases of planetary bodies, 2) how they are going to figure that out, and 3) what their discoveries imply for the world they live in. The ADI handout (Appendix A) leads students through this process and it starts by allowing students to learn what materials are available.

Generating and analyzing data

Appendix A (see "On the web") provides a list of materials students can use during their investigation to help answer their guiding question. Some groups struggle with where to start in order to answer the guiding question, but questions provided in the "Getting Started" section of the handout are a good place to point students. In addition, key words are included in the lesson that can help guide students to investigate specific things about phases. For example, key words and phrases include "lunar phases," "model of the Sun-Earth-Moon relationship," "lunar log," and "model of the planetary relationships." This way, students can find out more about the project by looking up words and phrases that they have not heard before, which can help guide the beginning of their investigations.

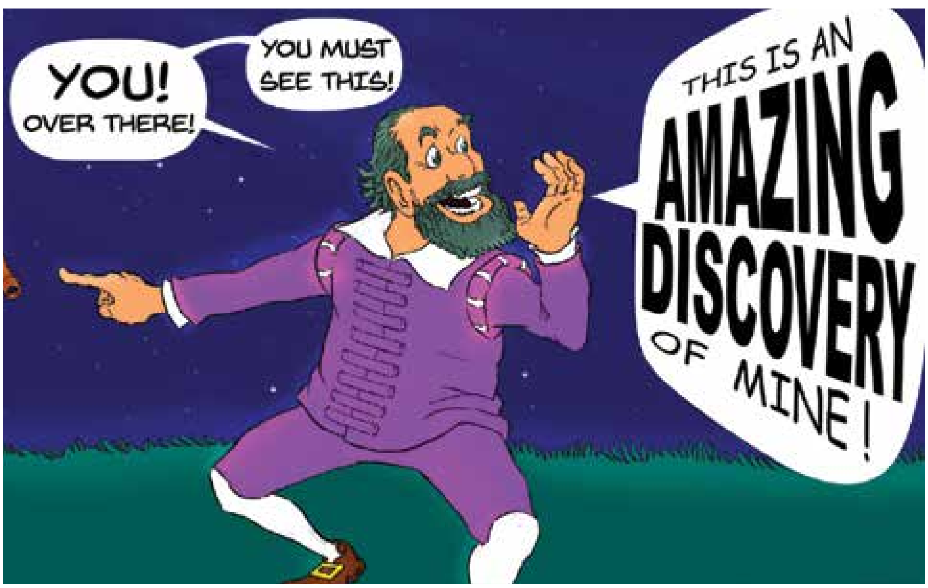
As a group, students must develop an investigation proposal and have the teacher approve it. This is an important opportunity to formatively assess where students are in the process. Students must decide what type of data they will collect, how they will collect it, and how they will analyze that data to answer the guiding question. Taking the time to informally assess their proposals is useful for preventing issues with data collection down the road.

It is useful to suggest students use a lunar log (journal) to track their observations of the Moon as they investigate lunar phases. Galileoscopes can be purchased (multiple online retailers sell these as do science supply companies) and loaned to students if students are making live observations. Another option if time or cost is an issue is using Stellarium (see "On the web"), software that shows exactly what you see when you look up at the stars on a set date, at a set time, in a set location. Stellarium allows the date, time, and location to be changed as desired, and allows students to quickly investigate the night sky at any time of the day.

If you choose to do live observations with your students, then you will need to introduce the assignment and provide students with 4–6 weeks to collect data and develop their arguments. When we have taught the lesson in this way, we have framed it more as a project and required students to keep lunar logs of their observations of the moon. During the 4–6 weeks in the classroom,

FIGURE 2

Galileo Galilei's introduction in the comic book.



other content can be taught and you can culminate with lessons tied to Moon phases, the solar system, and the importance of the scientific community's input and creation of new discoveries. In this case, it may also be wise to have periodic check-ins with students to make sure they are on-track to complete the project in the time frame provided.

If you use Stellarium, the lesson can be completed much more quickly with data collected for a month within 30 minutes, rather than four weeks. To find images of Venus and Jupiter students can search for these images online or you can provide a list of resources where students can start (Appendix B; see "On the web").

