Life on Spinning rocks

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Overview

Everything is chemistry, and teaching it is enjoyable in that students gain an intricate perspective on how we interpret our world and universe, in terms of matter and energy and their transformations. Biology on the other hand adds a systemic approach to how atoms combine and breathe life into the chemical arrangement. Students begin to ask questions that we as scientists and as a humanity have not quite figured out. The goal of this unit is to integrate student understanding of Biology, Chemistry and Cosmology. Students will appreciate the similarities and differences in the behavior of matter and energy, and how they affect the living and non-living in the universe.

The most pleasurable part of teaching chemistry is when students connect science concepts to experiences in everyday living. As they apply the conceptual understanding to different situations, they are provoked to ask different questions in the interplay of so many variables. As scientists, they begin to appreciate that we investigate and analyze consistent results within a specified, limited set of conditions. However, many variables beyond those mentioned in this curriculum ultimately affect outcomes in the natural world.

This unit seeks to engage students to initially deepen and extend their understanding of earth and the variety of environments, and then reconcile the variety of living organisms that thrive in some of these extreme conditions. Students will compare these conditions to planets in our universe to create the existence of an "alien" using a scientifically plausible argument.

Rationale

I structured this unit such that every subsequent topic builds on previous learning. It also reminds 11^{th} grade chemistry students of the biology course taken in their prior year as 10^{th} graders. Students can gain an appreciation of the integration of science disciplines from the systemic to the atomic and then enlarge and connect their years of science learning, into the discipline of cosmology. Students take on an online investigative approach, developing a series of inquiry experiences as digital natives. They develop competence and confidence as they develop domain specific language as scientists when

they navigate through information and then write, speak, listen, collaborate and express their understandings with the culmination of their final task, to create a fictional alien.

In pedagogy, both Piaget and Vygotsky contributed to our current understanding of cognitive development in a child. However, it was Vygotsky's theory that stressed the importance of cultural language on one's cognitive development. My students struggle to access scientific vocabulary to express their understanding. Repeated dialogue with their peer groups and during presentations will support strengthening the use of content specific vocabulary. The topics present opportunities for students to explain the meaning and then explain the concepts. They will learn how to research and shape the information they gather as they collaborate with their peers, with teacher facilitation.

The technology-supported Jigsaw approach is a student centered learning technique that provides a climate that enables inclusive, flexible, and unique learning for growth according to student interests, with the development of multiple levels of complexity. The environment fosters depth and expanded understanding with peer collaboration and teacher facilitated reflection, fostering enriched thinking and learning. According to Schon, 1983, learning is a dynamic process of "reflection-in-action" where action is used to extend thinking, and reflection is governed by the results of action.

In chemistry, students know the Periodic Table as the alphabet of atomic structure. The curriculum predominantly focuses on chemical interactions; nuclear chemistry may be an optional addition. In biology, students are already familiar with the characteristics and classification of life forms, so this unit section would serve as an extension to expand their thinking. The goal is to spark student curiosity into the infinitesimal realm of the universe.

Initially the unit starts with a reminder lesson by students in 10^{th} grade that have completed their Keystone State Tests in Biology. The students will share their understanding of the how we define life. A sample of topics that are questioned follows:

- How do we know something is alive?
- How does life result from chemical structure and function?
- How cellular structure and function affect life?
- How do organisms interact and depend on each other and their environment for survival?
- How do different organisms obtain and use energy to survive in their environment?

At this point 10^{th} grade students reflect on the depth of their understanding, as they present and share their year's learning with their 11^{th} grade school community.

After the 11th grade students have had an opportunity to remind themselves of the characteristics that define life, they will carry out their own investigatory experience on the types of extremophiles that exist on earth. Extremophiles are fascinating, not only will students gain an understanding of the extreme environments in which the organisms thrive, but also the anatomical and physiological traits that enable them to do so. Students will also find through their investigation that scientists study these characteristics as a means to find solutions to problems that humankind encounters.

Some of the intrigue would be for students to raise their own questions as they investigate the different types of extremophiles such as:

- What is life?
- What are the limits of life?
- What are the fundamental features of life?

