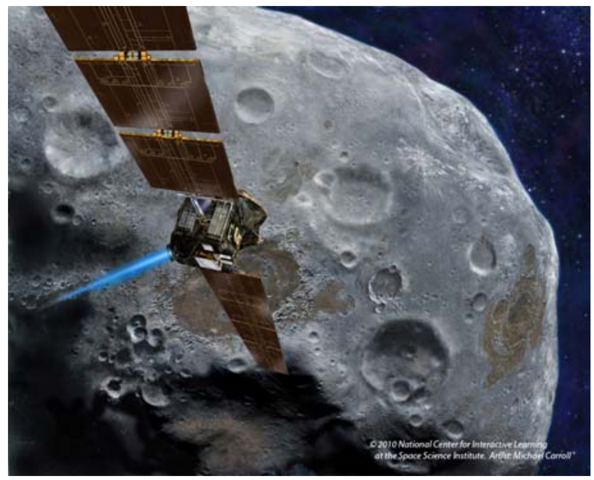
The Informal Learning Review, No. 119, 2013

Reflections on the *Asteroids* Project: Design, Implementation, and Outcomes

Paul B. Dusenbery & Sasha Palmquist

Overview



Artist's conception of the Dawn spacecraft in orbit around giant asteroid Vesta. Credit: NCIL.

On February 15, 2012 a sizable 150-foot space rock, named 2012 DA14, flew by Earth at an altitude of 17,000 miles well within geosynchronous orbit. It was traveling at a speed of about 17,000 mph. On the same day, a smaller space rock about 60 feet in diameter landed near Chelyabinsk in Russia. Its fiery and spectacular demise was caught on many dashboard and mobile cameras. It was the only meteor impact that is known to have injured people. Some news reports claimed over 1,000 people were hurt, mostly by flying glass. These recent encounters with space rocks are a reminder that our solar system is a very dynamic place. Earth has been hit many times in the past (Remember the dinosaurs?) and we will be impacted in the future. Asteroids and comets aren't just subjects for movies like *Deep Impact* or incitements to the imagination like the "comet madness" that arose with the approach of Hale-Bopp; they're also the subjects of intense scientific research. For example, NASA's Dawn spacecraft recently left orbit around a large asteroid called Vesta and is now traveling to Ceres, the largest object in the asteroid belt. The popularity of asteroids and comets among both the scientific community and public audiences provides a unique opportunity to explore STEM concepts and inspired the creation of the multi-faceted informal science education initiative: *Asteroids.*

The *Asteroids* project was designed to support public engagement and understanding of the dynamic structure of the Solar System through investigations of asteroids and comets and their relationship to Earth. The National Center for Interactive Learning (NCIL) at the Space Science Institute (SSI) developed this project in partnership with the Astronomical Society of the Pacific (ASP), New Mexico Museum of Natural History and Science (NMMNHS), the Catawba Science Center (CSC), and the Association of Science-Technology Centers (ASTC). PI Paul Dusenbery (NCIL) coordinated this NSF funded initiative and established collaborations with the NSF and NASA-funded

Finding NEO project (PI: James Harold, NCIL) and NASA's WISE, Dawn, and OSIRIS-REx missions.

The centerpiece of this project was a 3,500 sq. ft. traveling exhibition called *Great Balls of Fire: Comets, Asteroids, and Meteors*. The national tour began in May, 2011. To maximize audience reach, the project also designed and built a similar exhibit for small science centers (1,500 sq. ft.) that began its national tour in August, 2011. In partnership with the CSC in Hickory, NC, the project team developed activities for museum educators and docents as well as classroom teachers. ASP designed the *Space Rocks Toolkit* to support public outreach efforts by amateur astronomers. The activities and materials in the toolkit were developed to complement the topics featured in the traveling exhibitions. The *Finding NEO* project developed a public website, www.KillerAsteroids.org, and a small library exhibit on asteroids and asteroid research. A professional development program was conducted for the ISE community led by project partners: ASTC and the Institute for Learning Innovation (ILI). ILI also conducted the project evaluation. A programmatic website provides information about the large and small exhibits as well as the project's education and outreach programs. (www.GreatBallsOfFireExhibit.org).