Production of a tentative argument

Once students have collected and analyzed their data, groups should develop a tentative argument to answer the guiding questions (Sampson, Grooms, and Walker 2009). Groups initially create their arguments on whiteboards to share with others in the class. Instructions for what their whiteboards should look like and how they should present their argument is provided in their handout (Appendix A, online).

Argumentation session

During the argumentation session groups have the opportunity to share their arguments with others, receive feedback from their classmates on their arguments, and find mistakes in their arguments before submitting their investigation report. One member of the group stays at their lab station to share their

C.H.I.P. and Prof. Watt meet Henrietta Swan Leavitt and learn about how scientific discovery builds and advances.

group's argument, while the other group members visit their classmates' stations to critique and learn from one another.

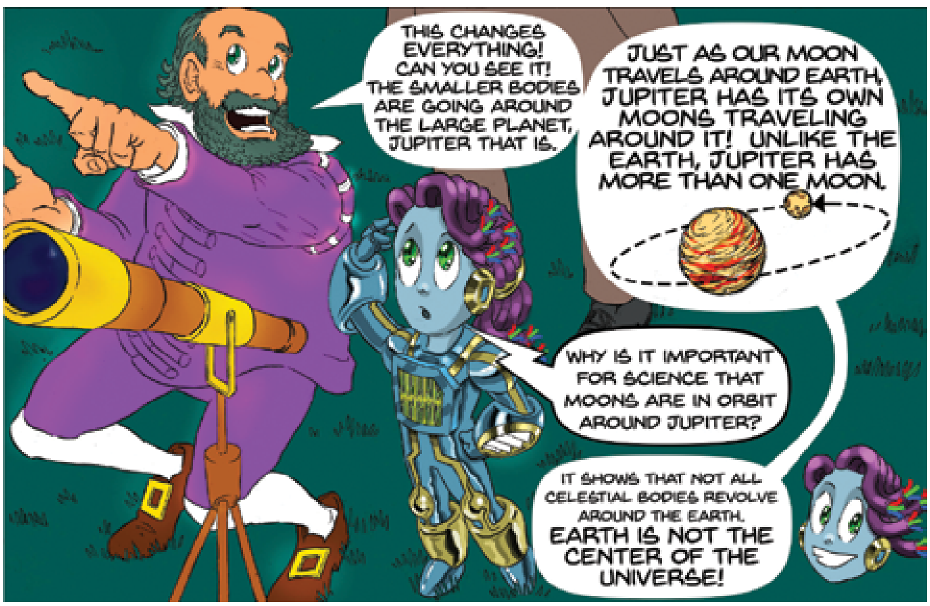
During the session, we often post sentence stems (listed in Appendix A) that students can use to help start their conversation as they visit other groups. After visiting other groups, the group members come back with the information they've gathered and reconsider their argument. Groups can revise their argument or collect more data as needed.

Assessment of student learning and progress during the argumentation session can be supported with a monitoring tool. A monitoring tool is a suggested support for preparing for and leading a task-based discussion (Smith et al. 2013). This tool, used in combination with monitoring the students' activities is the "process of paying attention to the thinking of students during the actual lesson as they work individually or collectively on a particular task" (Smith et al. 2013, p. 53). Often as teachers we circulate during class or group work time, but don't take the time to track what students and/or groups are doing. A monitoring tool allows you to track what your students are understanding and struggling with and to take the formative assessment of circulation and make it more useful. Teachers can use the data collected from a monitoring tool to guide the final explicit and reflective discussion with students.

Table 1 serves as an example but may be modified to meet the instructor's goals. When assessing the students teachers should take the following steps: 1) determine what each group of students actually did, 2) determine what was accurate and well-represented as

FIGURE 3

C.H.I.P.'s observation of Galileo's discovery of Jupiter's moons.



well as what facts were misrepresented or misunderstood, and 3) make note of any other pertinent observations. When reviewing these observations of each group, the teacher can assess the understandings of the whole class. This allows the educator to have a topic or topics to focus on in his or her follow-up with the students to ensure they have a complete understanding of the topic (Smith et al. 2013).