Students will explore how organisms can thrive in environments that have water at temperatures that are below freezing or are boiling, chemical extremes with pH <5 or >9 and conditions of salinity that are ten times that of water.

As students digest the vastness of organisms and environments on earth they will then continue their investigations on the possibility of the existence of life on other planets. In order to do this, they will need to understand and compare the conditions on earth with that available on other planets. Here students will explore the following questions:

- What are the possible characteristics of our nearest planetary neighbors?
- What would an experience of "a day" be on that planet?
- What form and lifestyle can be constructed based on the environment and the characteristics that enable the life of an organism?

In this section students will gain an understanding of the Terrestrial and Jovian planets, the Kuiper Belt, characteristics of the planets with their moons, the composition of meteorites, asteroids and comets, water in space and volcanism in space. Moreover, they will consider the Drake Equation used to estimate possible advanced civilizations in the Galaxy with radio transmission, and raise questions related to communication. Should student interest emerge in alien communication, it may be an opportunity towards watching and discussing the movie, The Arrival. The intervention would promote deeper discussions.

Objectives

This unit is intended for high school students in an urban setting. My students are diverse in how they engage with learning through narrative, conceptual and mathematical ideas.

Furthermore, my students are preoccupied with preparing for college admission. As they navigate and negotiate through the day, students are embedded in a digital, social, cultural environment in which communications are rapid and real-time. The same approach is used to respond to questioning through rapid research using digital media. Scanning and skimming through information predominates and the result is that compromises are made in the processes of reflection and creation. This unit attempts to explore that active learning space using structured development of student questioning, collaboration and contemplation.

This unit can be divided into four major themes. I want my 10th grade students to culminate their year's learning and share their expressions with my 11th grade students, this is also a time to reflect on the ideas that Biology brings to their perception of how we define life. On the receiving end of the teach-back that the 10th grade students have created, I want my 11th grade students to reflect on their course in Biology, a year later having grown through the lens of the chemistry course. Students from the 11th grade can take time to fuse their ideas on the characteristics that define life, through the lens of the elements of the periodic table, and the multitude of transformations of matter and energy.

It is through the reconciliation of the biology and chemistry courses that I hope my students will further develop an understanding of the extreme conditions that are here on earth, and how extremophiles exist using specialized anatomical and physiological attributes to co-exist in these environments. I trust it will provoke further questioning by students regarding the factors that promote and limit life – as we know it.

As students continue through the unit, they will develop an understanding of Cosmology and the different environments on different planets. Students will question and respond to the forces that affect each planet and the variety of celestial bodies that impact each planet. I want them to grasp the idea that everything in the universe is connected. What may appear as a random incident, bears connections to a series of incidences.

Finally, to apply what they have learned, students will create an alien that appears as a scientifically plausible organism. My students enjoy science fiction movies. In this final role, they become masters of creating their own species providing plausible scientific arguments to support their creation – of an alien.

Strategies

The major strategies implemented in this unit use the following learning progressions:

Activating prior knowledge in biology by reviewing the characteristics of life and the cell structures of living organisms. Followed by how organisms interact with their

environment to survive and thrive. The objective is achieved by the use of the Jigsaw Method developed by Elliot Aronson in 1971. It is a cooperative learning strategy where each student in a group takes responsibility for one chunk of the content, then teaches it to the other group members. Similar to a jigsaw puzzle, students fit their individual chunks together to form a complete body of knowledge. The Jigsaw Strategy is used in the activities on the first and second days to activate prior knowledge from the previous year. The topics are divided into content chunks and each group of students are assigned a topic chunk and are the the subject matter experts on the topic.

In the classroom students are divided into groups of 2-4 students to a group. Although the Jigsaw works best when there are an equal number of students in each group, it is necessary at times to modify and accommodate the arrangement for students who prefer to work on their own. However, care needs to be taken so that all the content is distributed amongst the students, and sections are not omitted.

The Jigsaw strategy is used not only to activate prior knowledge and meet the objectives at the start of the unit. It is also used to extend knowledge on the 3rd and 6th day activities. On the third day each student group investigates a category of extremophiles, and on the sixth day each student group investigates and compares the environmental conditions of a planet with that on earth. According to Marzano (2007) the strategy of comparison improves comprehension by highlighting important details, making abstract ideas more concrete, and reducing the confusion between related concepts.

