Space Sci Rev (2008) 141: 557–583
DOI 10.1007/s11214-008-9458-5

The Time History of Events and Macroscale Interactions during Substorms (THEMIS) Education and Outreach (E/PO) Program

L.M. Peticolas · N. Craig · S.F. Odenwald · A. Walker · C.T. Russell · V. Angelopoulos · C. Willard · M.B. Larson · W.A. Hiscock · J.M. Stoke · M.B. Moldwin

Received: 20 May 2008 / Accepted: 20 October 2008 / Published online: 10 December 2008

Abstract During the pre-launch phase of NASA's THEMIS mission, the Education and Public Outreach (E/PO) program successfully brought the excitement of THEMIS to the public, students and teachers through a variety of programs. The Geomagnetic Event Observation Network by Students (GEONS) was the main effort during this time, a project in which 13 magnetometers were placed in or near 13 rural schools across the country. High school teachers and a few middle school teachers at these and/or neighboring schools took part in a long-term professional development program based around space science and the

J.M. Stoke was previously at Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA.

L.M. Peticolas (✉) · N. Craig
Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA
e-mail: laura@ssl.berkeley.edu

S.F. Odenwald
Catholic University of America, Washington D.C., 20064, USA

A. Walker
Cornerstone Evaluation Associates LLC, 205 Peddler Place, Pittsburgh, PA 15212, USA

C.T. Russell · V. Angelopoulos · M.B. Moldwin
Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095, USA

C. Willard
Lawrence Hall of Science, University of California, Berkeley, CA 94720-5200, USA

M.B. Larson
Utah State University, 1435 Old Main Hill, Logan, UT 84322, USA

W.A. Hiscock
Montana Space Grant Consortium, Montana State University, 416 Cobleigh Hall, Bozeman, MT 59717-3835, USA

J.M. Stoke
North American ALMA Science Center, National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA

magnetometer data. The teachers created week-long to semester-long projects during which their students worked on THEMIS lessons that they, their colleagues, and the E/PO team created. In addition to this program, THEMIS E/PO also launched the only Lawrence Hall of Science (LHS) Great Explorations in Mathematics and Science (GEMS) site in Nevada. This site provides a sustainable place for teacher professional development using hands-on GEMS activities, and has been used by teachers around the state of Nevada. Short-term professional development for K-12 teachers (one-hour to two-day workshops), with a focus on the Tribal College and Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) communities have reached hundreds of teachers across the country. A Space Telescope Science Institute (STScI) ViewSpace show on auroras and THEMIS was created and distributed, and shown in over a hundred science centers and museums nationwide. The THEMIS E/PO program developed and maintained a THEMIS E/PO Website for dissemination of (1) information and multimedia about the science and engineering of THEMIS, (2) updated news about the mission in language appropriate for the public, (3) the GEONS data, the GEONS teacher guides with classroom activities, and (4) information about the THEMIS E/PO program. Hundreds of thousands of visitors have viewed this website. In this paper, we describe these programs along with the evaluation results, and discuss what lessons we learned along the way.

Keywords Education · Outreach · Earth's Magnetosphere · Aurora · Magnetometer

PACS 01.00.00 · 01.30.la · 01.30.lb · 01.30.Os · 01.40.-d · 01.40.Di · 01.40.E- · 01.40.ek · 01.40.G- · 01.40.gb · 01.40.J- · 01.40.jh · 01.50.-i · 01.50.F- · 01.50.H- · 94.05.-a · 94.05.Sd

1 Introduction

While the five THEMIS spacecraft (probes) and instruments were being built and tested for launch and operation, the THEMIS Education and Public Outreach (E/PO) program was creating opportunities for students, teachers, and the public at large to learn about magnetic fields, electromagnetism, Earth's magnetism, auroras, substorms, solar storms, and the THEMIS mission itself. This article describes these *pre-launch E/PO activities* as part of the topical issue of Space Sciences Review describing the THEMIS Mission and Science, of which E/PO is a component. Reflecting on these activities, we hope to (1) provide science educators with ideas for ways to incorporate research and data into the classroom, (2) share some of the evaluation results of our programs from which space scientists and future E/PO professionals can learn, (3) provide scientists who have not participated in E/PO activities with an understanding of E/PO, and (4) let space scientists and E/PO professionals know what E/PO resources are available from the THEMIS mission. Of particular emphasis is our magnetometer-in-the-classroom program. This paper provides guidance for the success of similar efforts placing magnetometers at schools. Note that due to the large number of acronyms throughout the paper, we have created an acronym list in Appendix, which may be helpful when reading this paper.

1.1 Education and Public Outreach at NASA

The THEMIS E/PO program was funded as part of the NASA requirement that each satellite mission use a small percentage (around 1%) of the mission budget, excluding launch costs, for E/PO projects. For more on the history of this requirement, as well as a discussion on the

general need in the U.S. of training more scientists and engineers, and the benefit of having education programs tied directly to science and engineering programs, see Peticolas et al. (2007) and Rosendhal et al. (2004).

During the early phases of THEMIS, the E/PO program was a part of a "White Paper" review of NASA education programs to "(1) Obtain a much more in-depth understanding of the quality of a subset of NASA Education Programs than was done during the 2003 Program Reviews; and (2) Test out a revised set of review procedures designed to examine programs both in more depth and in a more consistent way than has been done in the past" (Naik et al. 2004). THEMIS E/PO and the Mars Public Engagement were the two programs under NASA's then-called "Office of Space Science" (OSS) to be reviewed. The THEMIS E/PO was rated "Very Good" on all the review criteria: Customer Focus, Partnerships/Leverage/Sustainability, Evaluation, Content, Pipeline, and Diversity. Peticolas et al. (2007) discuss the meaning behind the 2006 NASA OSS E/PO proposal review criteria, which were the same as these 2004 criteria.

The review panel found that small programs that focused on doing a few things very well tended to suffer in the review process. There needs to be a way to review such programs that takes into account the size and cost of a program. The review panel also found that "with one or two exceptions, evaluation was a striking weakness in most programs" (Naik et al. 2004). Since THEMIS E/PO rated "Very Good" on these criteria, it is clear that it was one of these positive exceptions. Throughout the descriptions of the THEMIS programs in this paper, we include evaluation results of our programs.

Since this white-paper review in 2004, several new discussions about education have taken place at NASA. This resulted in attempts to gather data from all the education programs and use them to assess NASA's impact on educating students, teachers, and the public in science, technology, engineering, and mathematics (STEM) fields. As this NASA self-review of its educational programs continues, we hope that this paper provides some insight for scientists and E/PO professionals into (1) what is needed to create and sustain a successful NASA education program and (2) what influences these types of programs can have on teachers and their students.

1.2 Goals and Overview of the THEMIS E/PO Program

The THEMIS mission will determine the onset time and location of magnetic substorms in Earth's space environment. Its science is the science of auroras, Earth's magnetosphere, and sudden energy release in the form of plasma and electromagnetic fields. This energy release causes spectacular motions of auroras filling the night skies in the high latitudes of the northern and southern hemispheres. The THEMIS team, recognizing our country's need for improved STEM education (National Center for Education Statistics 2003), proposed a nation-wide partnership with science centers, K-14 educators, professional science organizations, and mission scientists to implement a comprehensive Education and Public Outreach (E/PO) program. The main goals for this program were to:

- Share the excitement of real-time measurements with science teachers and their students;
- Develop appropriate physical science and Earth and space science lesson plans that would be used in classrooms nationwide, adhere to appropriate grade-levels and National Science Education Standards (NSES), incorporate THEMIS data, and provide background content for teachers on the THEMIS magnetometers and mission;
- Share the awe of auroral substorms and the mystery of the trigger for the dynamical displays with the museum-going public around the country;

- Share THEMIS discoveries with teachers, students, and the general public through well-developed E/PO web pages;
- Share THEMIS science in the context of other NASA missions such as IMAGE, FAST, STEREO, and RHESSI;
- Motivate scientists involvement in E/PO;
- Use existing infrastructure in order to leverage THEMIS E/PO activities and to avoid duplication of effort;
- Partner with Tribal Colleges, schools on tribal lands, and the Society for Advancement of Chicanos and Native Americans in Science (SACNAS) to reach minority and underserved groups; and
- Provide teachers across the country with professional development opportunities to learn more about auroras and solar storms, and take appropriate lessons back to their classroom.

We have met all of these goals through five main projects:

1. The Geomagnetic Event Observation Network by Students (GEONS) in which 13 magnetometers are placed in or near 13 rural schools across the country. The primarily high-school teachers at these and/or neighboring schools take part in long-term professional development around space science and the magnetometer data. They can use their experience to inspire their students to learn about Earth's magnetic field and its changes related to substorm activity;
2. Launch of a new Lawrence Hall of Science (LHS) Great Explorations in Mathematics and Science (GEMS) site in Nevada to provide a sustainable teacher professional development site using the hands-on GEMS activities for elementary and middle school students;
3. Short-term professional development for K-12 teachers (1-hour to 2-day workshops), with a focus on the Tribal College and SACNAS communities;
4. Creation and dissemination of a Space Telescope Science Institute (STScI) ViewSpace show on auroras and THEMIS for the public and informal education venues;
5. Development and maintenance of a THEMIS E/PO Website for dissemination of (i) information and multimedia about the science and engineering of THEMIS, (ii) updated news about the mission in the language appropriate for the public, (iii) the GEONS data, the GEONS teacher guides with classroom activities, and (iv) information about the THEMIS E/PO program.

