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Survey of K–12 Science Teachers' Educational Product Needs from Planetary Scientists

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Abstract

Most education reform documents of the last two decades call for students to have authentic science inquiry experiences that mimic scientific research using real scientific data. In order for professional planetary scientists to provide the most useful data and professional development for K–12 teachers in support of science education reform, an extensive national survey of nearly 800 "alpha teachers" was undertaken to determine how teachers are currently using planetary science data and, if not, why not. Although teachers had considerable awareness of online data resources, few report frequent use of online data for authentic inquiry and analysis in the classroom. Teachers' primary use of the Internet for data is to download images to share with students. Only one-quarter of teachers report that they ever use any online data in the form of large WWW data sets, real-time data, or virtual online data to engage students in inquiry or data analysis and virtually no teachers reported using data sets delivered on CD-ROMS. Results suggest that the most influential role for the community of planetary scientists might be to support the creation and dissemination of two standards-based products: content courses for teachers that translate research into classroom ideas, and a limited number of data-driven inquiry products that focus on key scientific ideas.

1. INTRODUCTION

Since the awareness raised by the launch of Sputnik to improve the nation's scientifically trained workforce, teachers, scholars, and policy makers have aggressively worked to change how students learn science during elementary, secondary, and higher education experiences. These reforms have mostly changed science education in iterative steps, with some efforts being more fruitful in the past than others. In the earliest stages of the reform movements over the last four decades and with the onset of the cold war, science education endeavored to elevate the best and the brightest of young Americans to pursue science, technology, engineering, and mathematics (STEM) careers (Goodstein 1993). But as the world has become more "flat," in the vernacular of author Thomas Friedman, the world's economic engines now require that all students, not just the elite, become more knowledgeable and flexible users of science (Friedman 2006). The advent of the *National Science Education Standards* (NRC 1996) and the AAAS *Project 2061 Benchmarks* (AAAS 1993) not only outlined the range and domain of scientific ideas that all American students needed to understand to be productive members of the next century's citizenry, these reform documents enthusiastically promoted the notion that science is for everyone and that all students should learn science. Together, the movements articulated by these reforms put forth the vision that science education needs to move beyond wrote memorization of declarative scientific facts and engage students in the doing of science.

The focus of next generation of science education reform is likely to be characterized as building learning environments based on authentic student inquiry where students have extended intellectual engagements with pursuing scientific evidence to communicate answers to questions of their own devising. If planetary scientists are to meaningfully contribute to such an inquiry-oriented science education system, we need to better understand the current state of how scientific data are used in education and how to contribute to or how to build data pipelines and research support infrastructures specifically for student learning. This article first describes and documents some of the existing data-based curriculum and instruction projects and then goes on to describe the results of a large-scale national survey of science teachers who were asked to describe their perceived needs from planetary scientists who wish to help K–12 educators improve science teaching and learning. Specifically, we report: (i) the extent to which teachers use planetary data to help students learn science, ranging from assessing visual image data on lithographs to manipulating large, online, authentic data sets; (ii) what other data products they use in their science teaching and would use if available (e.g., earth system science); and (iii) if data products of any type are not being used, why not, and what would be necessary for more data products to be used in classrooms?

2. BACKGROUND AND CONTEXT

Two important enterprises have surfaced to fuel the most recent wave of science education reforms aimed at changing science learning by de-emphasizing the memorization of facts and emphasizing student engagement in the actual doing of science. First, a number of high-quality science curriculum packages, often in the form of everything-included science kits, were produced and widely marketed. These “boxes” for science teaching were designed to surpass the common barrier of teachers not having the right materials to offer hands-on science learning experiences to their students (Lopez and Schultz 2001). Although many exist, some of the most well known ones have been produced by the Lawrence Hall of Science at the University of California Berkeley under the monikers of GEMS and FOSS. The second was the creation of elaborate systems to deliver professional development to teachers both to fill deficiencies in scientific content knowledge and to increase teachers’ skills at managing a hands-on oriented classroom environment (Slater *et al.* 2001). In retrospect, although these efforts resulted in many important changes in the way some K–12 students engaged in learning science, reform is still far from achieving widespread adoption across the majority of classrooms.

Without question, the rallying cries for reformed science education today center around “inquiry.” Although the term inquiry is subject to substantial interpretation, probably the most common characteristics of inquiry instruction are that students are engaged in questions and the pursuit of evidence to formulate data-based conclusions (Bell, Smetana, and Binns 2005). In this sense, providing students learning science with the means to acquire and analyze scientific data might seem to be a hallmark of modern science education in the Internet age (Manduca and Mogk, 2003) and indeed there are many exciting examples of national efforts to help students and teachers have the opportunity to access and investigate authentic data.