There is a substantial amount of information that students will be assimilating and integrating, to meet the final objective of creating and then presenting a scientifically plausible alien on the 7th and 8th activity days for this unit. In their years of research into the defining characteristics of intelligent behavior and thought, Art Costa and Bena Kallick (2008, 2009) have identified 16 “habits of mind.” By nourishing these habits in our students, we give them sustainable study tools they need to use their minds well, thus increasing their chance for future success. Using the Compare & Contrast Strategy with the environmental conditions on earth with their assigned group planet and using the Jigsaw Method - combined, the approaches will help students develop these habits of mind: thinking flexibly; thinking about thinking (metacognition); striving for accuracy; applying past knowledge to new situations; and thinking and communicating with clarity and precision.

Finally, students will be practicing a variety of techniques to explain and detail their learning such as Think-Pair-Share and Presentations employing a variety of topics throughout this unit. These strategies in blended with the Jig-Saw Strategy enables students to integrate the disciplines of Biology, Chemistry and Cosmology with depth

and breadth, effectively managing time to collate scientifically detailed arguments to support the existence of their created alien.

Classroom Activities

In light of the numerous possibilities, a foundational core structure for this introductory unit is prepared for 10^{th} and 11^{th} grade students with 55- minute classes. The unit may be adapted for middle school students.

Activity Day 1

This day is dedicated to introducing the topic using an inquiry activity. For the carousel 7 Large Post-It Sheets are to be placed in the Lab. and the hallway, easily accessible for students to walk around and write. Each sheet is to be numbered from 1-7 for each of the groups. Each group will write their question(s) with their responses on their designated group sheet.

Students will be divided into 7 groups of 3-4 students, each group is given a card with two questions. Students will have colored post-it notes to park their responses onto the poster post-it. Students will read their questions Think – Pair - Share, and write on individual colored post-its. They will write their responses to these questions on post-it notes.

Group1
How do we know something is alive?
How does life result from chemical structure and function?
Group 2
How cellular structure and function affect life?
How is structure related to biological levels of organization?
Group 3
How do organisms maintain a biological balance between their internal and external environments?
What are the advantages of multicellularity?
Group 4
How do different organisms obtain and use energy to survive in their environment?
How is the hereditary information in genes inherited and expressed?
Group 5
How does DNA control growth and function of cells?
How do cells grow and reproduce?
Group 6

How does DNA control growth and function of cells?
How do we scientifically explain the evidence and mechanisms for biological evolution?
Group 7
How do organisms interact and depend on each other and their environment for survival?
How do different organisms obtain and use energy to survive in their environment?

Activity Day 2

10th Grade Biology students preparing for the Keystone State Test review the characteristics of life unit. Groups of 3-4 students each define and explain the 8 characteristics of life. Each student group creates a PowerPoint or Prezi teaching the 11th grade students the topic.
The group topics are:
1/ Cellular Organization
2/ Reproduction
3/ Metabolism
4/ Homeostasis
5/ Heredity
6/ Response to Stimuli
7/ Growth and Development
8/ Adaptation through Evolution.

11th Grade Chemistry students take notes as a reminder of the characteristics from the course taken in the previous year, and as a stacked scaffold towards the investigation into life beyond earth.

Activity Day 3

11th Grade Chemistry students are divided into groups to examine the categories of Extremophiles that exist on earth. Student Groups of 3-4, each investigate the environmental conditions and the living organisms that inhabit the environment. Students will then detail the specific conditions and, the necessary anatomical and physiological features, that enable extremophiles to thrive in their given environment. Each student group will create a Blog explaining the global locations where the extremophiles are found, with current updated information.