Investigation report

Students are then asked to individually write a two-page investigation report answering the questions outlined in Appendix A. Having students work in a group but then be responsible for an individual report holds students accountable for all of the work being done. Another means for holding students accountable for group work up to this point is having them self-assess and assess those in their group (Figure 4; see "On the web.").

Double-blind peer review

Students then take time to review one another's reports using a double-blind peer review process (Sampson, grooms, and Walker 2009). Students are assigned paper numbers that they add to the header of their paper. They then print four copies to be distributed blindly to another lab group. Lab groups review 3–4 papers and complete the peer review sheet for the paper.

We recommend using Sampson and colleagues' (2009) peer review sheet for the double-blind peer review (accessi-

TABLE 1

Example of Monitoring Tool

STUDENT GROUP	FEATURES CORRECTLY REPRESENTED	FEATURES MISSING OR INCORRECTLY REPRESENTED	ORDER AND NOTES
A	• Moon Phases • Model of the solar system • Model of the Earth-Moon-Sun System	• Incorrect Moon phases • Incorrect model of solar system • Incorrect model of the Earth-Moon-Sun System	
B	• Moon Phases • Model of the solar system • Model of the Earth-Moon-Sun System	• Incorrect Moon phases • Incorrect model of solar system • Incorrect model of the Earth-Moon-Sun System	
C	• Moon Phases • Model of the solar system • Model of the Earth-Moon-Sun System	• Incorrect Moon phases • Incorrect model of solar system • Incorrect model of the Earth-Moon-Sun System	
D	• Moon Phases • Model of the solar system • Model of the Earth-Moon-Sun System	• Incorrect Moon phases • Incorrect model of solar system • Incorrect model of the Earth-Moon-Sun System	
E	• Moon Phases • Model of the solar system • Model of the Earth-Moon-Sun System	• Incorrect Moon phases • Incorrect model of solar system • Incorrect model of the Earth-Moon-Sun System	
F	• Moon Phases • Model of the solar system • Model of the Earth-Moon-Sun System	• Incorrect Moon phases • Incorrect model of solar system • Incorrect model of the Earth-Moon-Sun System	

ble online). A review of their article and the process they use for double-blind peer review in ADI would be useful to any teacher working to implement ADI in their classroom. Reviewers rate papers as "accepted" or "revise and resubmit." It is rare for a paper to be accepted as-is, so students then have the opportunity to revise their report. Typically, we give students 1–2 nights to complete these revisions as homework, and the paper is then assessed by the teacher using the same peer review sheet that was used in the double-blind peer review (Sampson, Grooms, and Walker 2009).

Explicit and reflective discussion

Finally, teachers should have an explicit and reflective discussion around the explanations students developed to answer the original questions (Sampson, Grooms, and Walker 2009). In this lesson, some critical points and questions to address during the discussion are:

- How does the Moon change appearance over the course of a month? A year?
- How do different planets change appearance over the course of a month? A year? (Planets suggested to investigate are Venus and Jupiter.)
- Compare and contrast the images of the Moon and the planets, notice changes that occur in some and not others.
- Investigate the composition of the systems that are being investigated. For example, drawing the layouts of the Sun-Earth-Moon system and the Sun-Earth-Venus and Sun-Earth-Jupiter system on the board will be helpful. This can also be done with a hands-on demonstration using a light bulb to represent the Sun so that light and dark areas are easily seen by the students. Additionally, videos are available online that can portray this phenomenon (see "On the web).
- Try mixing up the organization of the systems (e.g., put the Earth at the center) and see if students can make the light from the Sun shine on the Moon or Venus to create the correct phases (this is not possible, so it should be a quick giveaway that the Earth is not the center of the solar system).

Modifications

It may seem that the tie to the comic book is not necessary for the lesson described; this was done intentionally. Educators may choose to do one or the other, or use both. The lesson plan and comic book are both resources that on their own contribute to the classroom; however, their relationship to one another may increase their impact in the classroom if used together.