Indeed there are many exciting examples of national efforts to help students and teachers have access to authentic data. Quite possibly the preeminent example of large numbers of students engaging in the work of scientists with the help of the Internet is the NASA-sponsored GLOBE project (de La Beaujardière *et al.* 1997). During the period of 1995–2005, 33 000 teachers were trained to support students in collecting countless data points of robust scientific data on Earth’s environment. The goal was to engage students in the enterprise of science and to collect data that would be used by professional scientists in their research. Even this massive effort, which now has substantial international participation, is dramatically changing its focus away from students collecting scientific data for scientists to use and toward students using data they collect or mine from databases, to doing scientific inquiry. In other words, the focus of science education in this instance has evolved from students memorizing scientific facts and formulas, to conducting hands-on activities, to collecting scientific data, and now to purposefully using data to design and pursue their own scientific questions.

There are scant few examples from the domain of planetary science, but there are some from the broader field of astronomy. One example of a data-based curriculum and data-access project is the *Sloan Digital Sky Survey-Sky Server* (http://cas.sdss.org/dr5/en/). This is an astronomical survey whose goal is to provide optical coverage of more than one fourth of the sky as well as a three-dimensional map of about a million galaxies and quasars. In *Sky Server*, a number of different learning activities are provided in basic, advanced, and challenge levels. There are opportunities for students to download data and create graphs, such as color-color diagrams. Data searches are performed via structured query language (SQL), a programming language for querying, modifying, and managing databases. Teacher’s guides are available on the site, but the only teacher training provided has been workshops such as AAPT and a few at the Wright Center. Approximately 100 teachers have been trained, but follow-up is difficult. Measurement of student use of the Websites is also difficult, as the projects only counts hits to the Websites, which number about 200-300 000 per month (80–85% are from the

United States, only a few hits coming through ".k12" addresses). The project leadership now believes that, although its initial materials were designed for undergraduate level, nonscience majoring students, much of the material was too difficult in that the prerequisite math skills and prior knowledge in astronomy was required. Concerted efforts are in place to revise these materials.

As another contemporary example, *Galaxy Zoo* (http://galaxyzoo.org) is an Internet-based public project to classify a million galaxies. It is similar to the dozen or so odd "citizen science" online projects that currently exist (*viz*., Mumford 2008). There are no special activities designed for students or teachers, but some teachers have students register individually to participate in the project. The total number of participants is known (100 000) and every galaxy has now been classified by more than 30 participants. However, there is no way to determine how many users are in educational settings until people start writing about specific projects in scholarly literature. It is reported by the project leaders that they observe through the online discussion forums that teachers want a way of regularly communicating with other teachers who want to use *Galaxy Zoo*, and that they are excited by the prospect of using real data in their classrooms. There have been no evaluations to date. In a similar way, the for-profit SLOOH.com provides citizens with access to real-time data gathering telescopes, but it is yet unclear if many teachers have found ways for students to become involved.

Although more related to earth science than planetary science, the NASA *S'COOL (Student Cloud Observations Online)* project helps K–12 students make cloud observations, which, if the site's data and processes are completed, support understanding of the impact of clouds in Earth's long-term climate and global climate change (http://asd-www.larc.nasa.gov/SCOOL/). Only a small fraction of the students making observations goes on to the next step with satellite matching data and comparing results for agreement. There may be other steps, which occur in classrooms that are not documented, such as graphing data for a given site. There are about 2,500 registrations but not all are active: there are about 300 active per month, and it is estimated that there are 25 students per registered teacher although the number varies depending on grade level. Developers did a couple surveys early in the program, but have done fewer evaluations in recent years due to the sunset of funding. The project leaders learned through this project that their participating teachers see connections to curriculum, but are not always aware of everything their site offers. Alternative language support for other languages has been requested and teachers' feedback is generally positive as seem to appreciate the project.

More recently the *MyNASA Data* project is making considerable progress in making NASA data about Earth, collected from space, accessible to K–12 teachers and students, who can explore the data using scientific inquiry and math skills (http://mynasadata.larc.nasa.gov/). There is a live access server to assist teachers in discovering data to help teach concepts, and there is an e-Mentor network to get and give help. Most importantly, the scientists who contribute data to the project have formatted their data into formats easy for most spreadsheet programs to manage. Lesson plans and tutorials are available. The project leaders have had the most success using a summer teacher-workshop model for the past three summers where about 20 teachers per year were trained. The leaders are, like many similar projects, unsure how many teachers use the site as they can only track Web stats, which show about 6,000 distinct users per month. They are currently working with an external evaluator to create and deliver a Web-based survey.

In terms of using telescopes directly, the *ARBSE—Astronomy Research Based Science Education* (formerly known as TLRBSE) is designed to help teachers become master teachers in research-based science education and provides opportunities for high school students to do authentic astronomical research. Initially funded by the NSF, this project has an ongoing distance-learning program and a 10-day summer workshop at Kitt Peak. There are about 16–18 teachers in the program per year. It is unknown how many students participate in classes taught by these teachers, but the impacted students do show up occasionally in other evaluations if they pursued STEM careers (Slater *et al.* 2008). There has been external evaluation of the program, but assessments have focused on how to do better workshops, and refining specific workshop techniques as well as how to handle the course groupings, interactions, and work on the mountain. A similar program exists for teachers working with infrared astronomical data through the education and public outreach programs for the Spitzer Space Telescope.