In addition to these five main programs, THEMIS has supported scientist and engineer visits to the classroom and the public relations efforts at NASA's Goddard Space Flight Center. In this paper we will describe all of these efforts, what was involved in starting the projects, what we learned along the way, and how we envision the future of these projects, in hopes of offering best practices and lessons learned to other scientists and E/PO professionals seeking effective programs.

1.3 Introduction to THEMIS E/PO Evaluation

The THEMIS E/PO partnerships, methods, activities, and visibility have been monitored and evaluated by Cornerstone Evaluation Associates (CEA), an established independent evaluation group with experience in evaluating the development of science learning resources and the use of technology in science education. CEA has assessed the effectiveness of the THEMIS E/PO effort as two major thrusts—(1) **Formative**—the documentation of partners' views of the strengths, weaknesses and necessary *improvements* of their programmatic

contributions, and (2) **Summative**—assistance to partners in gathering outcomes data to measure program impact.

In addition to CEA's evaluation and assessments, all THEMIS E/PO products are submitted to NASA's education review. Summaries or highlights from many evaluations are included throughout this paper. For more details on the evaluation, please refer to the evaluation reports that CEA has written and NASA product reviews, which can be found from the THEMIS E/PO web site under "About Us" (see Sect. 4). Because at the time of writing this paper, the THEMIS E/PO program is still in progress, the overall summative report has not been completed. We anticipate this report being completed by August, 2009.

2 THEMIS in the Classroom: Formal Education

As mentioned in Sect. 1.2, there are several ways in which we have aimed to bring THEMIS successfully into the classroom, increasing teachers' understanding of magnetism, aurora substorms, and solar storms, as well as helping them to bring this content knowledge and excitement about the THEMIS mission to their students. In this section, we first discuss the THEMIS project that has spent the most time and resources on several dedicated teachers in rural and underserved regions with the goal of ultimately creating a long-term, in-depth and sustainable program for high school teachers (and others). Because this has been the "flagship" of the THEMIS E/PO program, most of this paper is dedicated to it. Next we discuss the THEMIS project that leverages an existing teacher professional development network of math and science teachers around an already-established curriculum mostly for elementary and middle school teachers. The remaining two aspects of the THEMIS E/PO follow: short-term teacher professional development workshops and scientists/engineers involvement in the classroom.

2.1 GEONS Program

The nature of the THEMIS science investigation, in particular the correlation of ground-based measurements of auroral activity with spacecraft-based measurements of changes in the magnetosphere, holds tremendous potential for inquiry-based instruction of pre-college students and teachers. In recognition of this, THEMIS E/PO has established thirteen ground-based magnetometer stations, each located in the proximity of a rural school in traditionally under-served, under-represented communities. These thirteen sites are located in the following ten states: Alaska, Oregon, Nevada, North Dakota, South Dakota, Montana, Wisconsin, Michigan, Pennsylvania, and Vermont, as shown in Fig. 1. Two schools are located in Michigan and three schools in Alaska. The two most northern Alaska sites also have all-sky cameras to observe the auroras in white light. A teacher at each of these schools is responsible for their magnetometer data and system as well as using the resulting data with their students through lesson plans that the THEMIS E/PO team and some of the teachers have developed. Table 1 provides the name of the schools, the location of the schools, and the local teachers who have been intimately involved in the project.

We provide yearly professional development opportunities for these teachers to help them understand the science of THEMIS and introduce new or modified classroom lessons around the science and the magnetometer data. The magnetometer data are located on the THEMIS E/PO website so teachers and students all across the country can take part in the program and schools can compare their data with those of other schools. The network of the 13 teachers, students, and magnetometers, together with other teachers and students who participate, is called the Geomagnetic Event Observation Network by Students (GEONS).

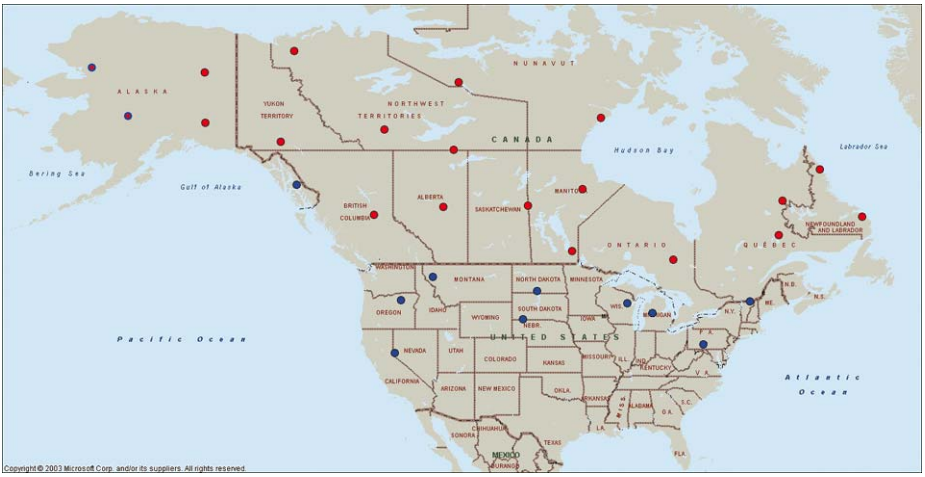

Fig. 1 Location of the GEONS magnetometers and schools are marked as *blue dots* and *dots* with *blue circles*. The *red dots* indicate the ground-based observatories (GBOs), which are part of the THEMIS science mission (Russell et al. 2008 and Mende et al. 2008). The *red dots* with *blue circles* are GBOs at schools and thus part of our E/PO program

Table 1 Name(s) of the school(s) involved in the GEONS project, location of the schools and magnetometers, and name(s) of the teacher(s) intimately involved in the GEONS project either presently or in the past

School(s)	City, State	Educator(s) *(past and present)*
Kiana School	Kiana, AK	Glenn Miller
McGrath School	McGrath, AK	Ray Benson
Petersburg City School	Petersburg, AK	Victor Trautman
Bay Mills Community College	Brimley, MI	Robert Dickinson, Michael Doyle
Standing Rock Public School	Fort Yates, ND	Harriet Howe, Frank Martin
Shawano Community High School	Shawano, WI	Wendy Esch
North Country Union Jr High School	Derby, VT	Holly Wyllie
Maine School of Science & Mathematics		Manju Prakash
Hot Springs High School	Hot Springs, MT	Sean Estil
Chippewa Hills High School	Remus, MI	Cris DeWolf
Red Cloud High School	Pine Ridge, SD	Wendell Gehman
Ukiah School	Ukiah, OR	Laura Orr
N. Bedford County High School	Loysburg, PA	Keith Little
Western Nevada Community College	Carson City, NV	Robert Collier
Carson City Middle School		Terry Parent
Carson City High School		Jim Bean

For scientists and E/PO professionals interested in finding schools to work with, we describe how the different magnetometer sites were chosen. We chose the Carson City, NV site to connect the magnetometer project with the THEMIS E/PO LHS GEMS site launch

program. The coordinators of this program helped identify the community college as a good location and brought in the local middle and high school to participate in the program.

The NASA's Office of Space Science Support Network (Cooper et al. 2004) in Boston selected the magnetometer site in Vermont. This school was a NASA Explorers School (Ruberg et al. 2007).

A magnetometer site in each of eight states were identified by statewide competitions run by the Space Grant Consortia of Montana working with the Space Grant Consortia of seven other states—AK, OR, ND, SD, WI, MI, and PA. The selection criteria were (1) commitment of the school/teacher and availability of local infrastructure, (2) demonstrable advancements to the education process at the particular school with particular consideration towards reaching underserved students, (3) the potential for reaching a large community of students and teachers, and (4) the site's potential for science discoveries, based on its geographic location within the state, that may result in stronger interactions with the THEMIS research team. At all the sites, we required that the school's administration, either a superintendent or principal, support the project to ensure sustainability of the project. Eight of twenty-four schools/teachers were selected.

Two additional magnetometer sites in Alaska were chosen as part of the science ground-based observatory (GBO) network with magnetometers and all-sky cameras across Alaska and Canada (Russell et al. 2008; Mende et al. 2008). For these two sites, the science team selected the region of Alaska appropriate for these observatories and then approached area schools where there might be teachers and school administrators interested in taking part in the project. The Space Grant in AK helped to find these schools as well, though they were not part of the initial E/PO competition because the idea of placing these observatories in schools came about after the competition.

The thirteenth magnetometer site came about through a separate proposal process. The THEMIS E/PO team worked with the Bay Mills Community College, a tribal community college in Brimley, MI, on a proposal to do teacher professional development for 2005 and 2006 on the THEMIS and GLOBE projects. This proposal was funded through the Earth Explorers: SPHERE (Students as Professionals Helping Educators Research the Earth), with one of its goals to support undergraduate research participation especially Minority Serving Institutions (MSIs) in NASA Earth Science. This grant included the installation of another THEMIS magnetometer. Drs. Craig, Peticolas, and Odenwald, as well as GEONS teacher Cris DeWolf from Remus, MI, were presenters of the THEMIS program, science, and student activities. This collaboration increased the number of magnetometers in the GEONS program from 12 to 13. In addition to this site, four other THEMIS schools are on tribal lands: two in AK, and one in each of the states SD, ND, and MT.