The group topics are:
1/ *Psychrophiles*
- Thrive in low temperatures below 15 Deg. C and as low as -20 Deg. C

2/ *Thermophiles*
- Thrive at high temperatures of 40 °C or higher

3/ *Radio resistant Microbes*

- Thrive in conditions of Ionizing (high energy) radiation

4/ *Alkaliphiles*

- Thrives in alkaline (high) pH value environments

5/ *Acidophiles*

- Thrive in acidic (low) pH value environments

6/ *Halophiles*

- *Thrive in high saline(salt) concentrations*

7/ *Xerophiles*

- Thrive in conditions of very low water activity

8/ *Barophiles(Piezophiles)*

- Thrive at high hydrostatic pressure

9/ *Endoliths*

- Thrive in rocks or pores between mineral grains

10/ *Toxitolerant*

- Survive and thrive in environments with high concentrations of toxins

11/ *Space Travel Survivor*

Tardigrades are currently the most recognized space survivor to date and has survived:

- Temperature ranges from zero to 150°C
- Survived space conditions resistant to radiation and pressure 2007
- Capable of losing 99% of water mass through cryptobiosis and reanimate after 10 years of desiccation.
- Macromolecule, tehalose presence in cells prevents damage from desiccation

Activity Day 4 & 5

Students share their learning with peers on the different organisms existing in each designated extreme condition. Each presenting group has 10 minutes to share the information: 7 minutes for the presentation and 3 minutes for questions and answers.

Activity Day 6

Students now have an understanding of a variety of anatomical and physiological characteristics that enable them to live through extreme conditions on earth. They will now gain an understanding of the variety of atmospheric conditions that exist on planets. The teacher will show an online presentation with information detailing the atmosphere, moons, density etc. on earth. Students are then assigned into groups each group will have

a planet to investigate. The characteristics of each planet will be compared to the atmospheric conditions on earth.
The group topics are:
Jovian Planets: Jupiter, Saturn, Uranus, Neptune
Terrestial Planets: Mercury, Venus, Mars, (Earth – Teacher)

Activity Day 7

Students work in groups of 3-4 students:
Create an extraterrestrial life form on another planet, connecting the scientific research between the organism and the environment, as if a character in a Science Fiction Movie.
Students will define

- The civilization in terms of living characteristics of the organism ecosystem, with the energy flow
- The physical and chemical needs of the organism and how the environment supports life.
- A typical "day" in the life of the organism, including length of time, seasons, threats that may exist for survival in the ecosystem.

Activity Day 8

Student groups will create a PowerPoint or Prezi presentation of their chosen planet and their Science Fiction organism. They will then construct an organism and define the environment with which it interacts to survive and perhaps thrive.

This unit focuses on a variety of scientific disciplines, and students may focus on one particular science discipline over another. Students should be prepared to defend their rationale and argument when presenting their life form and ecosystem in front of their peers. Science can be considered a practice that reconciles explanations through investigations and reflections. To learn, students will need to go through the experience of gathering pertinent information and then reapplying it to integrate and apply to create a new situation. The learning experience lends to growth and an expansive collaborative experience. Students will find at times, that gathering valid information is challenging. This is when perseverance and grit is most needed. All too often our digitally native students accustomed to a world of information at their fingertips, can easily succumb to misinformation. This unit encourages students to seek credible information, to make better decisions.

Annotated Bibliography

Reading List

Rothstein, D., & Santana, L. (2011). *Make just one change: Teach students to ask their own questions*. Cambridge, Mass: Harvard Education Press.

This is the key book that gave me the audacity to create this unit based on student driven questioning and responses.

Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional science*, *25*(3), 167-202.

In this article the authors argue that prior to technological advancements student-centered learning environments were formidable due to logistical problems. However, technology-enhanced student learning environments provide interrelated learning themes that provide for complimentary activities to address unique learning interests and needs.

Johnson, D. W., & Johnson, R. (1999). Learning together and alone: Cooperative, competitive, and individualistic learning (5th Ed.). Boston: Allyn & Bacon.

The authors in this article reinforce the interdependent learning value of collaborative groups and the roles that lead that lead towards accomplishing a common goal.

Wiggins, G. P., McTighe, J., Kiernan, L. J., Frost, F., & Association for Supervision and Curriculum Development. (1998). *Understanding by design*. Alexandria, Va: Association for Supervision and Curriculum Development.

This book cites Bloom (1956) and his creation of the taxonomy and that there are different types of understandings. He argues that knowledge and skill do not automatically lead to understanding

Myers, R. T., Oldha, K. B., & Tocci, S.(2004). Chemistry. New York: Holt, Rinehalt and Winston.