While there is no single framework for exhibit design that the informal science education (ISE) community agrees upon, there are a wealth of research and evaluation studies, and reviews of exemplary exhibitions that provide insights about best practices (e.g. McLean and McEver, 2004; Falk and Storksdieck, 2005; Humphrey and Gutwill, 2005; Bell et al., 2009, Russell, 2012; and Kehl, 2013). This literature has identified several key challenges to consider when designing effective educational experiences in free-choice learning environments such as science centers, museums, zoos, and aquaria. These environments attract a wide range of audiences: intergenerational groups, families, adult and youth peer groups, and students on school trips. Visitors to exhibitions bring unique prior knowledge, interests, and motivations to these experiences (Falk and Dierking, 2000; Falk and Storksdieck, 2005). Research and evaluation studies continue to explore the complexity of informal learning environments to better understand how different factors influence intended outcomes from these experiences like: increased knowledge, interest, and engagement with particular topics. Analysis of best practices for the design of effective informal learning experiences points to the importance of implementing: 1) Iterative design process, 2) Clear goals, 3) Effective partnerships (with scientists and educators), 4) Team planning, 5) Audience research, and 6) Prototyping (Bell et. al., 2009; Kehl, 2013). This paper examines the design and development process utilized in the *Asteroids* project and considers how the SSI/NCIL model may serve as an example of the implementation of best practices.

Project Design and Development

The *Asteroids* project followed a four-phase design and development model that has been used by SSI/NCIL for a number of years to produce traveling exhibitions

(Dusenbery and McLain, 2009): Concept Planning, Design Development and Prototyping, Final Design, and Implementation/Fabrication. The SSI/NCIL model has been refined since the 1990s in partnership with Jeff Kennedy Associates (JKA). This section focuses on the first three phases of the model. The following section describes key project deliverables and evaluation highlights.

After the start of the project in September, 2008, two planning meetings were held. The first was for the core development team and focused on defining clear goals and responsibilities for each member and defining the framework for the project's logic model. The second meeting, the Kickoff, occurred in November, 2008. This meeting included the core development team, science advisors, two psychology researchers (experts in risk and decision making), educators, Jeff Kennedy Associate staff, and evaluators. The goals for this critical meeting were to 1) refine project goals, 2) define exhibit themes and possible exhibit areas, 3) understand the science and psychology related to asteroid and comet impacts, and 4) recommend several interactive experiences and their learning goals. The meeting laid the foundation for the project's Concept Plan (discussed below). Such meetings can be both inspirational and sobering because this was the first time that an external group of experts reviewed the project's "big picture" and provided critical feedback to the developers.

The outcomes from both planning meetings were very positive. The topic of asteroids and comets and their impacts had great potential to connect to people. Despite the inherent challenge of integrating multiple components (exhibits, education program, outreach program, professional development program for the ISE community, and several websites), the team was committed to achieving this goal. The project's key science advisors (Dr. Al Harris, Dr. Clark Chapman, and backyard astronomer, Brian Warner) were instrumental to the success of the project. They participated in the Kickoff meeting and continued to be involved in the project through fabrication, providing advice on the science, reviewing exhibit labels, and helping the team acquire exhibit assets (e.g. asteroid models; video of high speed projectile impacts; asteroid light curve information).

As members of a primary target audience, the *Asteroids* project recruited three groups of middle school aged students to form Student Advisory Teams (SATs) to participate in the project's development phase. SATs were uniquely qualified to advise the project team about their impressions of components and what they found interesting and compelling. The SATs were located in three states: Colorado, New Mexico, and North Carolina. The Colorado team was sponsored by St. Vrain MESA (Mathematics, Engineering, Science, Achievement), an after-school program that met at Sunset Middle School in Longmont. NMMNHS hosted a team in Albuquerque, New Mexico and CSC hosted a team in Hickory, North Carolina. The

The New Mexico SAT. Credit: NMMNHS.

design and implementation of the SAT program was grounded in existing research and best practices for successful youth programs in out of school settings (Koke & Deirking, 2007; Bell et. al., 2009; Dussault, 2009).

