IBEX Education and Public Outreach

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Abstract The IBEX mission includes a comprehensive Education and Public Outreach (E/PO) program that develops programs and products in exciting themes from astronomy and space physics. With the active involvement of the Principal Investigator and several science team partners, it is overseen and implemented by the Adler Planetarium & Astronomy Museum. The program includes an internationally distributed planetarium show with accompanying informal education materials that are also accessible to individuals with special needs; a national Space Science Core Curriculum for grades 6–8 in collaboration with other NASA missions; a professional development program for teachers; and workshops that engage Hispanic and Native American students. Materials are made available for download or for order via the IBEX website: http://www.ibex.swri.edu/. Our program is developed, implemented and monitored for effectiveness by organizations with proven capabilities and

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experience in their respective areas of E/PO. This paper describes these program elements in detail and includes the rationale and design process for this E/PO program.

**Keywords** GEMS • Space Education • Teaching • Curriculum • Education and Public Outreach • EPO • STEM • Astronomy Education • Planetarium • LASSO • Teacher Workshop • LANL CSSE • Interactivities • TimeSpace • Adler • Lawrence Hall of Science • Science Literacy • Space Science Sequences

1 Overview

The Interstellar Boundary Explorer (IBEX) is a Small Explorer (SMEX) mission that launched October 19, 2008, SMEX missions are cost-capped, relatively inexpensive missions with focused science goals. IBEX is a remarkable mission of exploration and discovery that provides the first global images of the interstellar boundaries and unveils the physics of the heliosphere’s interstellar interaction. This investigation fills in the critical missing piece for understanding the connection of our Sun and solar system to the Galaxy, fulfills requirements from recent NASA and National Academy plans, makes fascinating connections to astrophysical phenomena, and addresses a serious challenge facing manned exploration by studying the region that shields out the vast majority of galactic cosmic ray radiation. This breakthrough mission is achieved with an innovative mission design using a simple, high heritage science payload and spacecraft described in the other chapters of this volume. The single, focused objective of IBEX is to discover the global interaction between the solar wind and the interstellar medium.

The Education and Public Outreach (E/PO) program is an integral part of the IBEX mission. It supports NASA’s strategic coordination framework, is designed to inspire the next generation of explorers in science and technology, and will engage the public in the excitement of innovative research. As a mission of exploration and discovery, the IBEX mission and E/PO program will provide the public with never before seen views of the boundary of the solar system.

The IBEX E/PO Program was designed using the process described below which has resulted in the following program elements: an internationally distributed planetarium show with accompanying informal education materials that are also accessible to individuals with special needs; a national Space Science Core Curriculum for grades 6–8 in collaboration with other NASA missions; a professional development program for teachers; and robotics workshops that engage Hispanic and Native American students. Materials are made available for download or for order via the IBEX website (http://www.ibex.swri.edu), which also contains games and information about the mission including monthly feature articles on team members.

2 Education and Public Outreach Design

Designing for Education and Public Outreach is similar in many ways to designing a scientific investigation. Just as scientists follow a process of inquiry into a scientific concept, E/PO professionals also follow a process to discover effective methods for teaching concepts. The steps may not always occur in the same order, but in general, research is done into the established knowledge base of the field, a general research question is formulated, hypotheses are created, and then the strategic design process begins. A scientific experiment
and E/PO program both begin with the creation of goals and requirements. Then the designers determine what evidence they need to discern if they have achieved those goals. Next, they develop a way to collect that evidence by designing a tool or technique. Various designs are prototyped, tested, revised and tested again. Ultimately, the designed tools or techniques are used to gather evidence that supports or changes an existing model of either a scientific concept or teaching method.

2.1 History and Informative Resources

Ever since humans have looked to the skies, they have been discussing and teaching each other about what they have learned. Although astronomy education has been around for a very long time, “the astronomy education and public outreach profession is [finally] coming into existence” (Freknov 2005, p. 19). Astronomy E/PO has borrowed largely from the field of science education and even more specifically from physics education research, however journals and general communications between practitioners in this emerging field have only recently become established.

One of the greatest challenges of E/PO professionals, and science educators in general, is understanding the needs of their targeted learners. Human beings are constantly constructing ways of making sense of the world around them. Sometimes their ideas about the world fit in with the current scientific understanding, but many times they do not. Researching these misconceptions and approaches for constructing ideas better aligned with current scientific thinking is part of what E/PO professionals must do as they design programs. Misconception research has been published in a number of different journals including, for example, the online journal The Astronomy Education Review (AER 2001), which provides an excellent source of information for E/PO programs.