This is a high school chemistry textbook.

http://www.nap.edu/read/13165/chapter/9

The nap.edu website addresses practices, crosscutting concepts and core ideas for the K-12 science educator. It is a tool to look at grade bands and conceptual systems rooted in the physical sciences.

Teacher Resources

Neil F. Comins and William Kaufmann III (2003)., *Discovering the Universe*, sixth edition New York: W.H. Freeman and Company

This is a useful resource as an overview on contemporary cosmology for reference and background understanding.

Evans, R. (2014). The Cosmic Microwave Background. Astronomers' Universe *Cosmic Microwave Background*, 55-89.

This resource gives a detailed historical account of the contributions made by scientists and technology that enabled mankind to better understand the universe and the associated technological advancements.

http://nasawavelength.org/resourcesearch?facetSort=1&educationalLevel=High+school&page=3

The NASA website has short clips and mini-lesson resources to assist students who may need additional support and assistance with video clips and resources.

http://cosmictimes.gsfc.nasa.gov/teachers/curriculum/lessons.html

NASA Lesson Plans and teacher resources to guide and support the needs of all students beyond the activities presented in this unit.

http://www.pbs.org/wgbh/nova/education/resources/subj_02_00.html

http://www.pbs.org/wgbh/nova/education/resources/subj_12_00.html

NOVA teachers guides for additional video resources

http://static.pdesas.org/content/documents/PA%20Core%20Standards%20for%20Reading%20in%20Science%20And%20Technical%20Subjects%20March%202014.pdf

A Pennsylvania State reference tool that addresses the academic standards for reading in science and technical subjects

https://21stcenturycompetencies.wikispaces.com/file/view/Blooms%20Taxonomy%20Flip%20Chart%20for%20Student%20Use.pdf/439574600/Blooms%20Taxonomy%20Flip%20Chart%20for%20Student%20Use.pdf

A website to access the Bloom's Taxonomy Questioning tool template for student use.

Coffey, H. (n.d.). Jigsaw (Educator's guides: North Carolina digital history). Retrieved from http://www.learnnc.org/lp/editions/nchist-eg/4584#noteref5

A useful guide to review and gain ideas to modify and use the Jigsaw strategy.

Hänze, M., & Berger, R. (2007). Cooperative learning, motivational effects, and student characteristics: An experimental study comparing cooperative learning and direct instruction in 12th grade physics classes. Learning and Instruction, 17(1), 29-41. Retrieved from http://www.sciencedirect.com/science/article/pii/S0959475206001174

A valuable tool to evaluate student characteristics when using cooperative learning strategies.

Marzano, R. J., Pickering, D., & Pollock, J. E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement.* Alexandria, VA: Association for Supervision and Curriculum Development.

Marzano's strategies have always been favored in my classroom, and have proven to be effective for student gains – in my experience.

Student Resources

Evans, R. (2014). The Cosmic Microwave Background. Astronomers' Universe *Cosmic Microwave Background*, 55-89.

This is a useful resource as an overview on contemporary cosmology for reference and background understanding.

Jackson, T. (2012). The elements: An illustrated history of the Periodic table. New York: Shelter Harbor Press.

This book gives multiple views at the understanding of the periodic table and lends to interesting questioning, folklore and discussions

https://solarsystem.nasa.gov/planets/

Overview information for each of the planets can be found on this NASA site.

https://www.youtube.com/watch?v=QL1RsvR7F78

This is an introductory video for students to understand the importance of technological revelations and the search for galactic life forms.

https://www.britannica.com/science/extremophile

http://www.iflscience.com/plants-and-animals/life-extreme-environments/

http://serc.carleton.edu/microbelife/extreme/extremophiles.html

http://geoscience.wisc.edu/astrobiology/

https://nai.nasa.gov/

Extremophile information and videos that will support student needs for background and audio visuals.