Although more specific to physics than planetary science, but widely recognized nationally, the *QuarkNet* program (http://quarknet.fnal.gov/) is a project where high school students learn kinematics, particles, waves, electricity and magnetism, energy and momentum, radioactive decay, optics, relativity, forces, and the structure of matter through inquiry-oriented investigations. A particularly important subgoal of *QuarkNet* is to help students ask science questions that are well formed and manageable. Their goals for teachers include deeper understanding of physics content, appreciation of processes of science, and an introduction to inquiry-based teaching. *Quarknet* provides professional development and ongoing support for physics teachers who become involved with the program. Depending on how long a teacher has been involved with the program, professional development can take different forms including one-week workshops at Fermilab, three-week workshops at other research facilities, seven-week research appointments, and an e-mail listserve. *QuarkNet* staff have developed an online professional development method that adapts an e-Lab for adult learners.

Similarly, again not from planetary science but a nonetheless prominent example of high-quality data-projects for students, is the Annenberg Journey North Project (http://learner.org/north). This highly subscribed project has teachers and students contribute observation data characterizing how spring moves northward across North America. Students report observations of robins, eagles, humming birds, tulip blooms, butterflies, and whales to a central database. This work is not widely described in scholarly science education literature but seems to reflect the elements necessary for a high-quality program based on scientific inquiry and analysis.

As is evident from even this short, and certainly nonexhaustive, sample of some data-based inquiry projects available for students and teachers, the focus of effort has clearly been on creating pathways for students to access data. There generally has been insufficient effort and attention paid to high-quality curriculum materials and teacher training. Almost none of this appears anywhere in scholarly education literature, particular with any strong evaluation component. As a result, when the funding sunsets or the central people involved move on to other things, there is little systematic infrastructure for evolution and or continuation. For the broadest possible community of teachers to adopt a practice, they need to know that the resources for it will be there for years to come.

3. NEXT GENERATION OF DATA INVESTIGATIONS

If the next evolutionary step for science education genuinely is for students to engage in questions of their own design, develop their own strategies to pursue data, and communicate their ideas based on data they have collected or analyzed, then planetary scientists have the opportunity to be first in line to assist in filling the data pipeline for science education. Planetary scientists already seem to have the scientific community's most complete data pipeline through the Internet (Slater and Beaudrie 1997; Slater 1998). This is more than just a reflection of the way planetary scientists conduct their science; it represents a commitment to making scientific data publically available.

The 21st century information-age within which we live and work demands very different knowledge and skills than the 20th century days gone by (Partnership for 21st Century Skills 2007). Foremost is that there are just far too many scientific facts one could try to memorize. As an example, if a student of 20 years ago was asked to write a report about the planet Neptune, the most common strategy would be to go to the school library and select the "*N*" volume from the school's encyclopedia set and start copying information by hand. In fact, the difficulty of such a research writing assignment for a middle school student might have increased tenfold if the teacher's requirements had challenged students to utilize three different resources. A student of today, however, might use their Web-enabled cellular telephone "to Google" (using the grammatical infinitive form of Google) the query the term "Neptune" and about 20 800 000 Web pages mentioning Neptune become instantly available. In short, whereas teachers once taught students to find and combine disparate resources; contemporary teachers need to teach students the very different skill to synthesize enormous amounts of relevant information. In other words, today there is simply too much information that one could try to memorize when the real educational goal is how to access, manage, and synthesize information that did not yet exist only several short years ago. More importantly, even if one could achieve memorizing a sufficient number of scientific facts and formulas, disconnected knowledge is of little value. As predicted several decades before by Naisbitt (1984) in *Megatrends*, "We are drowning in information, but starved for knowledge. …Uncontrolled and unorganized information is no longer a resource in an information society, instead it becomes the enemy."

Learning and understanding science today means having knowledge and understanding that can be used flexibly in a data-filled world to critical analyze ideas and know where and when to use a scientific approach. To achieve this, the NRC's *Taking Science to Schools* reform document clearly specifies that students learn science best when it is richly characterized by repeated engagements along four lines throughout schooling (Duschl, Scheingruber, and Shouse 2007). These four, interwoven strands state that students who are proficient in science:

a. know, use, and interpret scientific explanations of the natural world;
b. generate and evaluate scientific evidence and explanations;

c. understand the nature and development of scientific knowledge; and
d. participate productively in scientific practices and discourse.

It is in this context of science education reform based on students engaging in scientific inquiry that we have designed our survey in order to understand the current state of how teachers are using data for science education and to provide guidance to planetary scientists who want to use their limited time and resources in support of improving K–12 science education.