In our own classes, we have found the use of the comic book to increase student engagement and participation, and this is further supported by the findings of Project Tomorrow. Project Tomorrow found that 75% of teachers felt that the digital comic book enhanced student engagement in learning, performance, and achievement (Project Tomorrow 2008).

In addition, the "What's in the Center?" lesson plan may be expanded or decreased to suit the classroom context. For example, the teacher may want to only focus on images of the phases of the Moon and not include the observations of Venus and Jupiter.

Conclusion

The use of instructional models like ADI gives students the opportunity to apply knowledge from other classes in the format of report writing and presentation skills, as well as to teach about the scientific community's process and function. It teaches students the benefits of peer-review and constructive criticism, to not accept things at face-value but to investigate proposed facts with their own critical eye. Pairing this approach with the CIAN Comic Book offers an exciting new opportunity for educators to intentionally and successfully incorporate digital resources into their classroom. The CIAN Comic Book in combination with effective instructional models, like ADI, presents an opportunity to incorporate technology in the classroom, engage students through a medium of their interest, and implement the most up-to-date educational lesson plan models in a new way. ■

ON THE WEB

ADI template: *https://argumentdriveninquiry.com/*
CIAN Optics Adventures: *https://joom.ag/9jyp*
Wolfram Phases of the Planets video: *https://demonstrations.wolfram.com/PhasesOfPlanets/*
Stellarium planetarium software: *www.stellarium.org*

REFERENCES

Campbell, T., C. Schwarz, and M. Windschitl. 2016. What we call misconceptions may be necessary stepping-stones toward making sense of the world. *The Science Teacher* 83 (3): 69–73.

Goldenberg, L. 2011. What students really want in science class: The importance of good teaching practices—with and without technology. *The Science Teacher* 78 (6): 52–55.

Project Tomorrow. 2008. 21st century learners deserve a 21st-century education: Selected national findings of the Speak Up 2007 survey. *www.tomorrow.org/speakup/speakup_congress_2007.html*

Project Tomorrow. 2016. From print to pixel: The role of videos, games, animations and simulations within K–12 education. *www.tomorrow.org/speakup/from-print-to-pixel.html*

Sampson, V., J. Grooms, and J. Walker. 2009. Argument-driven inquiry. *The Science Teacher* 76 (8): 42–47.

Smith, M.S., J.L. Cartier, M.K. Stein, and D.K. Ross. 2013. *5 practices for orchestrating productive task-based discussions in science.* Arlington, VA: NSTA Press.

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard

MS-ESS1 Earth's Place in the Universe

Performance Expectations

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.

MS-ESS1-4. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
Developing and Using Models Develop and use a model to describe phenomena.	Students create a model of the Sun-Earth-Moon system (however they choose: physical, digital, etc.) and determine how it shows lunar phases.
Analyzing and Interpreting Data Analyze and interpret data to determine similarities and differences in findings.	Students learn about the Jupiter-moons system and discuss its implications to Earth being the center of the universe.
Constructing Explanations and Designing Solutions Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	Students compare findings to beliefs that the Earth is the center of the universe and how their findings impact this belief. Students construct explanations from their investigations to why the Earth is not the center of the universe and present to the class.
Disciplinary Core Ideas	
ESS1.A: The Universe and its Stars Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.	Students make observations about the motions and patterns of the Moon, Jupiter, and Venus either directly, or using information that is available to them through library and database materials. Then this information is developed into clear models that predict this motion.
ESS1.B: Earth and the Solar System The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.	Students learn about the basic organization and properties of the Earth and its solar system through their observations and investigations. Students use these models and information to develop their understanding and their ability to predict the phases of the Moon.
Crosscutting Concepts	
Patterns Patterns can be used to identify cause-and-effect relationships.	Students predict and explain the patterns of the Moon's phases, Venus' phases, and the lack of the apparent phases of Jupiter.
Scale, Proportion, and Quantity Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.	Through students' creation of models to predict the different phases of these celestial bodies, students will understand their basic properties, orientations, and organization.
Systems and System Models Models can be used to represent systems and their interactions.	Students will use the system models created to develop and explain their understanding of the model of the solar system.