The North Carolina SAT. Credit: Catawba Science Center

Beginning in 7th grade and continuing through the end of their 8th grade school year, SATs participated in a variety of experiences related to the project's space science content, scientific practice, the design development process, and the evaluation of exhibit components. In addition, each team created a project deliverable focused on a relevant space science topic that allowed them to work through an authentic design, development, and fabrication process. The team anticipated that keeping the SAT youth engaged for over a year would be a major challenge. To address this, each partner site developed a program experience that included: hands-on activities, field trips, in-person meetings with local space scientists, and virtual seminars with project science advisors. The relatively low participant attrition was a testament to the quality of the adult program leaders and the characteristics of the SAT program experience that they designed and implemented.

The Colorado SAT. Credit: Steve Davis

The project team next turned its attention to producing the most important document for any large and complex education program like the one described here – a Concept Plan. Similar to a strategic plan for an organization, the key elements of the concept plan were to define the Big Idea (Serrell, 1996), establish the scope and nature of exhibit content, develop an underlying organizational approach indicating how selected content could be organized effectively into thematic areas, and delineate an approach to the visitor experience designed to engage and inspire target audiences. The plan provided a blueprint for the integration of all project components and also included the findings from the front-end evaluation.

ILI researchers collaborated with the project team to design and conduct front-end evaluation that measured public audience knowledge of the structure of the Solar System, features and characteristics of asteroids and comets, as well as familiarity with the tools, processes, and evidence that scientists use to study the Solar System. Two primary studies were conducted as part of the audience research component of this phase of the project. The first study was a questionnaire completed by SAT members. The second study was an interview completed by museum visitors at the CSC to further explore the knowledge, understanding and mental models of the Solar System held by the target audiences (middle school aged youth, families, and adults). Taken together, these studies helped to establish a baseline for subsequent measures of change related to increased knowledge and positive attitudes about science as well as development of scientific skills and habits of mind.

According to Serrell (1996), a Big Idea statement clarifies, limits, and focuses the nature and scope of an exhibition and provides a well-defined goal against which to measure its success. The team drew on examples of successful Big Idea statements from other projects as inspiration. The Big Idea statement that was agreed upon after several iterations was:

> *Asteroids and comets are messengers from space that have had a significant effect on Earth's history and are likely to influence the future as well.*

With a Big Idea statement, key topics, and a preliminary inventory of activities in hand, the team was able to move forward with the principal task of the Concept Phase, development of the exhibition's thematic framework and content organization. The exhibit areas that finally emerged during the conceptual planning process were the following: 1) Origins of Asteroids and Comets, 2) The Story of Asteroids, 3) The Story of Comets, and 4) The Story of Impacts. Six high level content learning goals were then selected (e.g. Comets and asteroids are part of the Solar System and have very similar origins dating back to its formation). These goals were the key messages that visitors should take away from their experience with the exhibition.

Visitors at the prototyping event in New Mexico. Credit: NCIL

As part of the Design Development phase of the *Great Balls of Fire* exhibit, thirteen prototyped activities were developed to form a "mini-exhibition". NCIL staff, project scientists, and the exhibit designers worked in close collaboration to prepare these activities. During the fabrication process, JKA tested most of these components informally with s mall groups of subjects and revised them based on this feedback, so that activities were quite mature already when installed at NMMNHS for formative testing by ILI in January 2010. A smaller scale prototyping event was also held at CSC in North Carolina. SAT members from both groups participated in the formative testing. They were trained to conduct focused observations of specific components and their data was a tremendous help in refining a number of the exhibit components. Following formative testing, we were ready for the Final Design and Fabrication phases which involved hiring a text writer (Jennifer Chapman), an AV producer (Cortina Productions), and a fabrication firm (Kubik Malbie). JKA produced the final design documents and Kubik Maltbie began to fabricate the large and small exhibits. During this period (late 2010 and early 2011), other team members were busy finalizing their deliverables. The following section describes the deliverables that emerged from the design/development/ fabrication process and evaluation highlights.