4. SURVEY DESIGN

4.1. Participants

To pursue these issues summarized above and to gain insight into how to position planetary scientists to support the next generation of science education reform, we designed an online survey for K–12 teachers. The survey asked K–12 teachers to identify the extent to which they use planetary data to help students learn science, to articulate what barriers they face in using data, and how to close the gap between what is currently being done and what could be done with the appropriate resources. In order to obtain actionable information, we decided to pursue those individuals informally called "alpha teachers"—teachers that are highly effective, quick to respond to innovation, and rather ambitious in their pursuit of resources for themselves and their students. Alpha teachers aggressively pursue professional development opportunities and tend to function as agents of change in their schools, serving as bellwethers for science education. If an innovation is not adopted by these teachers, it is reasonable to assume that average teachers have not adopted it either.

4.2. Solicitation of Participants

Solicitations for survey participation were sent out through an electronic posting to the 565 members of the *astroed_news* Yahoo!Group with a personal appeal to participate from the group founder and moderator, who is the second author of this paper. A subset of these participants forwarded the solicitation on to other online Earth/Space Science education forums in which they participate, resulting in the total number of unique respondents exceeding the number in the solicited group. The 33 item survey was administered anonymously via the Internet using the infrastructure at www.surveymonkey.com. Survey participation and results were frequently monitored and analyzed. After three months the variance in the data stabilized and the survey instrument was taken offline.

4.3. Demographics of Participants

The findings reported here are based upon submissions by a nonrandom sample of 799 teachers representing 47 states (not all teachers responded to all items). Fifty-four percent teach in suburban areas, with the remainder evenly split between rural and urban areas, a breakdown that closely mirrors the distribution of teaching assignments nationwide. Eighty-nine percent of respondents teach either middle or high school. Eighty-eight percent of respondents have four or more years of experience, and 50% of the total spend more than half of the school year engaged in teaching Earth System Science (ESS) content. Most notably, all participants for this survey have engaged in ESS professional development activities, are active members in ongoing, online discussions concerned with the topic of quality ESS education, and were willing to spend time completing this survey at the beginning of the school year, a period in which teachers' time is at a premium. Collectively these factors indicate that these teachers are those who are most likely to be engaged in bringing ESS resources into classrooms from a position of comfort with technology and a strong background in content and pedagogical content knowledge. We judge our survey participants to be our desired population of alpha teachers. We believe that these demographics indicate that the participants represent a reasonable sampling of teachers nationwide and those teachers who are likely to serve as the target population for curriculum developers and those engaged in education and public outreach.

In reporting our findings, data from all participants have not been disaggregated. Our goal is to provide an encompassing snapshot of teacher practices and attitudes toward using online data sources in their classrooms. While an in-depth analysis of the data focused on the goal of illuminating differences between subsets of teachers will be reported in a subsequent paper, it should be noted that our initial analyses of the data do not indicate important differences between many potential subgroups, an interesting finding that may likely be due to the homogeneity of the population targeted. Contrary to what one might expect, our survey results indicate that there are no significant differences in data use between elementary, middle school, and high school alpha teachers, when considering the sources of data that they choose, the frequency with which they engage their students in data-based inquiry, and the structure of the types of inquiry that they choose.

5. RESULTS

The data from the survey were analyzed using two different methods, dependent upon the data type in question. Demographic data and data from forced-choice, Likert-type prompts were analyzed using descriptive statistics. A table is provided highlighting some of the most interesting quantitative results. Data from open ended responses were analyzed qualitatively. First, all responses were reviewed in order to develop an inductive coding system. All responses were then coded and binned in naturally recurring themes.

Teacher survey results: frequency for analyzing Earth and space science data.

How frequently do you ask students to analyze each of the following types of Earth and space scientific data each year?

	Rarely, if ever	One to five days each year	Five to 30 each year	Thirty or more days each year	Response count
a. Data students collect themselves (e.g., online weather station data, sample water pH levels, or GLOBE protocol data)	26.7% (185)	32.6% (226)	29.3% (203)	11.5% (80)	694
b. Hard-copy printed image data (e.g., color lithographs of planetary surfaces or static photographs of hurricanes)	25.0% (173)	38.6% (267)	29.9% (207)	6.5% (45)	692
c. Internet-delivered images (e.g., Ástronomy Picture of the Day and real-time satellite images of forest fires)	18.6% (128)	30.4% (210)	35.4% (244)	15.7% (108)	690
d. CD-ROM based data sets (e.g., virtual tours or ocean current models)	45.6% (313)	31.6% (217)	20.1% (138)	2.6% (18)	686
e. Large Internet-based scientific data sets (e.g., My NASA Data, Sloan Digital Sky Survey Data, and earthquake, volcano, or stream flow records)	43.3% (298)	33.2% (229)	19.2% (132)	4.4% (30)	689
f. Real-time Internet-based scientific databases (e.g., weather underground.net or SOHO images of Sun)	37.5% (259)	35.0% (242)	20.0% (138)	7.5% (52)	691
g. Data from virtual	47.4% (324)	31.0% (212)	17.3% (118)	4.4% (30)	684

How frequently do you ask students to analyze each of the following types of Earth and space scientific data each year?

