Getting A Feel For Other Worlds. C.J. Runyon[1], D. Hurd[2,], C. Hall[1], J. Minafra[3], K. Quinn[2] [1]College of Charleston, Charleston, SC, runyonc@cofc.edu; [2]Edinboro University, Edinboro, PA, [3]NASA SSERVI.

Introduction: For more than 50 years NASA has been collecting and returning exciting images of distant worlds in our solar system revealing interesting features and morphologies ranging from the familiar to bizarre. These resources have helped most of us to visualize, interpret and map distant planetary surfaces, leading to extraordinary discoveries. But, what about your colleague, friend or family member who is visually impaired or blind? How might these discoveries and observations be as powerful for them as it is for you? How might fellow taxpayers with disabilities have the same experiences as people without? How might they understand the differences between a small crater and a giant impact basin or between a lunar or solar eclipse?

Unfortunately, very few accessible resources related to Earth and Space Science exist for use by students and audiences with disabilities. With funding from NASA's Solar System Exploration Virtual Institute (SSERVI) we are creating and testing accessible resources, including: 1) an inquiry-based, hands-on curriculum packet and 2) tactile books and related accessible activities. To vet and share these resources we are working with teachers and administrators from the California, Florida, South Carolina and North Dakota Schools for the Blind and the National Federation of the Blind.

The World Ender Curriculum Packet 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 current news articles. This PBL forum provides students an opportunity to apply their knowledge, curiosity, creativity, and problem solving abilities to relevant problems that have the potential to improve the way we explore the solar system. The unit focuses on design thinking, which serves as an effective means of emphasizing real-world situations in a classroom setting. Students use content knowledge while also incorporating numerous 21st century skills.

The *World Ender* includes multiple lessons covering both physical Earth and Space sciences – particularly for 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 work collaboratively in teams to research and build a knowledge base, inquire and investigate phenomena that are relevant to the challenge or its criteria, and to think critically to solve the impact problem scenario. The scenario developed uses multiple resources including current and historic video clips, interactive apps, news feeds, NASA resources, online and hard copies of scientific articles and more and is based on the Next Generation Science Standards (NGSS). Teachers are provided with an in-depth guide to facilitating the engineering design process.

Through the *The World Ender* students investigate collisions and research impact events, asteroids, regolith, and meteorites. As they investigate collisions they read about historic impact events, redirecting and mining asteroids, and play games to learn about accretion using apps to solve Newton's Law problems. In addition, students develop and conduct experiments and share information with team members. Once students have grasped Newton's 1st and 2nd Laws they will explore Earth's gravity, relative size and distance and research space, orbits and galaxies before building a model that will inform their team's solution to redirecting the *"World Ender"* asteroid. Extension activities incorporated into the storyline guide the students should they choose to mine the asteroid before redirecting it. The collection of activities ensures student understanding of the difference(s) between properties and changes, both physical and chemical, and provide extensive exploration of density, porosity and magnetism.

Student assessment from initial and ongoing classroom testing of these activities indicates the students are highly engaged and are excited about creating their final models.

Tactile Resources - What and How?

Nearly 21 million people in the United States are Blind or visually impaired (B/VI). Of these, nearly 100,000 are students. To help this audience base better understand solar system concepts we are creating a series of tactile books. Although initially created to assist the B/VI audience, the books have become a helpful resource for students and audiences with different learning styles. For example, sighted tactile and kinesthetic learners report better understanding of lunar craters and the eclipse after exploring the tactile books and related online guides.

Each book is hand-made. The process starts with identifying the science content to be shared and the best illustrations to support the information within the context of the book. For each tactile graphic, a unique master is hand sculpted. We work hard to identify unique textures for the different planet surfaces and to keep them consistent through all of the books where that particular feature appeared. For example, the tex-

ture of the Sun is created using dried Spanish moss (Figure 1). Lunar surface textures are created using different grain sizes of sand and sawdust (Figure 2).

Figure 1: Tactile master graphic of the Sun created using spanish moss. Courtesy, J. Matelock

Figure 2: Tactile master of lunar nearside using sand and sawdust. Courtesy, J. Matelock

Braille labels are placed on the masters. Printed titles and text for each page is pre-printed on Braillon at a small family print shop, McCarty Printing. Once complete, the masters and Braillon are placed in a Thermoform machine, where heat and vacuum create the final book pages - one page at a time.

Why not use a 3D printer? We have been asked many times why we still use the older Thermoform process instead of the newer 3D printing technology. The answer – touch. Sensitive fingertips of the Braille readers may misinterpret the rows or layers of the 3D filament as 'data', thereby conveying false information to the 'viewer'.

Five recent books include:

- *Scale of the Solar System* is a comparative look at the size and distances between the planets in our solar system.
- *Our Place in Space* provides a more in depth look at the planets and moons in our solar system with some background information on missions
- *Getting a Feel for Lunar Craters* provides background information on the cratering process and a comparative view of different crater morphologies from simple bowl shaped craters to multi-ring basins.
- *Mars Exploration Program* provides an overview of the Mars Curiosity Rover and its mission to Gale Crater.
- *Getting a Feel for Eclipses* illustrates and describes how total solar eclipses occur. This particular book illustrated the recent 2017 All-American total solar eclipse.

Books currently in development and user testing include:

- *Ocean Worlds: The Lure of the Solar System* illustrates and describes those planetary bodies in our solar system that have or once had oceans and/or large bodies of water.
- *Understanding Small Worlds in the Solar System* is an introduction to the smaller bodies in our solar system and our current understanding of their nature and composition. Included are comets, asteroids, small moons and Pluto.
- *Catching the Wave: Remotely sensing our Solar System* explores the compositional similarities and differences in the solar system using remote sensing and sample analysis techniques.
- *Getting a Feel for Eclipses – South America* is an updated version of the August, 2017 total solar eclipse book. The 2019 and 2020 total solar eclipses will travel directly across the continent of South America. Tactile graphics will provide an illustration of the interaction and alignment of the Sun with the Moon and Earth. Associated interactive activities help to explain the nature of eclipses.

Each book includes an online guide that both leads the user/viewer through the graphics and provides background information and STEM content associated with the 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.