From evaluation results from questionnaires and interviews discussed below in Sect. 2.1.2, we collected information on the demographics of many of these teachers. We learned about their school environment:

- Most GEONS teachers work at rural schools.
- The majority of schools in which GEONS teachers work are middle and high schools.
- The average number of students in GEONS schools is slightly over 600.
- The average number of faculty in GEONS schools is slightly under 40.
- On average, half of their students are female, with class composition ranging from 30% to 65% females.
- More than three-fifths (61%) of their classes are comprised of minority students—both male and female—ranging from 2% to 100% minorities.

We learned about the teachers' educational backgrounds, teaching experience and current teaching circumstances:

Table 2 Percentages of teachers offering various reasons for becoming involved with the THEMIS project

Motivation for Involvement with THEMIS Project	Teachers ($N = 9$)
Students—Opportunity to motivate and/or involve students in 'real science'; share materials with students—Saw this as a great opportunity to motivate students; the opportunity to share this material with my students was too good to pass up; the students get to be involved in real data/research . . . good stuff!	67%
Personal—Interest in astronomy/space science/THEMIS project—Always have been into space science; the subjects THEMIS covers are some of my favorites; astronomy interest; general interest in project itself	44
Personal—Opportunity to learn—The opportunity to learn; great opportunity to re-energized my enthusiasm for teaching	22
Personal—Opportunity to work with NASA/globally significant project—The opportunity to work with NASA in a research capacity; opportunity to involve students in actual research and fact gathering that has global implications was simply too awesome to pass up	22
Discussions/sharing with colleagues—Talking to fellow teachers; opportunity to share this material with other teachers	22

- Nearly all GEONS teachers have undergraduate degrees in the sciences, but only a few with physics degrees.
- The majority of GEONS teachers have science degrees beyond their bachelors degree.
- The average GEONS teacher has almost 17 years of teaching experience.
- All GEONS teachers are teaching at the middle and high school level.

We also learned *why* the teachers wanted to participate in this program. This is useful to know in developing future education programs. Nine teacher's responses are presented in Table 2. Nine teachers responded giving multiple responses, thus percentages sum to greater than 100%.

Placing magnetometers in or near schools and ensuring that the real-time data and archived data were available on a student-friendly website required additional support of several engineers and a system administrator. This needs to be factored in for any other educational programs bringing data to the classroom. Don Dearborn (UCLA—University of California, Los Angeles) was in charge of most of the magnetometer installations and took the opportunity to explain in person to local students and teachers about the THEMIS mission and how the magnetometer worked. This was an important way of connecting with the teachers and students at the schools at a personal level while also setting up the scientific instrumentation. At most schools, students helped Don Dearborn to dig the trench and hole for the magnetometer cable and sensor

We found quickly, that even though these schools are in rural communities, there were locations where the magnetometers could not be placed due to either high magnetic noise levels or Internet restrictions imposed by the school system. In these cases, the magnetometers were placed at nearby elementary schools or, in one case, at the superintendent's home. The teachers or administrators at the magnetometer sites have been instrumental in keeping the magnetometers running and sending data. More about the installations and workings of the magnetometers, as well as what has been required to keep the magnetometers running, can be found in Russell et al. (2008).

In order to engage students successfully with these data, one requirement was that students could be able to access the real-time data on-line in a student-friendly manner. Moreover, we soon realized that the archived data needed to be available as well, because times of

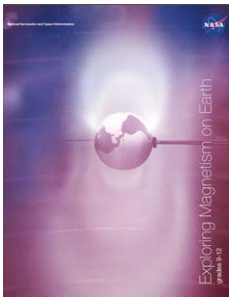

Fig. 2 Cover of "Exploring Magnetism on Earth"

active aurora occur when school is out. David Pierce (UCLA), Igor Ruderman (UCB—the University of California, Berkeley), and Tim Quinn (UCB) were instrumental in supporting this aspect of the GEONS project. The three types of data products produced are: the vector magnetic field—B_x, B_y, B_z (approximately geomagnetic coordinates); B_H, B_D, and B_{tot} (horizontal, declination, and total magnetic field); and power spectrograms of the magnetic field fluctuations. The teachers and students were most excited about the spectrograms because of the colors. But because spectrograms are not part of the local science education standards and because they are too complex for a high school level of science, these data have only been used as an indication of magnetic activity in a general sense. The B_x, B_y, B_z plots are used most frequently in the classrooms, in order to calculate local magnetic indices and to examine the total magnetic field variations over several months or even a year.

2.1.1 GEONS Teacher Guides

This GEONS project provides students and teachers with project-based activities that support access to real scientific data and at times inquiry, an important focus of the National Science Education Standards (NSES). We developed, in consultation with THEMIS Principal Investigator, THEMIS scientists, GEONS teachers, and existing technical magnetometer user manuals: (1) a ground magnetometer and background science "user manual" appropriate for high school teachers, (2) nationally-tested inquiry-based lesson plans in four theme-based teacher guides, and (3) learning materials on how to further utilize the magnetometer data to enhance classroom instruction in space science concepts. The teacher guides are titled: "Magnetism and Electromagnetism," "Exploring Magnetism on Earth," "Space Weather," and "Earth's Magnetic Personality." Figure 2 shows the cover of "Exploring Magnetism on Earth." The lesson plans within these guides include topics such as: ***Forces and Motion, Magnetic Induction, the Geomagnetic Field, Solar Storms and Space Weather and Data Analysis of the Magnetic Field Data.*** Teachers developed lessons for their students using the magnetometer data that went beyond the lessons in the fourth teacher guide, which contains all the lessons using data.

THEMIS utilizes this approach to introduce grade 8–12 students to themes of fundamental importance, such as space weather and its effects on the habitability of the near-Earth environment, on satellite communications, and on electrical power distribution on Earth. The THEMIS E/PO grade 8–14 module development leverages the resources from the Center for Science Education (CSE) at UCB and avoided duplication of products by coordinating with the existing IMAGE, FAST, STEREO/IMPACT, Science Education Gateway (SEGway), and selected theme-related Sun-Earth Connection Education Forum (SECEF) EP/O resources.

As any curriculum designer knows, creating teacher guides in such a way as to ensure they will be scientifically correct, useful, and well-employed is a challenge and can take

years of testing and revisions and creating the THEMIS guides was no exception. Working closely with the teachers on these lessons and evaluating the lessons helped immensely with this process. As described below in Sect. 2.1.2, CEA interviewed the teachers in 2006. CEA dedicated a large portion of this interview to gathering feedback about the classroom lessons after the teachers had a chance to use actually them in the classroom. The feedback showed us that many lessons then needed to be altered to make them more effective to use with students. In two lessons, we found we needed to develop our own website with aurora and magnetospheric information rather than having the students go to non-THEMIS websites, because navigating through the other websites was too tedious for them and thus detracted from the goals of the lesson. Comments and feedback from these interviews about the use of the lessons in particular types of classes (astronomy, geology, physics) spurred the decision to break the one teacher's guide into four teacher's guide that still built on one another, but could also be used as stand-alone teacher guides. See the full report on the THEMIS E/PO website for more information about the teachers' feedback. Many curriculum designers use such evaluation techniques and we strongly recommend this for scientists or E/PO professionals new to creating lessons who cannot afford to work with curriculum designers directly.

After an initial successful summer (2006) with one teacher doing research with the magnetometer data for use in his classroom, in summer 2007, we increased the number of teachers to four whom we paid a stipend to do research with the data and produce lessons that could involve their students in similar type research. So far, this been the most successful way of involving the teachers and their students in the actual magnetometer data. All of these teachers regularly use the data in their classrooms after these summer research opportunities, whereas most of the other teachers do not use the data, but rather use the other THEMIS hands-on science and mathematics magnetism and space weather lessons.

We have had the entire set of teacher guides reviewed at least once. Individual guides were reviewed more than once by the NASA education review board. The review board provided valuable feedback from an outside perspective and helped to make the teacher guides appropriate for non-GEONS teachers to pick up and use. NASA strongly suggests that all materials developed for NASA education projects go through this review and we hope scientists or E/PO professionals who have not used this NASA service, do so.

All the teacher guides are located on the THEMIS E/PO website under "In the Classroom," and reviews from the NASA panels are located under "About Us/Evaluations" (see Sect. 4 below.) As we discuss below, these lessons have been used in all of the GEONS teacher's classrooms for at least two years and in many cases for longer, as we discuss in Sect. 2.1.2.

2.1.2 GEONS Impact on Teachers and Students

The THEMIS E/PO team maintains regular contact with the GEONS teachers through weekly emails that are part of an established THEMIS Yahoo Group, bi-monthly teleconference calls, and yearly professional development workshops. These means of communication act not only to provide support to the teachers, but also provide the E/PO team a way to determine how the program is succeeding, what impact it is having on teachers and students, and what changes need to be made as it progresses. Regular communication with the teachers has been shown to be very important to keeping the teachers engaged in this type of E/PO project.

In addition to these opportunities embedded in the program, Cornerstone Evaluation Associates (CEA) had two telephone interviews with a subset of the GEONS teachers.

Fig. 3 Photograph of the teachers and THEMIS E/PO team at the second annual GEONS teacher professional development workshop in Nevada at the magnetometer site (Western Community College)

Throughout the pre-launch E/PO phase, Cornerstone Evaluation Associates produced several reports on the GEONS program from surveys and interviews with the teachers. These are available on the THEMIS E/PO website under "About Us/Evaluations" (see the website Sect. 4) The reports are carefully written with attention to the evaluation tool and its responses. Without going into too much detail here, we try to give a sense of what these evaluation reports tell us in terms of the success of the program, the impact of the program on teachers and students, and what changes we have made as a result of these evaluation reports. We recommend working closely with such an evaluator to increase the effectiveness of an E/PO effort.

During the years of 2004, 2005, and 2007, the THEMIS E/PO team held professional development workshops with the GEONS teachers. The project covered the teachers' expenses to attend the workshops. These workshops provided science content, time to model the THEMIS activities from the teacher guides, and provided an opportunity for us to get further feedback from the teachers on the program. At the first two workshops, THEMIS principal investigator, Dr. Angelopoulos and THEMIS co-investigator, Dr. Bonnell, gave additional presentations to the teachers. The teachers provided feedback, both informally during the course of the workshop as well as formally by responding to questionnaires developed and analyzed by CEA. A photograph of the teachers and THEMIS E/PO team attending the second THEMIS GEONS workshop is shown in Fig. 3.

In 2004, the GEONS teachers did not yet have magnetometers and had just started with the project. Nine teachers attended. The agenda for the workshop is shown in Fig. 4. The teachers completed workshop questionnaires expressing that they learned about magnetism lessons usable in the classroom; that they had a better sense of the THEMIS project and their role in it; and that they enjoyed interacting with colleagues and experts on the THEMIS project. Their suggestions led to future workshop and program improvements. Improvements were to: (1) make the workshops one day longer, (2) make each day shorter, (3) increase opportunities to share and collaborate with other teachers, (4) provide updates on the progress of the mission, and (3) create an email-support-network for the teachers.

In the 2005 GEONS workshop in NV, nine teachers attended the workshop, together with the Principal Investigator (PI) of the grant, "Bay Mills Community College Charter School Science Teachers and Native American Youth Serving Organization THEMIS and GLOBE Training Project," that was funded to provide a magnetometer in Brimely, MI at a Tribal College. (GLOBE stands for Global Learning and Observations to Benefit the Environment.) The Western Nevada Community College astronomy professor, who manages the magnetometer near his observatory in Carson City, NV, hosted this workshop.

Fig. 4 GEONS 2004 teacher professional development workshop agenda

AGENDA

DAY 1
- Overview of THEMIS E/PO
- Introduction to THEMIS Mission science
- Activities—magnetism, building magnetic bottle magnetometers, soda bottle measurements
- Introduction to magnetic storms, magnetic fields in the universe
- Introduction to professional magnetic data

DAY 2
- Mission science talk
- Activities—soda bottle measurements, exploring magnetism
- Magnetometer, installation and exploring magnetometer data
- Solar storm statistics, NASAs Student Observation Network introduction

At this time, five of the initial ten magnetometers had been installed. At this workshop, the teachers shared how they were using the classroom lessons developed by the THEMIS E/PO team. These lessons were also modeled with all the teachers. Through discussions and feedback from the use of the lessons in science classrooms, we learned what modifications were needed. Four of the teachers indicated that there were some barriers to using all the lessons in the classroom, mostly trying to determine what to eliminate from their curriculum in order to "fit" it in and finding time to prepare and deal with the time between the workshop and class starting. We think EPO professionals would be well-served to have these kinds of practical discussions with teachers using their materials. All the teachers did implement the lessons in some of their classes over the next years, as indicated in the 2007 GEONS workshop.

Eight of the GEONS teachers attended the third GEONS workshop: a two-day St. Louis workshop in 2007 that was intentionally planned to coincide with the National Science Teachers Association (NSTA) conference, as is helpful to maximize a teacher's time and travel budget by providing extra opportunities for professional development. Five of the teachers had been participants since the 2004 inception of GEONS, two since 2005 and one joined the project in 2006. The focus of this workshop was on the presentation of activities included in the fourth guide being rolled out for classroom use. The fourth guide includes activities previously developed using magnetometer data, but revised based on feedback from GEONS teachers and research done by one teacher during the Summer 2006.

GEONS teachers indicated that presentations of the six activities included in the fourth guide were clear, offering a mean rating of 3.5 on a 4-point scale ranging from '1-not clear at all' to '4-very clear'. Nearly two-thirds of the GEONS teachers had not yet tried the activities before this workshop. Teachers who had not yet tried the activities signaled that they were very likely to do so in the future. When asked if they could foresee any barriers to implementation for these activities, most of the GEONS teachers cited their concerns about fitting them into the curriculum and time constraints.

Because this workshop took place a few months after the launch of the THEMIS satellites, the data are a nice summary of the state of the GEONS project at the time of launch. Many of the GEONS teachers at this point had as many as three years of project experience. They were asked to provide information about their successes in implementing all activities and student reactions to them, as well as their efforts in dissemination and professional

development. We provide details from the CEA report based on these data in the following bulleted paragraphs

- **Implementation**—All of the teachers are using THEMIS materials, ideas, the Web site, etc. and do so primarily for courses in Earth Science/Geology (31%), Astronomy (23%) Physics/Physical Science (23%), General Science (15%) and Math (8%). Once the project ends, they reported that they will continue to use the materials and data from the magnetometer. Many (57%) feel they will not need additional help to do so, but would like to see teleconferences, updating activity guides and networking continue.
- Three-quarters of the teachers had used the THEMIS-GEONS Users Guide in the last school year. The majority (88%) reported using all or part of the four activity guides containing 20 THEMIS-related activities. On average, five of the eight teachers have tried each activity, with anywhere from one to eight teachers trying out any one activity.
- **Student impact**—The GEONS teachers who tried the activities report, on average, that the students have responded with interest as evidenced by a mean rating of 3.8 on a 5-point scale ranging from '1-extremely disinterested; bored' to '5-extremely interested; enthusiastic'. By activity, the mean ratings ranged from 3.0 to 4.0.
- Nearly three-fifths (57%) of the GEONS teachers reported seeing increased general interest in science among the elementary, middle and high school populations in their schools and school districts. Nearly three-fifths (57%) said that active participation in the project (real science) has sparked interest as students feel a vital connection to the mission. The materials and instructor's enthusiasm inspire students. Teachers have also reported science course enrollment increases.
- **Dissemination**—GEONS teachers engage in multiple means of disseminating THEMIS materials, both informally and formally. Most (86%) of the GEONS teachers said that they share THEMIS materials on an informal basis with their colleagues in department meetings, at lunch, in teachers' rooms, etc. More than two-fifths (43%) of the teachers shared THEMIS materials by making presentations at state teachers' conferences and within the community.
- Nearly three-fifths (57%) of the teachers have gained local or national media exposure—most notably with one teacher being featured on the Jim Lehrer News Hour on PBS. GEONS teachers also reported that they update the school's Web site with THEMIS news, make presentations at local community groups and are planning activities for future dissemination.
- **Professional development**—Inspired by involvement in THEMIS, the GEONS teachers have become involved in other NASA-related projects such as Cosmic Times and the NASA WISE Mission, in attending National Science Teachers Association (NSTA) conferences, in research/student activity projects and in the Teacher Leaders Research Based Science Education program (TLRBSE) at the National Optical Astronomy Observatory.

In each of the winters of 2005 and 2006, a subset of the GEONS teachers accepted invitations to participate in telephone interviews with CEA. These interviews provided information about

- teacher demographics
- how the teachers were informed about the competition for participation in the GEONS program and why they applied
- the communication with the THEMIS E/PO team and fellow teachers
- teacher outreach/dissemination efforts
- teacher involvement in other professional development activities
- feedback on the magnetometer installation process

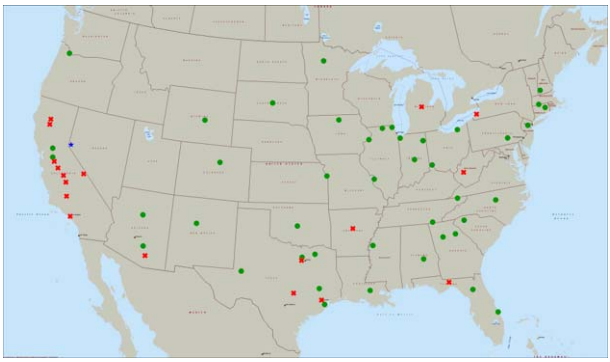

Fig. 5 GEMS sites (*green circles*) and centers (*red* ×'s) with the THEMIS-sponsored GEMS site in Nevada shown as a *blue star*

- plans for using or feedback on the use of the THEMIS-related classroom materials and activities

The full reports from these interviews can be found on the THEMIS E/PO web site. Together with the other reports mentioned above, they provide a sense of the perceptions of the program from the teacher perspectives, including how the teachers successfully anticipated their involvement in the program and in their classrooms. The ***PBS News Hour with Jim Lehrer*** report on the Petersburg, AK program provides an excellent window into the student's view of this program and its affect on their choices to become scientists. This is a goal of NASA E/PO in general. This PBS report can be seen on the THEMIS E/PO website from the "Gallery" page. A final evaluation report will be available on this program at the end of 2009.

2.2 Launch of a New LHS GEMS Site in Nevada

The THEMIS E/PO team, together with the Lawrence Hall of Science (LHS), launched a new GEMS Network site at the Carson City School District in Carson City, Nevada with a two-day Teacher Professional Development workshop in 2005. GEMS, the Great Explorations in Math and Science Teacher's Guide series, is a proven resource for excellence in inquiry-based mathematics and science. Developed at UCB's LHS, GEMS guides are used nationwide, from preschool through eighth grade. To support the growing number of teachers using GEMS materials, LHS GEMS maintains an international network of over 65 sites offering professional development and other services for teachers. The sites and centers as of 2008 are shown in Fig. 5 on the U.S.A. map as green circles and red ×'s respectively. The blue star marks the THEMIS-funded GEMS site. Centers offer more resources than do sites.