	Rarely, if ever	One to five days each year	Five to 30 each year	Thirty or more days each year	Response count
telescopes or virtual simulator software (e.g., Starry Night or Earth Browser programs)					
	n=				696

Teacher survey results: frequency for analyzing Web site data.

How frequently do you ask students to analyze data from each of the following Web sites each year?

	Rarely, if ever	One to five days each year	Five to 30 days each year	Thirty or more days each year	Response count
a. Data from live Webcams	68.1% (468)	24.7% (170)	5.7% (39)	1.5% (10)	687
b. Data from remotely controlled telescopes	75.8% (517)	18.5% (126)	4.1% (28)	1.6% (11)	682
c. Data from GoogleEarth.com	36.7% (252)	39.9% (274)	19.1% (131)	4.2% (29)	686
d. Data from GoogleSky.com	64.8% (438)	25.9% (175)	8.3% (56)	1.0% (7)	676
e. Data from USGS.gov	37.3% (255)	38.1% (260)	18.9% (129)	5.7% (39)	683
f. Data from Volcano World	65.5% (447)	23.9% (163)	8.7% (59)	1.9% (13)	682
g. Data from DLESE.org	80.6% (546)	13.0% (88)	5.2% (35)	1.2% (8)	677
	n=				691

Teacher survey results: barriers to analyzing Earth and space science data.

Which of the following are perceived barriers to inquiring about and analyzing authentic Earth and space science data?

	Not really a barrier	Somewhat of a barrier	A great barrier	An immense barrier to success	Response count
a. The state science assessment tests require too many topics to be covered	17.9% (112)	31.7% (199)	30.9% (194)	19.5% (122)	627
b. A lack of training in how to use authentic science data in the classroom	12.8% (82)	34.7% (222)	37.8% (242)	14.7% (94)	640
c. Difficulty in finding enough appropriate datasets	21.0% (133)	39.2% (248)	31.4% (199)	8.4% (53)	633
d. Overwhelmed by	31.5% (198)	38.3% (241)	22.6% (142)	7.6% (48)	629

Which of the following are perceived barriers to inquiring about and analyzing authentic Earth and space science data?

	Not really a barrier	Somewhat of a barrier	A great barrier	An immense barrier to success	Response count
too many appropriate datasets or software analysis tools					
e. Difficulty in finding easy to use software analysis tools	11.9% (75)	37.2% (235)	38.8% (245)	12.0% (76)	631
f. The excessive length of time it takes students to complete an authentic scientific inquiry	11.0% (70)	29.4% (187)	40.6% (258)	19.0% (121)	636
g. Lack of expert mentors who can help individual students	13.1% (83)	33.9% (214)	35.6% (225)	17.4% (110)	632
h. Insufficient data resources or Web sites or equipment that students can access and/or use	26.7% (170)	33.4% (213)	26.1% (166)	13.8% (88)	637
i. Lack of high-quality student work samples for other students to emulate	17.2% (109)	42.9% (271)	30.4% (192)	9.5% (60)	632
j. Difficulty in finding ways to appropriately include research activities in determining students' overall grades	31.0% (196)	40.3% (255)	21.3% (135)	7.4% (47)	633
					$n = 640$

The teachers who responded to this survey seem to be quite aware of and adept at accessing a wide variety of online resources for classroom use. When asked to identify the ESS online resources that they access five or more days per year, the three most commonly cited Web sites were USGS.gov (25%), GoogleEarth (23%), and Volcano World (11%). Other online resources are used far less frequently: Digital Library for Earth Science Education (DLESE) (6%), live Webcams (7%), and remote telescopes (6%). This should not be interpreted as teachers not using online resources; rather, there seems to be no broad consensus on which should be used. When asked to identify useful online data sources other than those provided in the survey instrument, respondents identified 56 unique online resources beyond those provided by question prompts. Web sites most repeatedly listed without prompting were www.weatherunderground.com, www.spaceweather.com, and www.noaa.gov.

This variety of responses suggests that these teachers are clearly knowledgeable about the online resources available to them. However, at the same time, it appears that they rarely use online or CD-ROM-based data sets for authentic scientific inquiry and analysis in the classroom. Survey results indicate that the educational products most often used are images and lithographs that teachers either access and project as real-time data or print as hard copies for student use. Examples of these types of data would include astronomy picture of the day and real-time satellite images of forest fires or weather systems. Fifty-one percent of teachers reported using these types of data five or more days per year. Sixty percent of the total report that they engage their students in creating data sets or retrieving data from online sources less than five days per year. Examples of this type of activity include having students collect and graph weather data on a particular city or chart the latitudes and longitudes of active volcanoes. Less than 25% of teachers report that they use digital data in forms such as large WWW data sets (e.g., Sloan, Digital Sky Survey, stream flow records), real-time data (e.g., SOHO images of the Sun), virtual telescopes (e.g: Earth Browser), or CD-ROM-based data (e.g.: virtual tours, ocean current models) with their students five or more days per year.