Project Deliverables and Findings

Key deliverables for the *Asteroids* project included a traveling exhibit program, a national outreach program targeting amateur astronomers, and in-person and online professional development workshops for the ISE community. Below is a description of each deliverable and selected evaluation findings

Traveling exhibits and Evaluation Highlights

Visitors at the GBoF exhibit in Richmond, VA. Credit: NCIL

The large (3,500 sq. ft.) and small (1,500 sq. ft.) exhibits, both named *Great Balls of Fire: Comets, Asteroids, and Meteors,* have been on tour since mid-2011. The large exhibit has been hosted by the Science Museum of Virginia, Strategic Air and Space Museum, Catawba Science Center, and is currently at the Reuben H. Fleet Science Center. The small exhibit has been hosted by Tyler Junior College Planetarium, Columbia Memorial Space Center, and is currently at Flandrau Science Center and Planetarium. Both exhibits include *Comet and Asteroid Quest* (see photo), an immersive, multimedia component that allows visitors to explore the solar system in search of asteroids and comets. Other components include *Science Fact or Fiction*, in which visitors compare Hollywood science with reality; the *Itokawa Asteroid Model*, an accurate depiction of the asteroid with a scale model of the Hayabusa spacecraft that landed on it; *What If It Hit My Town*, an interactive that lets visitors explore the impact areas from large or small asteroid and comet collisions; and *Is It a Rock or a Meteorite?* in which visitors use various tests to determine if a rock sample is a meteorite. A much smaller exhibit was also developed for public libraries as part of the *Finding NEO* project. It includes a pop-up banner and two computer kiosks with games (*Rubble Pile* and *What If It Hit My Town*), as well as a video about amateur astronomers who are tracking asteroids.

Two approaches were used to measure the visitor experience and outcomes associated with *GBoF:* Timing & tracking observations and exit interviews. *Great Balls of Fire* had a sweep rate index of 171—lower than the typical museum exhibition. This indicated that visitors to GBoF spent a longer duration of time per square foot of exhibition floor space. Data collected through observations and interviews indicated that visitors found

GBoF to be a positive experience. Children and teens especially seemed interested and excited about exhibit elements suggesting that the exhibition succeeded in serving the target audience. Visitors to the exhibition were able to describe characteristics of comets, asteroids, and meteors as well as the potential risks and implications of Earth impacts. Following their experiences in the exhibition, visitors commented on asteroid and comet composition, temperature, size, shape, movement, and location in the Solar System. Respondents also indicated an increased awareness of the relationships between Earth and space rocks, citing meteor showers and the abundance of asteroids recently discovered by scientists. Finally, experiences in the exhibition seemed to increase awareness of the range of tools, methods, and strategies that scientists use to study space objects.

Visitors at the GBoF exhibit in Richmond, VA. Credit: NCIL

Space Rocks Toolkit and Evaluation Highlights

ASP developed the *Space Rocks Toolkit* for use by amateur astronomers. *Space Rocks* was designed and developed through an established, iterative process that included two phases of implementation, feedback, and revision (e.g. alpha and beta testing). *Space Rocks* was released in November 2010. The completed toolkit was distributed through the ASP's Night Sky Network—an online community of practice with approximately 900 members. The toolkit included a range of hands on activities focused on comets, asteroids, and meteors; the dynamics of the asteroid belt; the origins and movement of comets; the past impacts on Earth of our rocky neighbors, and the risk, probability, and implications of future Earth impacts. In addition, kits also included DVDs that provided information and resources as well as demonstrations of how to conduct the activities. ASP distributed 173 kits to amateur astronomy clubs nationwide, which have been used in 1,118 outreach events reaching over 152,000 people.

Evaluation of the *Space Rocks Kits* utilized an online database where members of the Night Sky Network can record and share details of the events they offer to their local communities. Analysis revealed that kit activities were most frequently used at star parties (53%), classroom presentations (21%) and community events (8%) like science festivals. In addition, evaluation suggested that the kits were most frequently used to support events focused on: asteroids and meteors (70% of events); the moon (57% of events) and telescopes, comets, and size/scale concepts (40% of events). The frequency of *Space Rocks* activity use continues to increase suggesting that these are some of the most popular learning experiences offered by the ASP.

Professional Development and Evaluation Highlights

Making comets at an educator workshop in Richmond, VA. Credit: NCIL

The *Asteroids* project used several strategies to provide professional development opportunities to the ISE community. Project team members conducted in-person professional development workshops for informal science educators, teachers, and museum docents at the Denver Museum of Nature and Science and the Science Museum of Virginia. These professional development workshops were half-day training opportunities. A virtual workshop was also conducted for educators at the Columbia Memorial Space Center. Post-workshop online surveys, review of implementation artifacts (agendas, slides, activity training materials), and personal communications with workshop facilitators were used to measure the impact of these experiences. Analysis indicated that workshops increased educators' familiarity with the available resources and enabled them to be used with both visitor and student populations.

Another strategy was to work through existing professional development mechanisms coordinated by our ASTC project partners. Several ASTC annual meeting sessions were conducted on the role of youth in developing informal education programs. In addition in September 2011, an ASTC Connect Forum was conducted for informal science educators. The forum discussion developed as a way to address one of the aims of the *Asteroids* project: to provide informal science educators with a professional development opportunity to increase science communication skills, practices, and resources. The topic for the discussion was chosen based on the *Asteroid* Team's experience in creating programs with youth through the SAT program.

The online *Expanding Roles for Youth in Informal Learning Experiences ASTC Connect* forum served 110 participants. Over half of the respondents (58%) identified as educators, 42% as evaluators, and 22% as researchers. Approximately one-third (30%) of the respondents identified with more than one category. Analysis of an online survey revealed that participants enjoyed learning from other professionals and gained a greater understanding of the challenges and opportunities of youth programming. Participants indicated that after they had engaged in this session they had also improved their ability to articulate and measure the impact of youth programming—critical communication skills. In addition, reflections on case studies and conversations with colleagues provided opportunities to refine practice around youth programming. Analysis also suggested that providing several different types of resources was an effective strategy to increase the utilization of these materials.

Conclusions

Visitors at the small GBoF exhibit in Los Angeles, CA. Credit: NCIL

The evaluation findings suggest that the *Asteroids* project ac hieved many of its target impacts and has been well received by public and professional audiences. Managing this multi-faceted education initiative required the consistent application of best practices for effective design and collaboration. In addition to in-person plan ning meetings at the beginning of the project, the team held monthly "progress report" telecons that helped to keep our complex set of deliverables on track. One of the strengths of how the SSI/NCIL model was applied to this project was the ability for the team to communicate about lessons learned during the design, prototyping, and formative evaluation phases. These discussions informed evidence based decisions that shaped the final deliverables of the project. For example, in the original proposal, the project intended to create a primary exhibition and four small exhibit components (SECs). Project partners anticipated using the SECs to engage a broader range of audiences with STEM learning experiences by placing them in community settings, small science centers, and public libraries. It quickly became apparent that multiple organizations managing multiple tours would be impossible to sustain especially after the grant period ended. In order to reach more communities, we decided to build both a large exhibit and a small version that would be managed by NCIL alone. The success of the *Asteroids* project provides an example of how the application of the SSI/NCIL model facilitated the project team's ability to consistently use design and development best practices from concept planning through implementation.

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Authors

Paul Dusenbery is the Executive Director of the Space Science Institute (SSI) and the Director of SSI's National Center for Interactive Learning. He was the PI for the NSF-funded *Asteroids* project (DRL-0813528). He may be reached at dusenbery@spacescience.org.

Sasha Palmquist is a learning sciences researcher and professional evaluator of informal learning experiences. She was the lead evaluator of the *Asteroids* project and is currently the Principal of Palmquist & Associates, LLC a research and evaluation consultancy in Washington, D.C. She may be reached at s.palmquist@gmail.com.