Education and Public Outreach professionals also draw upon guiding documents for science education such as the National Science Education Standards (National Research Council 1996), the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy (AAAS 1993) and the Project 2061 Atlas of Science Literacy Vols. 1 and 2 (Project 2061, 2001 and 2007). These publications outline standards for education as well as detailing concepts that should be taught at various ages. The Atlas contains concept maps that break down science concepts into components, and links the components together. In addition, it highlights misconception research relevant to the concepts.

The design of E/PO programs is often done following an approach described by Wiggins and McTighe in Understanding by Design (2005). In this approach, the designers of an educational experience must first determine the most essential part of a concept that a participant should retain 5-10 years after an experience. In other words, what is the core idea that should stick with a participant, regardless of how they use the information in their life? The next step is to figure out how an educator will know if their participants have grasped this concept; how will participants provide evidence that they understand the concept? After that, an assessment is designed to provide the structure for collecting the evidence about participant understanding. Finally, the activity that helps the participant achieve that understanding is designed. When the activity is prototyped with a group of participants, evaluation is conducted to determine if the participants can produce evidence that they understand the concept. If not, the educational designer needs to go back to the activity to redesign or modify the approach.

A large number of E/PO professionals are involved with NASA’s Science Mission Directorate E/PO Program, set in motion by NASA’s commitment to education, which started with the 1958 Space Act. Since many E/PO professionals are designing programs that are
smaller components of the larger educational portfolio, NASA has compiled a number of documents describing E/PO history, how to become involved, resources, evaluation factors and evaluation reports of Science Mission Directorate efforts in E/PO. These documents are available at NASA's "Education and Public Outreach—Science Mission Directorate" webpage, [http://nasascience.nasa.gov/researchers/education-public-outreach](http://nasascience.nasa.gov/researchers/education-public-outreach) (NASA 2008a).

2.2 Designing the IBEX E/PO

The Adler Planetarium & Astronomy Museum joined the IBEX mission as the E/PO Lead institution during our initial proposal phase and has been leading this component of the mission ever since. We assembled a team of scientists and educators to help design our E/PO program. Collectively, we used our knowledge and expertise in astronomy education to create a proposal for the E/PO activities that brought together a national team of experts in program evaluation, curriculum design, professional development, electronic communications and educational design for individuals with special needs. Preliminary research assessed the existing programs and needs of target audiences that relate to the science and engineering of the IBEX mission, as well as the goals of NASA's overarching E/PO program. The results were used to create a program that was positioned to be exciting, useful and distinctive.

The following sections describe the purpose and goals of IBEX's E/PO program and the program elements that have been designed to achieve them. For those efforts that are already underway, more description of the formative evaluation and details are available than for other activities that are scheduled to begin later in the mission.

2.2.1 Purpose and Goals of the E/PO Program

The purpose of the IBEX E/PO program is to inspire the next generation of explorers by highlighting the exploration and discovery aspects of the IBEX mission and offering broad educational and societal benefits beyond the scientific opportunities provided by imaging the global interaction between the solar wind and the interstellar medium.

The goals of the Interstellar Boundary Explorer E/PO are to:

- Communicate the scientific goals and results of the IBEX mission to the public in various locations and formats in ways that make the science, technology, engineering and math relevant to the learner.
- Address the needs of students/individuals with learning disabilities.
- Involve minority communities in our educational efforts.
- Conduct educational research about the public understanding of the boundaries of the Solar System, existence and behavior of charged particles, and mixing of fluids.
- Contribute to educational endeavors of NASA's Science Mission Directorate E/PO Initiatives.

A number of program elements have been chosen to help a national audience achieve the goals of the IBEX E/PO Program. Those program elements include:

- Create and widely distribute a planetarium show that communicates the scientific goals and results of IBEX to the public and shares with them the excitement of this Explorer mission.
- Create educational products and demonstrations to be distributed with the show, including interactive software for use on electronic kiosks.
- Partner with the Special Needs Working Group (SNWG) and the International Dyslexia Association (IDA) to create educational products accessible to individuals with special needs; specifically dyslexia, visual-impairment and hearing-impairment.
• Produce and distribute Spanish language versions of our educational products and interactive software for teachers and students.