When these teachers do engage students in the use of online data, they employ a variety of instructional techniques, ranging from teacher talk to various stages of inquiry. This is consistent with the notions of "faded scaffolding" that effective teachers frequently engage their students in learning cycles that scaffold the acquisition of content knowledge and inquiry skills (McNeill *et al.* 2006). One surprising finding from our survey is that 89% of surveyed teachers report that they rarely or never use available ESS data to engage their students in the most open and authentic forms of inquiry. Similarly, 73% rarely have students use online data to engage in guided inquiry. Data indicate that the types of inquiry always or usually used by teachers are confirmation activities (37%) or structured inquiry (42%), in which students investigate the teacher-provided question, using a prescribed procedure. In order to uncover why these targeted alpha teachers do not readily use online data to engage in the most sophisticated inquiry techniques with their students, our future surveys and interviews may need to go beyond asking what they do and how often they do it, and begin probing the teacher thought processes that influence this important instructional decision.

Survey respondents did seem to be highly interested in providing inquiry learning experiences for their students. When asked about the use of inquiry instruction in their classrooms, 81% of ESS teachers stated that the amount of time allocated to inquiry in their classrooms is either not enough or wholly insufficient. At the same time, respondents stated that inquiry learning benefits their students in several key areas: preparing students to address complex, real-world problems and critically evaluate the validity of scientific evidence and data-based conclusions, teaching quantitative skills, technical methods and scientific concepts, and increasing students' verbal, written, and graphical communication skills. This is consistent with the qualitative results presented earlier by Manduca and Mogk (2003).

Overall, teachers did not perceive that teaching by inquiry increases students' scores on state and national standardized tests. When questioned about barriers to using inquiry in the classroom, 51% of respondents stated that the number of topics covered by state assessments is a great or immense barrier. The other most frequently stated barrier is the perceived amount of time required to teach students to analyze and inquire using authentic data. It seems plausible to argue that these two barriers are really just two sides of the same coin. In the age of teacher-centered accountability, the desire to have their students perform well on standardized assessments seems to overpower these teachers' beliefs in the benefits of teaching by inquiry.

When asked to name one thing that scientists could do to help increase the amount of time in which students engage in analyzing authentic ESS data in the classroom, teachers' responses converged in several clear themes. We will briefly present efforts that teachers did not view as critically important, followed by a more extended discussion of teachers' self-reported needs.

Two commonly proposed and funded educational interventions are programs that involve original student-driven research and the engagement of scientists in K–12 classrooms. The results of this survey do not support these two efforts. These alpha teachers stated that most students do not benefit from programs designed to involve students in producing original, publishable research. One participant framed this perspective succinctly: "We do not need students to engage in original research. Resources that would provide data and tools to allow students to replicate existing research would be better for 98% of students." In addition, participants did not state a desire for programs that focus on bringing scientists into the classroom. Only one teacher stated a belief that this type of assistance was important. Many programs and scientists quickly exhaust their scarce resources by visiting classrooms based on a common unexamined belief that visiting classrooms will have a powerful and lasting impact on student learning. This perspective is not supported by the responses of nearly 800 teachers. We realize that these results may be in direct conflict with the types of programs that the authors of this study and that many readers are intimately familiar with. It is not our intention to make blanket statements about such programs, but we feel that it is important to include this observation if we are to objectively report our findings.

Overwhelmingly, teachers pleaded for assistance in narrowing the content coverage of their particular state standards. Bybee and Morrow (1998) point out that advocacy in education by planetary scientists is an important role for scientists—one that is all too often overlooked. While planetary scientists may not normally engage in the arena of education politics, this survey result deserves mention here as it emphasizes that teachers need external support if they are to focus on pedagogically sound, legitimate alignment with standards on all educational products.

When addressing the issue of educational products, teachers clearly stated ways that curriculum materials could be improved for classroom use in several ways. As stated previously, data set curriculum materials that make extensive use of authentic scientific planetary data sets should legitimately align with standards. In addition, participants requested that scientists begin to target their efforts toward the middle school setting. This recommendation is in line with the sequence of science courses across the nation. In most school districts, earth science is rarely taught beyond eighth grade, and when it is taught in high school, it is usually offered as an elective. Instead planetary science content material is sprinkled across the elementary standards with a year of ESS offered in the middle school years. One pragmatic argument would be that if scientists are going to engage in interventions that will impact the greatest number of students, they should gear their efforts toward those middle grades in which those interventions will have the greatest likelihood of being used.

In addition to scope and sequence issues, participants offered recommendations with regard to the structure of online data-based curriculum materials. These responding teachers report that the time required to find quality online materials is excessive. While there have been some Herculean attempts to aggregate widely displaced curriculum materials, there is some feeling by in-service teachers that using these meta-Web sites is akin to searching through a rabbit's warren of hyperlinks. Materials must also be easy for students to access in terms of formatting. Given the large amount of content they are expected to cover in the course of a year, teachers stated that they cannot spend time teaching students how use a software package that is limited in scope. Data sets delivered in familiar formats, such as Excel spreadsheets, are more sensible. When considering how to utilize these data sets teachers find that technology, most notably graphing software and data set formatting, hinders their ability to use data sets in student inquiry. In particular, teachers noted that they need graphing tools for students that are much easier to use. User-friendly imaging programs that allow the construction of 3D models are lacking. This may be a particularly important issue to consider given the highly spatial nature of many concepts in astronomy and the earth sciences.

Teachers also stated that data would be more manageable for classrooms if it could be packaged in limited sets. These alpha teachers reported that large, unsorted data sets are overwhelming for teachers and students alike. Teachers and students have a tremendous load of science topics that they must cover to meet state standards. If they are going to use authentic data for inquiry purposes, they must focus on data that allow students to construct key scientific concepts identified by their curriculum. They reported it would be helpful to sort data into sets that are associated with key concepts that must be covered, with recommendations for ways in which the data sets might be used. Specifically, they requested meta-tags with the core concept addressed by the data set, an introductory conceptual question that might be answered with each data set, and additional questions that might be used to further investigate that concept.

Finally, teachers desire three specific types of training. First, teachers believe that they would benefit from additional content knowledge. In particular, graduate courses delivered online are highly likely to attract a teaching population that struggles to juggle multiple demands. Given that the majority of K–12 science teachers have degrees in areas other than ESS, and that content knowledge supports the inquiry process, offering content courses may be fruitful. Further, teachers stated a desire for professional development that would hone their personal inquiry skills and provide training in how to scaffold the inquiry experiences for their students.

6. CONCLUSIONS

The findings presented here strongly suggest there is an important role for planetary scientists in helping create access to authentic data sets for inquiry-oriented instruction, particularly in the middle school grades. Teachers we surveyed reported that they know of many online Web sites to find authentic data, perhaps bordering on too many different places. However, at the same time, teachers are overwhelmed by what is available considering their lack of time to learn "yet another software package." It seems that the best course of action is to recognize that the high leverage point for planetary scientists is to reduce and simplify the solution space. As one pointed suggestion, the My_NASA_Data project might have the most promising model because it asks for scientists to provide their data in comma delimited forms that can be easily analyzed by simple spreadsheet programs. Unfortunately, at the present time, most of the scientific data at My_NASA_Data is only distantly tied to concepts in state standards. In the end, teachers, planetary scientists, and, of course, students, really want and need the same thing—simple access to easy-to-understand and -analyze data sets and, at the same time, they plead for fewer and less diverse solutions than they are currently being offered.

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Appendix

CLASSROOM SCIENCE TEACHER SURVEY

Teaching with Earth and Space Science Data

This short survey is designed to help planetary scientists determine how to best provide resources and materials to teachers to support Earth and space science teaching with authentic science data. The survey is completely anonymous—your responses are never associated with your name. There are no known risks or benefits nor financial incentives to complete this survey. It should take less than 10 min to complete. Thank you for your valuable input!

Page I of III: Demographic Information				
Which grade range do you most frequently teach?	PreK-4 ❍	5-8 ❍	9-12 ❍	Other/All/NA ❍
How many years have you been teaching science?	1-3 years ❍	4-10 years ❍	More than 10 years ❍	None/NA ❍
In which state did you teach last year?				

What type of school did you teach in last year?	Urban ❍	Suburban ❍	Rural ❍	Other/NA ❍
Did you teach at school designated as a NASA Explorer School last year?	Yes ❍	No ❍	Unknown or N/A ❍	
Do you allocate more than half of each year to teaching EARTH and/or SPACE science topics?	Yes ❍	No ❍	Unknown or N/A ❍	

Page II of III: Frequency of Earth and Space Science Data for Student Investigations

How frequently do you ask students to analyze each of the following types of EARTH and SPACE scientific data each year?	Rarely, if ever	One to five days each year	Five to 30 each year	30 or more days each year

a. Data students collect themselves (e.g., online weather station data, sample water pH levels, or GLOBE protocol data)	❍	❍	❍	❍
b. Hard-copy printed image data (e.g., color lithographs of planetary surfaces or static photographs of hurricanes)	❍	❍	❍	❍
c. Internet-delivered images (e.g., Astronomy Picture of the Day and real-time satellite images of forest fires)	❍	❍	❍	❍
d. CD-ROM based data sets (e.g., virtual tours or ocean current models)	❍	❍	❍	❍
e. Large Internet-based scientific data sets (e.g., My NASA Data, Sloan Digital Sky Survey Data, and earthquake, volcano, or stream flow records)	❍	❍	❍	❍
f. Real-Time Internet-based scientific databases (e.g., weather underground.net or SOHO images of Sun)	❍	❍	❍	❍