https://whyy.pbslearningmedia.org/resource/nsn09.sci.ess.eiu.detectlife/detecting-life-on-other-planets/#.WUBR1BPyvow

https://whyy.pbslearningmedia.org/resource/ess05.sci.ess.eiu.carbon/ingredients-for-life-carbon/#.WUBSDBPyvow

https://whyy.pbslearningmedia.org/resource/ess05.sci.ess.eiu.water/ingredients-for-life-water/#.WUBSIxPyvow

https://whyy.pbslearningmedia.org/resource/ess05.sci.ess.eiu.planetsearch/the-search-for-another-earth/#.WUBS0xPyvow

https://whyy.pbslearningmedia.org/resource/ess05.sci.ess.eiu.jupitersrole/jupiter-earths-shield/#.WUBTDRPyvow

https://www.nasa.gov/content/goddard/nasa-research-gives-guideline-for-future-alien-life-search

http://io9.gizmodo.com/nasa-has-released-a-free-ebook-about-communicating-with-1581151218

http://www.pbs.org/wgbh/nova/space/finding-earth-planets.html

http://www.economist.com/news/science-and-technology/21718861-or-maybe-something-equally-weird-not-alive-strange-signals-sky-may

The above are selections of writings, interactives and videos by NASA and for interactives and videos in association with NOVA, with other publications that allow students to think about the tools, the importance of carbon and water for the existence of life forms.

http://www.physicsoftheuniverse.com/glossary.html

https://pics-about-space.com/jovian-planets-vs-terrestrial-planets?p=1

http://www.space.com/30372-gas-giants.html

These websites are introductory glossary of vocabulary and concept starting points for students

http://www.hippocampus.org/HippoCampus/Chemistry;jsessionid=A10D345F132F27C1A9DF8A46698E4937

http://open.umn.edu/opentextbooks/BookDetail.aspx?bookId=155

Although most of my students have a preference for audiovisual materials to access learning, these open source textbooks are options to deepen inquiry.

http://www.space.com/science-astronomy/4?type=infographic

Info graphics appear to provide context and data for further discussion, so it is a useful accompaniment

https://www.sciencedaily.com/news/space_time/nasa/
http://www.space.com/science-astronomy/5

Current space news introductory websites

http://www.elementsdatabase.com/

Any chemistry unit would be incomplete without a reference periodic table on hand.

https://www.space.com/25526-earthsize-planet-kepler-186f-habitable-infographic.html

https://www.space.com/18790-habitable-exoplanets-catalog-photos.html

A selection of infographics and information for students to consider exoplanets.

Appendix/Content Standards

21st Century Skills
Learning Skills: Global awareness, Environmental Literacy
Critical Learning and Innovation Skills: Communicate clearly, collaborate with others, creativity and innovation
Information, Media, and Technology Skills: Information Literacy, Technological Literacy
Life and Career Skills: Flexibility and adaptability, initiative and self-direction

PA Common Core Standards (http://www.pdesas.org/Standard/PACore)

PA Common Core standards are implemented by the The Philadelphia School District. The Science Curriculum integrates the English Language Arts and Mathematical skills.

Writing:

- Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
- Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
- Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
- Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
- Draw evidence from literary or informational texts to support analysis, reflection, and research.

Speaking and Listening:

- Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.
- Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

Language:

- Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when encountering an unknown term important to comprehension or expression.

Standards of Mathematical Practice:

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Construct viable arguments and critique the reasoning of others.

- Use appropriate tools strategically.

Pennsylvania Common Core State Standards http://www.pdesas.org/Standard/PACore)

CC.3.5.9-10.A. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CC.3.6.9-10.E. Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.

CC.3.6.9-10.F. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Next Generation Science Standards (http://www.nextgenscience.org/)

This unit directly addresses the following standards:

- Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, jointly developed and agreed-upon design criteria, empirical

evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and
- Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

In addition, on the topic of Reflecting on the Processes of Science and Engineering, the authors of the standards state:

> Engaging students in the practices of science and engineering outlined in this section is not sufficient for science literacy. It is also important for students to stand back and reflect on how these practices have contributed to their own development, and to the accumulation of scientific knowledge and engineering accomplishments over the ages. Accomplishing this is a matter for curriculum and instruction, rather than standards, so specific guidelines are not provided in this document. Nonetheless, this section would not be complete without an acknowledgment that reflection is essential if students are to become aware of themselves as competent and confident learners and doers in the realms of science and engineering.