• Collaborate with Los Alamos National Labs Center for Space Science Exploration (LANL_CSE) staff to sustain and improve the Los Alamos Space Science Outreach (LASSO) teacher workshop, which targets teachers of Hispanic and Native American students in New Mexico and is now being expanded to include teachers of Hispanic students nationally and involve students in Science, Technology, Engineering and Mathematics (STEM) improvement robotics workshops.

• Collaborate with Lawrence Hall of Science and Great Explorations in Math and Science (GEMS) to create and fund the Space Science Core Curriculum Sequence for grades 6-8 based on National Science Education Standards.

• Create and maintain an educational website, which allows access to electronic versions of the educational products that we produce and distribution of products that cannot be downloaded.

• Determine the needs of our audiences and assess and evaluate the success of our program to address those needs.

• Ensure close alignment with NASA’s educational endeavors by working closely with NASA’s Science Mission Directorate E/PO Initiatives.

All of the goals and program elements have different sets of audiences and partners. These relationships are detailed in Fig. 1. The purple section in the top left describes top level NASA goals and shows that NASA Space Science Advisory Committee E/PO Task Force Recommendations (SScAC E/PO T/F Recms, NASA 2003) influenced the choice of IBEX E/PO goals (shown in yellow). The alignment between program elements and IBEX E/PO goals are shown with green squares. The deeper green squares (core) show a goal that is achieved by participation in one program element while the lighter green squares (supporting) contribute to the achievement of a goal but do not achieve them on their own. The orange thematic strands show how topics in IBEX E/PO content are spread through the program elements. Different program elements concentrate on different science content aspects of the mission. Some of these choices are made due to the timing of their creation and availability of IBEX data, for example the planetarium show will not help audiences to understand IBEX data because it is completed before IBEX data is released.

IBEX E/PO received 2% of the overall mission budget (excluding launch vehicle). Ten percent of that is dedicated for evaluation, and the program elements’ total cost in descending order are: GEMS Space Science Curriculum, IBEX planetarium show, LASSO professional development program, educational products, website, and other program costs. At the time of publication of this paper, some program elements have been completed (for example, the GEMS Space Science Core Curriculum and the IBEX: Search for the Edge of the Solar System planetarium show) while others are still in the very early stages of development (materials for people with special needs and LASSO professional development program). The section lengths in this paper reflect both the total costs and completeness of the program elements.

2.2.2 E/PO Program Alignment

As part of NASA’s education efforts, the IBEX E/PO program is designed to reflect recommendations of SScAC Task Force and with the Office of Space Science (OSS) Education Strategy and Implementation Plan. In addition, the E/PO team is involved with annual conferences and retreats in an effort to navigate NASA’s changing education infrastructure. The
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**Fig. 1** IBEX EPO overview table
Fig 2  Schematic of pyramid structure for IBEX E/PO program elements

current plan aligns with the document from Headquarters: NASA Education Strategic Coordination Framework: A Portfolio Approach (NASA 2007).

NASA's Education Office has the lead role in accomplishing the goal to "inspire and motivate students to pursue careers in science, technology, engineering, and mathematics" (STEM) and a strong supporting role in achieving the goal to "engage the public in shaping and sharing the experience of exploration and discovery." Special attention is paid to under-represented and under-served communities, in order to fill the "pipeline" with students throughout their education, who will then be well prepared to seek STEM careers, helping our nation to meet its workforce needs through the 21st century.

The IBEX E/PO program is aligned with these goals, and supports a suite of formal and informal educational and public outreach program elements that are specifically targeted at under-represented and under-served populations on all scales.

As shown in Fig. 2, IBEX E/PO program elements follow a "pyramid structure," with the program elements at the peak directly supporting STEM training, while those at the base are aimed at improving the science literacy of the general public. The peak elements focus on smaller groups of students through formal or informal settings, while the base elements reach a wide-spread audience that numbers in the millions.

3 Program Elements

3.1 Evaluation and Educational Research

Early in the E/PO program, the E/PO team met with the researcher from Program Evaluation and Research Group (PERG) at Lesley University to determine the scope of program evaluation that would take place over the life of the mission. Both parties agreed that the first step should be to conduct a needs assessment evaluation to determine what the audiences of IBEX’s E/PO programs knew and were interested in about the science of the IBEX mission. Since a large portion of the activities were going to take place in an informal setting, PERG conducted a front-end evaluation, interviewing 90 visitors at 3 science museums about their
knowledge of the Solar System, the Sun, and states of matter (including plasma), as well as their interest in unmanned space science missions and the people who work on them. Below are some interesting points summarized from the data. Due to the nature of the study, these results may be used to estimate the density of positive attitudes towards and knowledge of IBEX specific science topics in a population similar to the sample used for analysis. In this case, the sample consisted of science museum visitors who were willing to complete a survey. Their responses are likely representative of science museum visitors, and possibly the science-attentive public. They are unlikely to represent general public, many of whom do not visit science museums. For these reasons, the following study results were primarily used for developing the planetarium shows and supporting materials, the bulk of which will be distributed through informal science institutions.

- Data indicate that the Sun and the planets are the most salient features of the Solar System.
- About one-third of our respondents think the Solar System has a boundary; data suggest that people believe the boundary is defined by the Sun’s gravitational pull.
- More than one-half of the respondents believe that the Solar System contains stars, constellations, or galaxies.
- Most respondents know basic information about the Sun; they are aware that it is a hot star, the largest object in the Solar System, with a gravitational pull that keeps the Earth in orbit, and that without the Sun, there would be no life on Earth.
- Data indicate that there is interest in the life cycle of the Sun; in particular, participants expressed curiosity about whether and when the Sun would die, and how that would affect life on Earth.
- Data indicate that there is a wide range of understanding about states of matter and atoms. In particular, our participants expressed confusion about what happens when an atom loses electrons; many indicated that they believe this to be fission and that it would cause an explosion.
- While most of our participants were familiar with the term “plasma,” few had an understanding of it as an energized state of matter; many identified it with blood or television.
- In general, our participants are concerned about danger and safety. They believe that ionization is dangerous and are concerned with whether plasma is dangerous.
- Participants expressed interest in the engineering aspects of NASA missions, including spacecraft, robotics, communication with land-based teams, and repairs of unmanned ships.
- Participants also expressed interest in why NASA chooses certain missions, why people work in the field, and the types of scientific questions answered by NASA missions.
- Participants expressed less interest in the people working on missions than in the missions’ details or the scientific knowledge gleaned from the missions.
- Participants indicated that they believe scientists’ and engineers’ intelligence and thought processes were different from their own.

Our E/PO team discussed the findings from the full report (Gutbezahl 2006) with the PERG team and used this information in preparing many of the activities described below.

The E/PO team also formed a plan for formative and summative evaluation with the PERG team. This plan includes focus groups and surveys on the TimeSpace planetarium show module, focus groups and surveys for the full-length planetarium show, focus groups (including groups of differently-abled users) for the website, rapid prototyping of educational products, observation and impact evaluation for teacher and student workshops at LANL and a summative evaluation of the entire program. Currently, unpublished memos and reports from the front-end evaluation, module focus groups and surveys, and full show focus groups and survey are available by contacting the IBEX E/PO Lead.
3.2 Planetarium Module and Full Show

The show production process began with the creation of an IBEX themed module that integrated into Adler’s existing Digistar 3 planetarium show called TimeSpace. The TimeSpace show is an imaginative trip through space and time with several “stops” along the way. An extra “stop” 500 years in the future at the boundary of our Solar System was added to the already existing show in August of 2006. In the 5 minute module, the crew of a fictitious craft at the boundary of the Solar System celebrates the historic IBEX mission of 2008-9, which created the first maps of the boundary region allowing eventual travel to the boundary region and beyond. That module was used as a prototype for audience focus groups and surveys, which helped determine the content of our full-length production.

The full-length show, Search for the Edge of the Solar System, concentrates on the science of the Solar System boundary, how the IBEX mission explores the boundary, and the international team that works together to create and support the mission. The show begins as an electronic chat between two teens wondering where the Solar System ends. They do a search and discover information about the boundary region and the IBEX mission to study it. High quality video, interviews with team members, and full dome animation are incorporated into the show to help tell the story. Adler worked with the National Center for Supercomputing Applications at the University of Illinois, Urbana-Champaign to create visual representations of the Universe including the motion of stars through the Milky Way Galaxy.

As part of the full-length show production process, an ‘animatic,’ which consists of still pictures and simple narration, was created. This animatic was shown to focus groups of high school students. Data from the focus groups was quite consistent. Participants found the show engaging and entertaining. Some participants were confused by the content, and would have liked more context for some of the ideas. They had several specific suggestions, which were taken into account when Adler staff revised the narration and visuals.

After the full-length show was almost complete in December 2008, it was shown in two formats, to small groups in a mini-dome and in a large theater. The small groups participated in focus groups, and the participants in the larger theater completed survey questions. The intent of this work was primarily to test the ability of the show to meet the following educational outcomes:

1. After viewing the show, participants would KNOW that:
   - There is only one star inside our Solar System.
   - The Solar System has boundaries.
   - One boundary is created by an interaction between charged particles coming from the Sun and the stuff that surrounds the Solar System.
   - The boundary changes as the Sun moves through the galaxy.
   - This boundary is invisible, but detectable by using specially designed tools.
   - The IBEX mission is investigating the boundary.
   - The Solar System boundary protects us from damaging rays.
   - NASA missions are complex, involving many diverse people, skills, and technologies from around the world.

2. Participants would UNDERSTAND the following concepts:
   - The Solar System has boundaries and components that are affected by forces inside and outside the boundaries.
   - IBEX is exploring the boundary.
   - “It takes a team” to explore.
3. **Participants are able to answer these ESSENTIAL QUESTIONS:**

- Does the Solar System have a boundary? What is it like?
- If the boundary changes, how will that affect the Earth/me?
- How can we investigate an invisible boundary?
- What skills/traits/jobs are necessary to complete a mission?

4. **Participants would be able to demonstrate their ability to DO the following:**

- State the Solar System has a boundary that contains only one Star.
- Describe how the boundary is created.
- Explain how IBEX will explore that boundary.
- List at least one way the boundary or changing boundary affects them.
- Express positive reactions about exploration of space.
- Name at least one occupation/skill associated with unmanned space missions.
- Express interest in learning more about the IBEX mission or science.

Results from the draft report include that after viewing the show, 91% of the participants answered correctly that the purpose of the IBEX mission is to investigate the boundary of the Solar System, 98% understood that the boundary is invisible to the naked eye and 97% responded that IBEX is collecting particles.

The front-end evaluation (Gutbechtal 2006) revealed another very interesting result: that “More than one half of the respondents believe that the solar system contains stars, constellations or galaxies.” After viewing the show, participants were asked in a full-show survey, “How many stars does our Solar System contain?” and 75% answered correctly “one” on the open-ended question. We consider this to be a huge improvement on what can be a deeply held misconception about the organization of the Universe.

Adler has partnered with specialists to produce the show in other formats including digital portable dome format. The show will be translated into Spanish and will be closed captioned for the hearing impaired. Dome-masters for this show are available for the cost of shipping and handling, and a trailer can be viewed at [http://ibex.swri.edu/planetaria/index.shtml](http://ibex.swri.edu/planetaria/index.shtml). The IBEX show premiered March 2009 and is also now available to other planetaria.

### 3.3 Educational Products

Adler leads the design and content creation of several IBEX themed educational products, which include museum floor demonstration resources, educational posters/postcards for families, electronic materials for individuals with dyslexia, and tactile products for individuals with visual impairments. The educational content for the products is chosen using the results from the front end evaluation, conducted by PERG and the ability of these new resources to fill a hole in existing NASA educational material portfolios. The products are submitted to NASA's Science Mission Directorate education product review and communication review prior to production. Currently, eleven products have been prototyped and submitted for NASA review and more are in development. These approved products are available in print and as electronic copies at the IBEX website [http://ibex.swri.edu/planetaria/index.shtml](http://ibex.swri.edu/planetaria/index.shtml). Some of the current products include two posters, one lithograph, several floor demonstrations and activities, and two tactile diagrams with audio walkthrough. More products will be produced after launch and data release, describing the scientific results and discoveries of the IBEX mission.
3.4 Website

Adler has created and maintains an educational website where people can learn about the mission. It provides access to electronic versions of the educational products and distribution of products that cannot be downloaded. The address for the website is http://ibex.swri.edu (IBEX 2008). All sections of the website are section 508 compliant and accessible to screenreading software applications. The IBEX website contains separate sections for students, educators, museums and researchers. The IBEX website will be mirrored in Spanish.

The IBEX web team produces interactive online activities that allow visitors to explore IBEX mission and science related content. So far, three animations/interactives have been created. An interactive timeline allows visitors to click through a timeline to view images relating to various mission milestones. The second interactive allows students to explore how adding energy to a substance changes the state of matter between solid, liquid, gas and plasma. The third interactive addresses a common educational misconception that the “Universe” is a jumble of objects with no organization or structure. This interactive takes advantage of the focus of the IBEX mission, the boundary region of the Solar System to help users “sort out” objects into realms of the Universe, for example objects that belong inside and outside of the Heliosphere.

Monthly highlights feature different individuals that work on the IBEX mission in order to describe the different types of jobs, preparations and backgrounds needed to make a mission successful. The highlights are emailed monthly to subscribers, and people wishing to subscribe can do so through the website. The website also contains information and links for researchers and IBEX team members. The website has had over 30,000 unique visitors over the past 3 years.

In addition to the main IBEX website, there are also IBEX pages on the NASA Portal, Facebook.com, and twitter.com.

3.5 GEMS Space Science Sequences

3.5.1 Introduction

The Space Science Sequences are two sets of curricula for grades 3-5 and 6-8 developed at Lawrence Hall of Science in partnership with NASA educational public outreach efforts. NASA partners included:

- IBEX Mission Education and Public Outreach,
- Kepler Mission Education and Public Outreach,
- Origins Education Forum/Hubble Space Telescope,
- Solar System Education Forum,
- Sun-Earth Connection Education Forum.

The Lawrence Hall of Science is a science and math education center at the University of California in Berkeley. It includes a hands-on museum and an interactive planetarium that serve schools and the general public, and is the home of many curriculum projects. One of these projects is Great Explorations in Math and Science (GEMS), which developed the Space Science Sequences, http://www.lhsgems.org/CurriculumSequences.htm. Since 1986 GEMS has developed supplemental math and science activities in units that require two to twelve sessions to teach in a school classroom. Many of these activities originated in programs that have been taught in the instructional labs and the planetarium at Lawrence Hall for many years. Great Explorations in Math and Science materials are known for their
teacher-friendly instructions, use of simple materials, and extensive testing that insures that GEMS activities will be successful educational experiences in school classrooms.

Astronomical content has been included in GEMS materials from the very beginning, but formal collaboration with NASA did not begin until 1999 when GEMS developed *The Real Reasons for Seasons* with NASA’s Sun-Earth Connection Educational Forum. Other successful collaborations followed, which resulted in the units *Living With a Star*, and *Invisible Universe*. With these and other GEMS units already developed it became apparent that GEMS units were not simply useful as an add-on to an astronomy curriculum, but that they could become a curriculum in their own right. Because GEMS units were originally designed to be supplemental activities, the process of creating a coherent sequence with comprehensive treatment of core concepts involved much more than simply concatenating the materials that were already developed.

### 3.5.2 Determining the Scope and Format of the Space Science Sequences

Teachers spend varying amounts of their classroom time on space science depending on their state standards and also on their own interests. The Space Science Sequences had to be devised to accommodate teachers who have no special interest in astronomy, but need to teach some basic required topics. A survey of teachers in the GEMS Network revealed that almost any school could realistically spend six weeks of its science time on space science during grades 3–5, and six more weeks during grades 6–8.

Having limited ourselves to six weeks of instruction for each sequence, we had to narrow the scope of topics so that each one we addressed could be taught effectively. This led to some hard choices, especially when it came to eliminating some well-loved topics such as constellations, astrobiology, and space travel. Choices were made based on the following:

- **Common misconceptions.**

  Astronomy educators are very familiar with inaccurate ideas people hold about reasons for phases of the Moon, why the Earth has seasons, and how the Solar System and the Universe are structured. The Space Science Sequences address these and other misunderstood topics in depth.

- **Space science research of the present and near future.**

  Space science is not simply a set of known facts and explanations. The partnership with NASA helped us to incorporate current questions and research into the Space Science Sequences. For example, students investigate how extra-solar planets could be discovered in the manner of the Kepler mission, and they read about the IBEX mission’s exploration of the boundary of the heliosphere.

- **State and National Standards.**

  There is wide variation in state standards, but we were able to apply the trends in standards to our curriculum design. For example, many state standards place understanding of phases of the Moon in the elementary grades. For this reason, we placed it in the sequence for grades 3–5 rather than in the middle school sequence, where it could also have been effectively addressed.

- **Other requirements for basic space science literacy.**

  The structure of the Universe beyond the Solar System does not appear in most education standards until high school, if at all. NASA partners and developers at GEMS agreed that
there is a place for this topic in a basic middle school astronomy curriculum. One reason is the high level of student interest and the flood of exciting new knowledge and ongoing research in this topic. Another reason is that instruction about the larger Universe supports learning about the more close-to-home topics, such as the structure of the Solar System, which is part of many middle school standards.

Each sequence has four units, with each unit focusing on an important topic over several class sessions.

**Space Science Sequence for grades 3–5,**

- Unit 1 How Big and How Far
- Unit 2 Earth's Shape and Gravity.
- Unit 3 How does the Earth Move?
- Unit 4 Moon Phases and Eclipses.

**Space Science Sequence for grades 6–8,**

- Unit 1 How Does the Sun Affect the Earth?
- Unit 2 Why Are There Seasons?
- Unit 3 The Solar System.
- Unit 4 Beyond the Solar System.

Each unit within a sequence can be taught by itself, although ideas build through the units. This gives schools options for flexible implementation. All units in a sequence can be taught in the same grade, or the units can be spread out over the grade range for which the sequence was designed.

### 3.5.3 Development and Testing the Space Science Sequence for Grades 6–8

In October, 2003 NASA partners met in one group for the first time with GEMS staff at Lawrence Hall of Science to begin development of the Space Science Sequences. The overarching topics and the basic structure were decided upon fairly quickly. The fleshing out of a “concept storyline” that would be the foundation for the actual curriculum was a process that involved many more meetings over the next two years.

We began the process by using the principles of “backward design.” This term, coined by Wiggins and McTighe in Understanding by Design (2005), describes a process wherein the goals of instruction are defined, then the assessments, and finally the methods of instruction. In their previous development of *The Real Reasons for Seasons*, GEMS had successfully tailored instruction to an assessment questionnaire, and we decided to pursue a similar strategy with the development of the Space Science Sequences. Having developed a list of key concepts for each unit, we developed assessment questionnaires for each unit. In practice we did not apply the principles of backward design rigidly. At various stages during actual development and testing we revised our key concepts and our assessments, making the process more iterative, rather than strictly backward design.

The pilot outlines of the 6–8 Space Science Sequence were tested in local schools by the GEMS staff. Activities were modified or discarded according to the success of the pilot tests. Trial versions of the four units were written for teachers across the country to test. Each unit was tested by 14 to 23 teachers. Feedback surveys from teachers and the results of the pre- and post-assessment questionnaires from students were analyzed. In general, the results showed that instruction was sound, but there were logistical concerns about timing and material management that make a great difference to teachers. Some activities were simplified, reordered, or rewritten to extend over more class sessions. In one case, a key activity was changed so much that we chose to have local teachers retest it in their classrooms before we wrote the final version.
3.5.4 Features of the Space Science Sequence For Grades 6–8

Assessment  Each unit includes a brief pre- and post-questionnaire meant to measure student understanding of the overarching ideas of the units. They include a mixture of multiple choice and open ended questions. These questionnaires are not simply assessments for the teacher—they are learning tools for the students as well. As each unit progresses students are asked to reflect back on their answers to the pre-questionnaire and to consider whether and why their understanding has changed.

Figure 3 shows an example of an item from the questionnaire for Unit 4, Beyond the Solar System.

What is the order of these things from smallest to largest?

The Universe.
The Sun.
The Milky Way Galaxy.
The Solar System.
The Earth.

Within each unit there are multiple opportunities for assessment as students proceed through the activities. Rubrics are provided in the 6–8 Sequence for teachers to gauge students’ learning. At critical junctures the Sequence provides extra activities for the students that a teacher can use if formative assessments indicate that students need more instruction before proceeding to other topics in the unit.

Focus on Scientific Models  Students learn that scientists use models to understand, explain, and make predictions. Models presented in the 6–8 Sequence show scale, structure, and change over time in various astronomical systems. With each model that the students are involved with, they are invited to explore what is accurate and what is inaccurate, and how the models could be improved.

![Graph showing percent identified as smallest, 4th largest, etc.](image)

**Fig 3** GEMS field test data

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Focus on Evidence and Discourse  In each unit students have a chance to apply evidence from readings, research, and classroom activities and observations, to make a case for or against a statement or explanation. In Unit 2, Why are There Seasons?, they use scale models and data about temperatures and day-length around the world to discuss whether seasons are caused by the Earth’s distance from the Sun. The evidence is against it, therefore in this case the discourse steers them toward an important explanation for seasons. In Unit 4, Beyond the Solar System, students discuss the probability of extra-terrestrial life, and whether and how there could be communication. In this case the discourse allows them to synthesize and apply what they have learned about the scale and structure of the Universe and the nature of stars and planetary systems.

Key Concepts and the Concept Wall  Learning goals in the 6–8 Sequence are made explicit to students as the units progress. Key concepts are written out and posted for each session, building a wall of ideas about science content and the nature of science.

CD ROM  The 6–8 Sequence comes with a CD ROM that gives the teacher alternative means of presentation as well as additional activities and resources. Many activities have group or class versions on the CD. For example, students explore models of the tilted Earth revolving around the Sun using spheres and light bulbs. The CD has an interactive computer model that students can explore individually or that the teacher can project for students to examine as a class to supplement their classroom experience. Field tests of the units in the 6–8 Sequence were conducted with and without the CD, and the results showed the CD made differences in student learning.

Educative Teacher Guide  The teacher guide format allows teachers to easily access material that will help and inform their teaching. On each spread the left page has the instructions for presenting the activities, and the right page has “teacher considerations,” which includes a variety of material. Rubrics for assessment, relevant science content, classroom management suggestions, alternative and supplementary activities, and general teaching strategies are all laid out on an as-you-need-it basis alongside the step-by-step instructions for the activities. Each unit also has a science background section with material that goes beyond the scope of the units to help teachers comfortably address student questions.

3.5.5 Dissemination of the Space Science Sequences

A GEMS Network has been established to support educators who use GEMS materials. Sites and centers in the GEMS Network are run by school districts, universities, and science centers to provide professional development and material support to teachers. The success of this network model has led us to start a similar network specifically for the Space Science Sequences. With the support of a NASA Shared Services Award to UC Berkeley’s Space Sciences Lab and Lawrence Hall of Science, a project called Advancing Teacher Leaders in Space Science (ATLSS) was initiated in 2008. Four ATLSS sites for the 3–5 Sequence and four sites for the 6–8 Sequence have been selected for training and other professional support for educators.

3.6 LASSO Teacher and Student Workshops

Los Alamos National Laboratory Center for Space Science Exploration (LANLCSSE) will engage master teachers in sustained learning activities directly tied to IBEX thus supporting
improved science, math, and technology content knowledge as well as life-long learning process skills. The Los Alamos Space Science Outreach (LASSO) science education effort adheres to an effective instructional model based on education research and cognitive theory. During the program, teachers will critically investigate projects through the examination of basic and advanced science concepts behind the project goals. The teachers will incorporate what they learn into standards-based lessons and activities that will be featured on the IBEX website. The student robotics workshops, also sponsored by LANLCSSE, will bring the excitement and education of engineering design to area schools.

3.7 Collaborative Programs

In order to ensure close alignment with NASA’s educational endeavors, the IBEX E/PO team works closely with NASA’s Science Mission Directorate (SMD) E/PO Initiatives. The E/PO Lead participates in monthly telecons and occasional meetings of collaborating SMD E/POs. IBEX contributes to the collective efforts of Heliophysics mission E/POs, such as Sun-Earth Day and International Year of Astronomy (IYA) 2009. Specifically, IBEX E/PO contributes to a number of NASA IYA presentations at national and regional conferences. IBEX is collaborating with several Heliophysics missions which received funding during their senior review process. The resulting program is called Heliophysics Educator Ambassadors and will train educator ambassadors to teach other teachers and their own students about Heliophysics. The first workshop is scheduled for summer of 2009 in Alaska. IBEX plans to make use of available NASA infrastructure to disseminate products, especially the Museum Alliance, and NASA's IYA website, http://astronomy2009.nasa.gov/ (NASA 2008b). IBEX is working together with the Heliophysics Forum to revise the "Sun-Earth Viewer" to include appropriate IBEX related resources.

4 Conclusion

A carefully designed Education and Public Outreach program can meet the needs of the critical stakeholders by leveraging diverse partnerships. Education and Public Outreach programs must be designed with evaluation as a key component in order to maximize and measure effectiveness. The IBEX E/PO program was designed with these principles in mind and will contribute significantly to the overall success of the NASA mission.

References


Project 2061, Atlas of Science Literacy (American Association for the Advancement of Science and National Science Teachers Association, Washington, 2001)