The Carson City GEMS Network Site serves teachers in northern Nevada. Many of these teachers are in very remote and under-served school districts, including ones on tribal lands. Carson City was selected as a GEMS site because it satisfies the conditions for being a prime candidate for E/PO magnetometer installation and the because of its strong ties with the GEMS effort.

Gail Bushey, a committed and active Associate of the GEMS Program is the lead at the new site with the strong support of District Assistant Superintendent Mike Watty. The Nevada State Science Coordinator and the Director of the new observatory at nearby Western Nevada Community College also lend their support. It is important in these types of programs to include this type of local support for sustainability of the program. Because of

Table 3 Percentages of teachers indicating various motivations for participating in GEMS site launch workshop

THEMIS GEMS SITE LAUNCH LEADERSHIP WORKSHOP 2005: Motivation to Participate	Teachers ($N = 38$)
Familiarity with GEMS—I have several GEMS guides and think they are very well written and explain the concepts very well	37%
Materials—Seeking new or free materials/resources/ideas—The six free handouts; I needed new ideas for teaching science; wanting more science information and experience	24
Colleague's encouragement—Encouragement from mentor/colleague/district—Judith Dragon's announcement at school; teaching with Gail Bushey kept me informed of GEMS activity; asked by the district to attend; encouragement from another teacher	18
Workshop convenience—Convenient time, date, location, no cost—I was already in Carson City for a workshop preceding this one; I was in the location; summer date; the fact it's free!	16
Credits—Recertification credit—I needed a credit for my teaching certificate; credit; I needed a recertification credit; in-service credit	16
Inquiry-based learning interest—I'm excited about inquiry-based science curriculum; my interest in hands-on science	16
Love of science—I enjoy science as a topic; interest in science; my love of science	13
Sharing knowledge—desire to share knowledge with other teachers or students—I wanted to teach a GEMS class to teachers	5

this strong local support, this GEMS site is continuing long after its initial funding provided by the THEMIS E/PO program.

Laura Tucker of LHS led the launching of the GEMS site in the Summer of 2005 with a 2-day leadership workshop, emphasizing space science, Earth science, and physical science. The THEMIS E/PO team gave two presentations at the workshop including Mapping the Magnetic Field and Living with a Star. The agenda for the workshop can be found in CEA's complete evaluation report of this site launch. The report is found on the THEMIS E/PO website. We provide some of the details from this report to give a sense of the impact of the workshop and the anticipated use by Nevada teachers of this GEMS site launch. These evaluation results suggest that partnering with the LHS for future GEMS sites is a worthwhile project for future NASA E/PO programs planned by scientists and E/PO professionals.

A total of 38 teachers, primarily from Nevada, attended the two-day workshop. Five of the teachers were also GEONS (Geomagnetic Event Observation Network by Students) teachers, who had attended a GEONS workshop in Carson City prior to this one. Most of the participants reported that they were teaching at pre-school/elementary level and/or at the middle school level, with minorities representing 30% of their students, on average, and that they were teaching on average 92 students. Of the 38 teachers at the workshop, 26 indicated that there are, on average, 39 teachers in their schools with whom they might share the GEMS materials in some way. The reason for teachers attending the workshop is shown in Table 3. Multiple responses were allowed, thus the percentages sum to over 100%.

Teachers indicated that all topics presented at the workshops were solidly in the 'somewhat likely to use' to 'very likely to use' range. The 'Mapping the Magnetic Field' and 'Living with a Star' presentations were some of the highest rated in anticipated use of materials but among some of the lowest mean ratings for understanding for GEMS presentations.

Table 4 Percentages of teachers indicating various ways they anticipate the Carson City GEMS site will assist them

THEMIS GEMS SITE LAUNCH LEADERSHIP WORKSHOP 2005: Anticipated Assistance from Carson City GEMS Site	Teachers ($N = 32$)
Training/resource person available—get questions answered—Contacts, more leadership trainings; training; Gail teaches two doors down, borrow and steal; It will be easy to get questions answered	50%
Materials/resources availability—GEMS site will be a great resource for finding information, borrowing kits, etc; borrowing materials for workshop; it will be easier to check out a guide I don't have; nice to know kits are available to present to staff and allow them to experience the activities	47
Facilitating connections with colleagues/support—Teacher support and dialogue; moral support; contact/network; love to collaborate with Gail Bushey; Be close to communicate with other teachers doing the same thing!; support with resources and awareness	28
Uncertain—I am not certain at this point; I will more likely use a GEMS center closer to me	6
Proximity—It's close!	3

These lessons were the lessons the most related to THEMIS science. This anti-correlation in expected use with understanding emphasizes the need for lessons and background science content around physics and space physics at the elementary level. This knowledge can help scientists and E/PO professionals create physical science workshops that elementary teachers need.

Just under half of the teachers responding to the question about what barriers would keep them from using these materials cited having limited time to prepare lessons and make kit components in advance as well as having difficulties in finding time to actually implement lessons. The THEMIS team anticipated this barrier in advance by providing 10 kits to the Carson City Site.

Table 4 summarizes the comments of the 32 teachers who responded to the question of how they might use the Carson City GEMS Site. Multiple responses result in the percentages totaling more than 100%.

Since the launch of this GEMS site, it continues to operate independently, maintaining contact with LHS and using district funds, fees and grants to support its work. In follow-up interviews, three teachers indicated that they really liked the GEMS lessons because they are user friendly with scripts and background science and because of the inquiry nature of the lessons. All three emphasized that aligning the GEMS lessons to the local state standards was very important and something they had to do themselves. One of these three teachers made an effort to determine which lessons met the state standards and she was able to use GEMS as the core of what she teaches. Due to the difficulty of obtaining responses from all 29 teachers, we do not know how many of them used the materials from the workshop. However, in 2006 and 2008, Gail Bushey informed us that several teachers had gone on to provide teacher professional development opportunities on GEMS guides in their region of Nevada and that many teachers have checked out GEMS kits throughout the years following the GEMS site launch.

2.3 Professional Development for Teachers with a Focus on the Tribal College and SACNAS Communities

THEMIS E/PO provides teacher professional development to teachers nationwide as well as those who are part of GEONS. These workshops have some of the same content elements as those mentioned in the GEONS section, but they are short-term workshops held at state and national conferences such as the NSTA, California Science Teachers Association (CSTA), and at the Center for Science Education (CSE) at UCB. As a part of these workshops, we aim to reach teachers other than the GEONS teachers who work with Native American students. In order to be more effective at such trainings, we took part in "One Earth, One Universe" workshops hosted by the Sun-Earth Connection Education Forum on understanding Native American science and culture in 2005. As one of many valuable lessons, these workshops helped the THEMIS E/PO team to understand NASA's involvement with tribal communities around the United States from the perspective of the tribal members. EPO professionals seeking to reach Native American populations may want to research the results of these workshops or other valuable materials, for example, see http://www.oneearthoneuniverse.com/.

In order to reach teachers whose students are Native American, we have presented THEMIS workshops at a SACNAS conference in 2004. The Society for Advancement of Chicanos and Native Americans in Science (SACNAS) has as its primary aim to promote careers in science and engineering to under-served minorities, particularly Chicanos and Native Americans. Its annual conference offers an educational component for K-12 teachers, providing useful professional development opportunities for participants teaching minority students.

At the October 2004 SACNAS conference, a total of twenty teachers attended a workshop offered in two similar sessions by the THEMIS E/PO team. This workshop focused on teaching magnetism and exploring the Earth's magnetic field. Across the twenty teachers, they reported that they would reach upwards of 1700 students with these materials and share this information with some 80 other teachers. The teachers rated all aspects of the session very highly—nearly three-quarters of the teachers said that this session was better than most. The complete report on this workshop is available on the THEMIS E/PO website.

The short-term teacher professional development workshops we gave nationally and locally (Berkeley, CA) on average reached teachers who indicated that 20% of their students were non-White and non-Asian male students. This indicates that these teachers had > 20% males who are underserved in science. Note that on our evaluation forms we did not ask about students who are White and Hispanic and so some of the 30% may come from this underserved population. We plan on revising this evaluation form to better gather demographic data on the students whose teachers we are reaching. On average, 50% of their students were female, also an underserved population in the physical sciences. The particular focus of the workshop determines what teachers will attend—elementary, middle, high school, or college. At high school and community college levels, we model the THEMIS teacher guides. For elementary teachers, the THEMIS E/PO team taps existing K-4 education resources at Center for Science Education at UCB, namely the "Eye on the Sky" program as well as other Sun-Earth Connection Education Forum (SECEF) resources. The majority of these workshops served as a partnership between THEMIS and three other NASA missions—FAST, STEREO-IMPACT and RHESSI—as well as SECEF at Berkeley.

We began teaching these short-term workshops at the beginning of the THEMIS E/PO program in 2004. We incorporated many lessons we learned through our experience over the course of the years from 2004 to 2007. Some such lessons that EPO professionals might

make note of were to allow more time for discussion with the teachers, to provide and explicitly mention the state or national science education standards for the lessons we were presenting, to give a definition of magnetism, to help teachers focus on a couple key concepts in the content part of the workshop, to provide the presentation on a CD-ROM to the teachers as well as to provide notes during the session for teachers to write down extra information, and in the longer workshops, to provide time for teachers to contemplate how to incorporate the lessons into their curriculum.

CEA analyzed data from questionnaires from most of these workshops and for many of them created in-depth reports from the results, which can be found on the THEMIS website. In 2008, CEA analyzed most all the teacher workshops that THEMIS participated in (nine workshops) during FY2007 (Oct, 2006–Oct, 2007), which included the workshop in Florida at the time of the THEMIS launch. A total of 168 of the teachers attending these workshops completed questionnaires regarding their workshop experience. This report does not include the GEONS 2007 workshop that was discussed above, in Sect. 2.1. We quote the report created for these workshops in the following paragraphs.

General Workshops—The 168 teachers who attended the nine workshops offering topics related to the THEMIS mission told us a little about themselves and the environments in which they teach...

- **Experience**—$N = 156$. Teachers averaged 11.4 years experience ranging from 1 to 40 years.
- Grade Levels—$N = 168$. Over two-fifths taught at the elementary grade level and more than one-quarter at both the high school and middle school levels.
- **Setting**—$N = 154$. More than half taught in suburban schools, nearly one-third in urban schools and a little more than one-tenth in rural schools.
- **Student Population**—Two-fifths of the teachers responding said they were teaching in Title I schools—$N = 110$. On average, half of their students receive free or reduced lunches—$N = 106$. Teachers said that their classes included 47% females and 20% non-White, non-Asian males (a set of underserved populations in science)—$N = 117$.

Most of the teachers told us that they learned about the opportunity from e-mails that piqued their interest in the workshop topics. Thus, having a good email listserve interesting workshop topics are important to bringing in teachers to workshops. The nine workshops presented a total of 38 sessions related to the THEMIS Mission.

Teachers rated their *understanding of the topics* presented in these sessions as being 'clear.' This is in stark contrast to their prior knowledge of the topics. They told us that before attending the workshops, their knowledge of the topics was between 'just a little' and 'moderate.'

Teachers reported that they were 'very likely' to use the materials and ideas in their classroom. A full 61% of the teachers anticipated they would be using the information gleaned from these workshops primarily as integral parts of basic science courses and 46% envisioned using these materials as resources or supplements to basic science courses. This is dramatically different from their use of these topics prior to the workshops. Before THEMIS, an average of 29% said that they never taught the topics presented, 34% had used the topics as resources or supplements to basic science courses, and 31% had used the topics as integral parts of their courses.

Despite the high percentage of teachers eager to implement THEMIS materials and ideas, some expressed concern that their ability to use the materials would be constrained by a lack of financial support to purchase materials, scarce resources and a deficiency in classroom technology. They were also concerned about time constraints. EPO professionals should consider these kinds of concerns when developing curriculum and products.

These findings suggest that the workshops have presented complex materials to teachers in a clear manner that gives them the confidence to present the materials to their students. Additionally, they are now more likely to include the materials and ideas as integral parts of or resources to supplement their basic science courses.

3 THEMIS ViewSpace Show and Public Events: Informal Education

The E/PO plan also contributed (and at the time of this publication continues to contribute) THEMIS science discoveries through a visually captivating ViewSpace show produced in collaboration with the Space Telescope Science Institute (STScI), which contributed its services at no cost to the project. This show, for plasma screen displays and projection mini-theaters at science centers around the nation, consists of auroral images, all-sky movies, THEMIS animations, and interpretive text, woven together to tell the THEMIS story. STScI distributes it though a network of self-updating displays that STScI has developed over the past eight years. As of May, 2008, ViewSpace was showing in 188 venues around the world, with three to four new venues joining the network each month. Most of these venues are Planetariums and Science Centers. The THEMIS program, entitled "Exploring the Mysterious Aurora," receives in excess of 5,500 performances per month. The ViewSpace "Sun Report" news segment, which features the latest results from a variety of solar observatories and probes, including THEMIS, is performed some 14,000 times per month. The total number of visitors at the venues showing ViewSpace who see the THEMIS ViewSpace show depends on such factors as the quality of the installation, the quality and quantity of the "competition" within the venue, the degree to which a lengthy experience fits the desire of the visitor base, and the number of other ViewSpace shows being shown in a "loop" of shows. We do not have the impact evaluation of the show on venue visitors at this time. THEMIS programming will continue to be presented on ViewSpace through the duration of the mission. This indicates that working with STScI to create ViewSpace shows is an effective way of reaching a large audience through an E/PO program.

As per most NASA science E/PO programs, we have attended public events where we distribute THEMIS materials we've produced for the public—flyers about the THEMIS mission and education program, lithographs, stickers, and THEMIS pins. We have participated at Cal Day at the University of California, Berkeley Open House, Sun-Earth Day where we participate at local science museums, Space Weather Day in Maryland, and amateur astronomy club at Mt. Diablo, East of the San Francisco Bay Area in CA. At several of these events, THEMIS scientists have also given talks as part of the event. These events typically reached thousands of people, another effective form of outreach to many.

4 The THEMIS E/PO Website

The Internet is an incredibly rich resource of information, and almost all of the THEMIS E/PO efforts are documented on the web or have web components. The projects and activities described in the sections above and below can be found on the THEMIS E/PO website, URL: http://ds9.ssl.berkeley.edu/themis.

The education and public outreach and the mission websites of any NASA mission are their primary doors to the public. The THEMIS E/PO website has proved an excellent source for the general public to come and learn about THEMIS mission and its science in language appropriate for a general audience. At this website, one can learn how to bring THEMIS science and GEONS activities into the classroom, how to understand THEMIS data, and where

the THEMIS public activities are taking place. All the GEONS data and information about the schools and teachers are located on these webpages. In addition, this site contains many images of aurora, auroral movies, and the THEMIS instrumentation in a gallery page. The public has great enthusiasm for this beautiful imagery, which they can download if desired. This gallery page includes videos of scientist and engineer interviews, several videos made by different public affairs offices (NASA and UCB) as well as the segment of the PBS News Hour with Jim Lehrer about student involvement in the GEONS program in Petersburg, AK. This webpage is accessible and friendly to the public, teachers, and to the students who visit it—very important for any outreach webpage—and it is designed to be easily updated. This webpage is also accessible to those with disabilities.

The THEMIS E/PO website has been up and running since December 2003. Our focus for the following paragraphs is on the website statistics for FY06 and FY07 during which time the actual mission launch was successfully completed on February 17, 2007.

Visitor Profile—In each of the fiscal years, the domain names for visitors to the Web site were catalogued. This offers an avenue for identifying visitors' countries of origin. We found that during the two years, about half of the site's visitors can be identified as residents of the United States. In FY06, 2% were from other countries—with Canada, Spain, and the United Kingdom leading the list. In FY07, 3% were from other countries—with Canada, Switzerland, and Germany leading the list. The remaining visitors to the E/PO website could not be identified.

We found that the visitors to the site had an 83% 'hit' rate in FY06 and FY07, that is, the percentage of times (requests) a visitor was successful in accessing the specific files of which a Web page is composed, and did so without receiving an error message. This is not a very good 'hit' rate and will absolutely improve upon this percentage in the remaining years of THEMIS.

A single Web page can be made up of any number of unique files (hundreds even). Since there may be multiple files making up a Web page—resulting in hundreds of 'successful requests' or 'hits'—counting those requests may not be the most accurate reflection of Web traffic. Consequently, for the remainder of this discussion we will refer to the Web site's activity levels in terms of requests for a page—a page that has been viewed by a visitor rather than all of the files that make up the Web page. Note that when comparing our web statistic numbers with other website statistics, the number of 'requests for pages' will be an order of magnitude smaller than the number of 'successful requests' or 'hits.'

Activity Levels—A general summary (Table 5) indicates activity levels as reflected in successful requests for pages. These numbers are not the millions that the most popular sites on the web get, but for a NASA E/PO website, the request for pages are relatively high. For the number counts and averages for FY06 and FY07, we will discuss specific patterns of activity by month, day-of-the-week and hour. We note that activity for FY07 was 46% higher than that for FY06, most likely due to the February 2007 launch.

- **Monthly**—In FY06, above average activity of 31,275 pages was noted in October 2005. The week of October 15 brought a partial eclipse of the Sun, which may have accounted for the above average activity.
- For FY07, it was the period from January to April 2007 that saw the greatest spike in activity as the build up to the launch generated higher than average requests, maximizing at in 41,130 requests in March. It is noteworthy that in addition to the February launch, the Sun-Earth Day Forum highlighted all missions during a March 22 Webcast. This exposure also may have contributed to the higher than average activity and is worth noting that launches are important times for E/PO programs to provide their materials and programs

Table 5 Website activity in FY06 (pre-launch) and FY07 (year of launch). See: http://ds9.ssl.berkeley.edu/themis/stats/themisstatfy06.html and http://ds9.ssl.berkeley.edu/themis/stats/themisstatfy07.html for more details on the FY06 and FY07 webpage statistics respectively

Requests for Pages	FY06	FY07
Total # Successful Requests for Pages	168,756	246,261
Average Successful Requests for Pages per Month	16,298	20,522
Average Successful Requests for Pages per Day	462	674
# of Page Requests in Peak Month for Entire Year—Oct/Mar	31,275	41,130
# of Page Requests on Peak Day for Entire Year—Thursday	33,772	42,474
# of Page Requests in Peak Hour for Entire Year—7amET	9417	14,657

on their website. It also helps to have the E/PO website as the "primary" website listed in press releases.

The daily- and hourly-use statistics are outlined in more details in the THEMIS evaluation report for FY06-07 found on the THEMIS website. These statistics indicate high traffic during the work/school week and during months in which school is in session—October and March. While these monthly and daily activity patterns immediately point to student traffic, the early morning pattern of peak requests is unlikely to be due to student activity.

We suspect that the early morning hours Eastern Time may be reflecting a strong European contingency that checked onto the THEMIS Web site between 9 am and 5 pm. With almost half of the THEMIS Web site users having unidentifiable addresses, we speculate that many of these may be Europeans, drawn to the site after seeing PR events—particularly in Germany, France, Austria and Great Britain. Furthermore, since the THEMIS science Web site was temporarily off-line at this time, all THEMIS traffic around launch time was coming to the THEMIS E/PO site. In the final report in 2009, we will provide a comparison of these statistics with those in 2004 and 2005—the early years of THEMIS, and 2008–2009—the dissemination years of THEMIS E/PO.

5 Discussion

Most of the THEMIS pre-launch activities have focused around formal education, which is bringing THEMIS and science, technology, engineering, and mathematics into the K-12 classroom. We described these efforts in Sect. 2. In this discussion section, we share the "White Paper comments" from NASA on the THEMIS program as a way to describe the strengths of the program and how we have addressed some of the initial concerns from this review, which includes our plans for dissemination and sustainability of the program. We then elaborate on the lessons we have learned from such an exciting and large E/PO project. And end with a short description of the future education and outreach plans for with the THEMIS satellites in orbit.

5.1 White Paper Review, Dissemination and Sustainability

As mentioned in Sect. 1.1 during the early phases of THEMIS, in 2004 the E/PO program was part of a "White Paper" review of ten NASA education programs. This review required that we provide a description of our program in light of several education criteria and then arrive in person to answer questions posed by the review panel. At the end of the review

process, we were provided with comments from the committee. Their feedback was that the THEMIS E/PO program was 'Very Good' and that it was well defined, well managed, and successful. Only one education program was rated purely 'Excellent,' one 'Excellent/Very Good' and two were rated purely 'Good.' The other seven NASA education programs rated in this review obtained ratings 'Very Good/Good' or 'Very Good.' A few of the strengths mentioned in the final THEMIS E/PO review are included here.

- The program is certainly accessible to its intended audience, and it's based on a mutual need—educators' need for compelling teaching tools and NASA's need for well-educated future scientists.
- The creative partnerships that have been established for THEMIS add to the strength of this program.
- THEMIS uses lessons learned from previous missions and the program is not wasting time or resources to reinvent the wheel.
- The program clearly will promote improvement of STEM skills for the students who participate, and this is likely to inspire interest in STEM careers.
- The program makes a special effort to include Native American and Hispanic students

The full review can be found on the "Evaluations" page on the THEMIS E/PO website (see Sect. 4). One way we have measured our success in the accessibility to the educators in the GEONS program (first bullet above) is from feedback from the GEONS teachers. Several teachers have shared with us that they were planning on retiring a couple of years ago, but this program has kept them actively teaching.

The major concern of this NASA review committee was that we were spending a large number of resources on a small number of teachers. Our response to this concern at the time was that we felt these teachers would become "Magnetometer Ambassadors." By this, we meant that in addition to being experts in educating students about magnetism and THEMIS, especially using the magnetometer data, that they would then disseminate this information to other teachers in their states, reaching far more teachers than we could reach alone. This has indeed happened with several of our teachers. The GEONS teachers in OR, MI, ND, and WI have all given workshops on the THEMIS materials at state teacher conferences in their respective states. In addition to this statewide teacher training, most of the GEONS teachers have shared THEMIS materials with other teachers at their schools and neighboring schools. As the program continues, more teachers join the GEONS network and we anticipate this to continue throughout the coming years. We started with 10 teachers and have worked with a total of 18 teachers associated with the magnetometers throughout the span of the program.

Another concern in the white paper was that there was "no plan to promote the THEMIS (E/PO) website and attract large numbers of participants is apparent." As described in Sect. 4, we have actually attracted hundreds of thousands of visitors to this site annually by leveraging the Public Relations (PR) work based out of NASA Goddard Space Flight Center (GSFC) prior to and after launch and through our work with teachers across the nation. We also worked with the PR group to help develop a lithograph with one of our magnetism lessons on the back (THEMIS satellites on the front), which directed the public to the lessons on the THEMIS E/PO website. As the mission continues, the E/PO team will work with the NASA GSFC PR team to help bring the public to the THEMIS E/PO site, as well as distribute the URL at science teacher workshops nationally. In addition to these venues, we will distribute lithographs and postcards through the well-established "Night Sky Network" of amateur astronomers run by the Astronomical Society of the Pacific. These amateur astronomers distribute materials to hundreds of members of the public. We anticipate reaching over 10,000 members of the public through this venue.

In addition to these excellent dissemination venues, we have worked in other ways to ensure dissemination of the program and in particular the teacher guides on magnetism, space weather, and THEMIS magnetometer data. We have continued to improve the teacher guides, and to make sure they are accessible to people with disabilities and through these improvements, we anticipate that we will be able to provide these guides to other NASA education programs such as the Educator Resource Center programs and the Aerospace Education Services Project (AESP) programs. We have already placed the guides on NASA's Space Science Education Resource Directory, where most of NASA's space science curriculum is collected. And we have printed 16,000 CD-ROMs with the suite of magnetism guides developed not only by THEMIS but also by STEREO, RHESSI, and FAST Education programs. A full 10,000 of these CD-ROMs were distributed to educators nationally and internationally through the SECEF Sun-Earth Day packets for Sun-Earth Day, 2008.

We are also collaborating with the NASA-funded, Space Math Weekly Problems program of SpaceMath@NASA to develop simple math problems featuring THEMIS data (Odenwald 2008). SpaceMath@NASA has been in operation since 2004 and is the primary resource at NASA for creating and disseminating real-world math problems to the K12 community through a broad network of Listserves. Through this collaboration, we will extend our contact to the K12 community through our contribution of THEMIS-themed math problems to teacher workshops supported by SpaceMathg@NASA, in particular at national conventions for mathematics teachers (e.g. NCTM). Currently, all of the GEONS teachers participate in the SpaceMath@NASA program during the school year.

In addition to these types of dissemination and the teacher professional development workshops modeling lessons from the teacher guides, we have partnered with several other groups bringing magnetometer and radio wave data related to space weather into the classroom in the U.S. and in Canada. These programs are making use of the THEMIS magnetism guides as well. We are also working with a middle school teacher in southern CA to create a summer school course for middle-school students based around THEMIS and magnetism. We anticipate that these types of programs using the THEMIS materials will continue beyond THEMIS. It is important to think about how to sustain the projects in an E/PO program after the funding is no longer available.

Another concern mentioned in the review was that "Younger students—those who have no understanding of physics—are less likely to benefit from involvement in an effort that is over their heads." This is true with the GEONS program, which is why we partnered with the LHS with the GEMS program, reaching predominantly K-5 teachers as well as middle school teachers. In addition to the LHS GEMS program, we have also partnered in many teacher workshops with SECEF and in particular, R. Paglierani (UCB), who has several successful and widely used elementary lessons about the Sun and the solar system. We will continue to work with her to reach the younger students and will also work with the NASA-funded education group located at the University of Colorado, Boulder, which has developed elementary lessons around auroras. All of the above-mentioned elementary lessons incorporate reading, writing, and mathematics since this is the primary need for students at this young age.

5.2 Lessons Learned

What have we learned by running this program? What advice would we give for others expecting to place magnetometers in classrooms? What advice would we give other scientists and EPO professionals hoping to make significant increases in the breadth and depth of their program? The first lesson comes from listening to a teacher at the beginning of our GEONS

program and following through on our initial promise to stay in close touch with the teachers at the schools where the magnetometers are located. A teacher at the very first GEONS workshop told us of a seismometer program where a seismometer was placed in his school. No teacher was trained on the seismometer, no lessons were provided to bring the data to the classroom, and no support was given to the teachers. He said that if our program turned out like that one—just placing a scientific instrument at the school and expecting the teacher to do all the rest of the work—he was not interested in it, and would quit. Although THEMIS always intended to more supportive than the seismic program, this teacher's comments did drive home with us the need to stay responsive to the teacher's needs—staying in regular contact, providing them with in-depth professional development and classroom lessons at yearly workshops, providing support when the magnetometers or computer servers had technical difficulties, and providing teachers an opportunity to do compensated research with the data that was appropriate for the classroom. As an addendum, we are happy to say that this aforementioned teacher took part in all of these activities and has since become our biggest advocates, and one of our strongest teachers! Several of his students have since gone on to college with the intention of becoming scientists.

For this type of success, it is imperative that programs involving complex data, such as magnetometer data, provide this kind of in-depth support to teachers. Only three of the 18 teachers shown in Table 1 had physics bachelor degrees. The others had degrees in other sciences and therefore did not have the content knowledge to support their students with the magnetometer data. We have needed to provide this support and training throughout the program. In part because of the request of teachers for more regular contact, we started bimonthly teleconference calls, weekly emails to the teachers, and a Yahoo Group. Because of the time needed for such regular contact, it has been necessary to have an E/PO team member designated to be in charge of this aspect of the program and we recommend having such a person for similar programs.

To our dismay, we learned that the impact of No Child Left Behind, which came into full-force soon after the THEMIS E/PO effort was begun, may have had a chilling effect upon teacher adoption of extensive new curriculum packages such as our six magnetometer guides. In the modern test-oriented classroom, where topics are covered rapidly and teachers may tend to "teach to the test," future curriculum guides may need to be simplified and greatly de-scoped to insure broader utilization.

Another lesson learned is to keep in contact not only with the teachers as previously stressed, but also the administrators (superintendents, principals, etc.) who were involved at the start in helping us find teachers for this program. We have lost teachers in the past due to personal issues and migrations to other school districts. But with the help of superintendents, we have replaced most of those teachers. We actively engage the new teachers to fill in when GEONS teachers leave the project and will continue to do so. Sometimes this process can take on the order of a year, however, depending on the responsiveness of the potential new teachers to the program. Continuing to bring in new teachers has taken much more time and effort than initially expected. For such programs in the future, it would be wise to have the partner who helps find teachers, also agree to help to fill in gaps when teachers or administrators leave.

We also like to add that when it comes to data that is complex, such as magnetometer data, it helps to fund the participating teachers in "research" with the raw magnetometer data. They can adapt lessons for use with their students either as labs, special projects, or science fair projects. From our own experience, there seems to be an assumption in the science community that teachers will jump at the chance to have real data associated with a NASA program in their classroom. This is consistent with the intention of some teachers,

but in reality, most of the teachers in our program did not have their students actually work with the data until they were *funded* to be involved with the data themselves. We are still trying to find ways to help other teachers around the country to use the teachers' magnetometer data lessons without the financial incentive. This problem was only applicable to the magnetometer lessons, due to their complexity. Most all of the GEONS teachers used the basic magnetism and space weather lessons in their classrooms without the financial incentive. And non-GEONS teachers at our short-term teacher professional development workshops indicated on evaluations that they were very likely to use the basic science lessons in their classrooms—but only somewhat likely to use the magnetometer data lessons in their classrooms.

For the GEONS program, it has also been crucial to have the technical expertise and support of the THEMIS ground-based observatory hardware and software engineering team. Without their help with installations of the magnetometers, maintaining the magnetometer network, creating software for web-based displays and access of the real-time and archived data, maintaining the web presence of the magnetometer data, the use of this data in the classroom would simply not be possible. In several cases, teachers have had to ship hardware back to UCLA to have it fixed and returned. This exchange takes additional funding, as well as commitments from the teachers and the engineering team.

The final lesson we have learned, and one that is applicable for all those doing mission-related E/PO is that it is important to build in support for, and education of, the THEMIS scientists. In some cases, it really is necessary to train the scientists how to effectively and engagingly interact with the public or with teachers. The scientists need to understand what the public and teachers need and how to best provide it to them. The idea that if one can do science research, one can also teach it is not necessarily true. It has helped our program to involve scientists in as many projects as possible, giving them an opportunity to learn about education through project-based learning, just as we educate teachers and students through inquiry-based lessons. Luckily THEMIS scientists have willingly gone into classrooms, staffed tables at public events, given public talks at universities and amateur astronomy clubs, and provided input to our educational products, and been willing to understand the points-of-view of non-scientists. The THEMIS scientists provide the enthusiasm for the THEMIS science necessary to help bring the specific aurora and magnetospheric science to teachers, students and the public and have been an invaluable part of our program. We hope to bring in their generous time and enthusiasm to our future programs as well.

5.3 Future Programs

The future of the THEMIS E/PO program is to continue to disseminate the products developed and to bring new discoveries to teachers, students and the public. To disseminate resources nationally and prevent duplication of effort, our E/PO program is coordinated with the Sun-Earth Connection Education Forum, a UCB-GSFC collaboration, and with networks supported by NASA Education. Working within the Science Education Gateway, an organization at SSL@UCB that encompasses many NASA education and outreach programs, allows us to leverage these programs and existing partnerships. Other E/PO programs can make use of such strong support networks.

Particular programs coming in the following years include:

- mapping data to sounds (sonification)
- adding new THEMIS science updates to the ViewSpace THEMIS show
- supporting the update of SECEF's Space Weather Multimedia Viewer
- finalizing the THEMIS teacher guides and printing them

- broadening the impact of the GEONS program
- Collaborating with SpaceMath@NASA to develop more math problems featuring THEMIS
- creating and printing new materials to distribute through networks of amateur astronomers
- updating the THEMIS website with new science results and educational materials

We will continue evaluation of these programs and creating a summative evaluation report of the entire THEMIS E/PO program. This final report will be placed on the THEMIS E/PO website. And we will write articles about different aspects of the program in science education journals.

Acknowledgements This project would not have been possible without the support and dedication of the following GEONS teachers: V. Trautman, C. DeWolf, L. Orr, W. Gehman, T. Parent, W. Esch, J. Bean, S. Estill, H. Howe, R. Benson, F. Martin, M. Prakash and the support technicians at the magnetometer schools. We would like to thank them for their exemplary work and dedication to the education project. We also would like to thank the engineers who helped to make this project possible, D. Dearborn, D. Pierce, I. Ruderman, T. Quinn, and K. Rowe. D. Dearborn was instrumental in installing most of the magnetometers and giving talks to the community while he was at the installation site. D. Pierce developed the software to display the THEMIS data as the teachers and program required. I. Ruderman and T. Quinn made it possible to display the THEMIS data, both the real-time data and archived data, on-line and with an easy interface to access the data. K. Rowe interacted with the teachers and school support staff to ensure that the magnetometers were continuing to work and getting them back to UCLA when there were problems with the system that needed fixing. We would also like to thank Gail Bushey for her hard work creating a successful GEMS site in Carson City after we launched the site. And we would like to thank Laura Tucker for her work getting the GEMS site launch organized. We would also like to thank Karin Hauck for editing this paper. This paper was written with the support of NASA NAS5-02099.

Appendix: Acronym List

AESP	Aerospace Education Services Project
ASTC	Association of Science-Technology Centers
CEA	Cornerstone Evaluation Associates
CSE	Center for Science Education
E/PO	Education and Outreach
GEMS	Great Explorations in Mathematics and Science
GEONS	Geomagnetic Event Observation Network by Students
GLOBE	Global Learning and Observations to Benefit the Environment
GSFC	Goddard Space Flight Center
LHS	Lawrence Hall of Science
NSES	National Science Education Standards
NSTA	National Science Teachers Association
OSS	Office of Space Science
PBS	Public Broadcast System
PR	Public Relations
SACNAS	Society for the Advancement of Chicanos and Native Americans in Science
SECEF	Sun-Earth Connection Education Forum
SEGway	Science Education Gateway
STEM	Science, Technology, Engineering, and Mathematics
STScI	Space Telescope Science Institute
THEMIS	Time History of Events and Macroscale Interactions during Substorms
TLRBSE	Teacher Leaders Research Based Science Education program
UCB	University of California, Berkeley
UCLA	University of California, Los Angeles

References

L.P. Cooper, C.A. Morrow, R.A. Pertzborn, J. Rosendhal, P. Sakimoto, An explanatory guide to NASA Office of Space Science Education and public outreach evaluation criteria (2004). http://science.hq.nasa.gov/research/guide.pdf

S.B. Mende, S.E. Harris, H.U. Frey, V. Angelopoulos, C.T. Russell, E. Donovan, B. Jackel, M. Greffen, L.M. Peticolas, The THEMIS array of ground-based observatories for the study of auroral substorms. Space Sci. Rev. (2008). doi:10.1007/s11214-008-9380-x. ISSN0038-6308 (Print) 1572-9672 (Online)

N. Naik, B. Anderson, D. Conrod, B. Eisenhamer, P. Kassaie, B. Komisaruk, C. Person, D. Temple, S. Williams, NASA: August 2004 program review summary (2004)

National Center for Education Statistics (NCES) Trends in international mathematics and science study. Report (2003). http://nces.ed.gov/timss

S. Odenwald, SpaceMath@NASA (2008). http://spacemath.gsfc.nasa.gov

L.M. Peticolas, N. Craig, T. Kucera, D.J. Michels, J. Gerulskis, R.J. MacDowall, K. Beisser, C. Chrissotimos, J.G. Luhmann, A.B. Galvin, L. Ratta, E. Drobnes, B.J. Méndez, S. Hill, K. Marren, R. Howard, The STEREO education and public outreach program. Space Sci. Rev. (2007). doi:10.1007/s11214-007-9287-y. ISN 0038-6308 (Print) 1572-9672 (Online)

J. Rosendhal, P.L. Sakimoto, R. Pertzborn, L. Cooper, The NASA Office of Space Science Education and Public Outreach Program. Adv. Space Res. **34**(10), 2127 (2004) doi:10.1016/j.asr.2003.03.069

J. Ruberg, K. Chen, J. Huang Martin, NASA explorer schools project evaluation: Summer 2003 to Spring 2006. Final Report (2007). http://explorerschools.nasa.gov/pdf/202270main_2003-2006EvaluationSummary.pdf

C.T. Russell, P.J. Chi, D.J. Dearborn, Y.S. Ge, B. Kuo-Tiong, J.D. Means, D.R. Pierce, K.M. Rowe, R.C. Snare, THEMIS ground-based Magnetometers. Space Sci. Rev. (2008)