g. Data from virtual telescopes or virtual simulator software (e.g., Starry Night or Earth Browser programs)	❍	❍	❍	❍
How frequently do you ask students to analyze data from each of the following web sites each year?	Rarely, if ever	One to five days each year	Five to 30 each year	30 or more days each year
a. Data from Live WebCams	❍	❍	❍	❍
b. Data from remotely controlled telescopes	❍	❍	❍	❍
c. Data from GoogleEarth.com	❍	❍	❍	❍
d. Data from GoogleSky.com	❍	❍	❍	❍
e. Data from USGS.gov	❍	❍	❍	❍
f. Data from Volcano World	❍	❍	❍	❍
g. Data from DLESE.org	❍	❍	❍	❍
In the space provided, please list any other				

EARTH and SPACE science data sources your frequently ask students to analyze.				
When you do use online data with students in the classroom, how often do you do the following?	Rarely, if ever	Sometimes	Usually	Almost always
a. Teacher shows students the data and teacher explains it	❍	❍	❍	❍
b. Teacher shows students data and gives students procedures for how to graph or analyze the data	❍	❍	❍	❍
c. Teacher poses questions for students and then students design their own procedures to graph or analyze the data	❍	❍	❍	❍
d. Students pose their own questions to answer from the data	❍	❍	❍	❍
e. Students design their own questions then pursue additional data to answer their own questions	❍	❍	❍	❍

Page III of III: Benefits and Barriers to Students Analyzing EARTH and SPACE Science Data

In your professional opinion, how valuable is the TIME do students in your classes spend inquiring about and analyzing EARTH and SPACE science data?	More time is spent than is really necessary	Just about enough time	Not enough time is allocated to this	Wholly insufficient
	❍	❍	❍	❍

Which of the following are perceived BENEFITS to inquiring about and analyzing authentic EARTH and SPACE science data?	Not really a benefit	Somewhat of a benefit	A great benefit	Of immense benefit & value
a. Increases students' state assessment test scores	❍	❍	❍	❍
b. Prepares students to address complex, real-world problems	❍	❍	❍	❍

c. Develops students' ability to use scientific methods and processes	❍	❍	❍	❍
d. Prepares students to critically evaluate the validity of scientific evidence	❍	❍	❍	❍
e. Prepares students to critically evaluate data-based conclusions	❍	❍	❍	❍
f. Teaches quantitative skills, technical methods, and scientific concepts	❍	❍	❍	❍
g. Increases students' verbal, written, and graphical communication skills	❍	❍	❍	❍
h. Trains students in the values and ethics of working with scientific data	❍	❍	❍	❍
i. Encourages students to compete in science fairs	❍	❍	❍	❍
Which of the following are perceived BARRIERS to inquiring about and analyzing authentic EARTH and SPACE science data?	Not really a barrier	Somewhat of a barrier	A great barrier	An immense barrier to success

a. The state science assessment tests require too many topics to be covered	❍	❍	❍	❍
b. A lack of training in how to use authentic science data in the classroom	❍	❍	❍	❍
c. Difficulty in finding enough appropriate datasets	❍	❍	❍	❍
d. Overwhelmed by too many appropriate datasets or software analysis tools	❍	❍	❍	❍
e. Difficultly in finding easy to use software analysis tools	❍	❍	❍	❍
f. The excessive length of time it takes students to complete an authentic scientific inquiry	❍	❍	❍	❍
g. Lack of expert mentors who can help individual students	❍	❍	❍	❍
h. Insufficient data resources or websites or equipment that students can access and/or use	❍	❍	❍	❍

i. Lack of high quality student work samples for other students to emulate	❍	❍	❍	❍
j. Difficulty in finding ways to appropriately include research activities in determining students' overall grades	❍	❍	❍	❍
If there was a single thing that professional scientists could create to dramatically increase the amount of time students engage with analyzing authentic EARTH and SPACE science data in the classroom, what would it be? *Please enter your response in the space provided.*				
CONSENT: Please press DONE when finished. Pressing DONE indicates that you have read and understood the description of the study and you agree to participate. Thank you for your time!	**DONE**			

References

American Association for the Advancement of Science 1993, *Project 2061: Benchmarks for Science Literacy*, Oxford: Oxford University Press.

Bell, R. L., Smetana, L., and Binns, I. 2005, "Simplifying Inquiry Instruction," *Sci. Teach., October 2005,* 30.

Bybee, R., and Morrow, C. A. 1998, "Improving Science Education: The Role of Scientists," in *Newsletter of the Education Forum of the American Physical Society*, Fall 1998.

de La Beaujardièrel, J-F., Cavallo, J., Hasler, A. F., Mitchell, H., O'Handley, C., Shiri, R., and White, R. 1997, "The GLOBE Visualization Project: Using WWW in the Classroom," *J. Sci. Educ. Technol.,* 6, 15.

Duschl, R., