AN INQUIRY-BASED APPROACH TO UNDERSTADNING SMALL BODIES IN OUR SOLAR SYSTEM

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Introduction: According to the U.S. Department of Education and the Whitehouse, in many urban areas, industry has stated that American students are not workforce ready; they do not have the skills required for many of these new and technical positions. Many of these skills do not necessarily fall under content knowledge (although science literacy is one of those), but rather 21st century skills. Five 21st century competencies stand out: problem solving/critical thinking, flexibility/creativity, teamwork/collaboration, persistence, and communication [1,2,3].

Over the past three years, two SSERVI Education/Public Engagement (EPE) teams have been actively involved in the development of a creative approach, integrating the 21st century compentencies, to delivering NASA asteroid and small bodies content to a large formal and informal education audience, including those with special needs. Our EPE program and activities being developed with SEEED at Brown/MIT and CLASS at University of Central Florida promote science, technology, engineering, arts, mathematics and design (STEAMD) literacy using the excitement generated from the success of recent exploration missions and the SSERVI team research. Project activities and materials highlight not just science, engineering, math, and technology but also how they may be infused with art and design. Examples include, but are not limited to, artistic drawings of the features and changing 'faces' or phases of the moon and morphologic interpretations based on solar incidence angle, and compositional variation.

The curricula being developed and tested incorporates effective and engaging pedagogical strategies, such as problem-based learning (PBL), design thinking, and document based questioning, using authentic data and articles, such as *Science News for Students*, based on current peer-reviewed scientific research. A curricula, such as this, provides a forum for students to apply their knowledge, curiosity, creativity, and problem solving abilities to relevant problems that have the potential to improve the way we live and how we interact with and explore in the solar system. The unit incorporates PBL, weaving in deisgn thinking, which serves as an effective means of emphasizing real-world situations in a classroom setting. Students who actively engage in PBL activities show better long-term retention of information and performance improvement [4,5]. Students engaged in PBL with design thinking, are involved in the all forms of cognitive activity from Blooms's revised taxonomy, from remembering to creating. Students are using content knowledge while also incorporating numerous 21st century skills. Students are required through this process to synthesize information from any number of sources, especially those based in scientific research. All of the materials developed are made accessible so that all audiences, specifically those with disabilities can access and explore.

Problem Based Exploration: The Small Body / Asteroid Unit under development comprises multiple lessons covering both physical and Earth sciences. Our problem based unit focuses specifically on an engineering design challenge in which students must develop a process for redirecting an asteroid, which may or may not include harvesting or mining it. Students are required to work collaboratively in teams to create a knowledge base of research, inquire and investigate phenomena that are relevant to the challenge or its criteria, and be able to think critically to solve the problem scenario presented. The scenario is being developed using multiple resources which will be presented at strategic times during the unit while students and teachers work to define the problem(s). The resources include current and historic video clips, interactive apps, news feeds, access to NASA resources, online and hard copies of scientific articles as well as a rich and diverse resource list for middle school level research. Teachers will be provided with a deeper information and resource base to further their knowledge and understanding of the physical and earth sciences as well as an in-depth guide to facilitating the engineering design process.

The content is based on the National Generation Science Standards (NGSS) for Middle School for Physical and Earth Sciences and Arts and Humaities. Standards addressed directly within the unit in the order or in connection with other standards include: *MS-PS1-2 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* – The scenario: *The World Ender*, is introduced, students investigate collisions and research impact events, asteroids, regoliths and meteorites. As they investigate collisions they will engage in MS-PS2-2 *Plan an investigation to provide evidence that the change in an objects motion depends on the sum of the forces on the object and the mass of the object (and determine the relationship: a=F/m) – teachers should facilitate, collaborate and differentiate for students as* *needed.)* Activities include reading about impact events, redirecting and mining asteroids, playing games to learn about accretion, using apps to solve newton's law problems, developing and conducting experiments and sharing information with team members as well as the broader community. Once students have grasped Newton's 1st and 2nd Laws (MS-PS2-2) they will explore *MS-ESS 1-2 Develop and use a model to describe the role of gravity in the motions within the galaxies and solar system.* Students investigate earth's gravity, explore relative size and distance and research space, orbits and galaxies before creating a model that will function to inform their team's solution to redirecting the asteroid. Activities include "Art & the Cosmic Connection" and are presented with an art challenge that will serve as one of the culminating assessments for the unit. Leading them to *MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and special scales. Activities include regolith 'space math', exploring an impact crater and introductory activities in spectroscopy (identifying rock types and exploring deep space)* which leads them into *MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. The introductory activity is exploring the question "How important is light when studying the planets?"* – How spectroscopy is used to identify minerals/compounds present in space or celestial bodies – this investigation will produce data that the students can then use to develop their model. It will be used to support their solution to redirect the asteroid.

Extension activities are included but have not been fully developed as part of the unit. Extension Mining the asteroid - *MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.* There are a set of activities that have been incorporated into the storyline as extension activities for students that wish to mine the asteroid in addition to redirecting it. The activities ensure student understanding of the difference between properties and changes, both physical and chemical, and provide extensive exploration of density, porosity and magnetism. Also included are activities that address *MS-PS1-4 Develop and use a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.* An activity specifically designed for excavation (composition, rotation, position, temperature variance etc…)

Tactile resources: In coordination with SSERVI Central and NASA Headquarters we recently published and are distributing: *Getting a Feel for Eclipses* (fig. 1) The book includes an oral guide to help the user/viewer through background information and STEM content illustrated in the tactile graphics. Access to the digital text is provided via a QR code and link to SSERVI's web site: http://sservi.nasa.gov/books/. Kinesthetic and hands-on activities associated with the book help to further explain the content shared in the tactiles. In development are three additional texts: *Catching the wave: Understanding Spectroscopy, Understanding Small Bodies in the Solar System and Ocean Worlds*. These resources will provide a unique opportunity for people with visual impairments to experience the wonder of NASA missions and SSERVI science.

Figure 1: Tribal Chief from Micronesia, who is Blind, exploring a total solar eclipse with the tactile guide with assistance from T. Cline, during the February 2016 total solar eclipse (photo: NASA GSFC Heliophysics group).

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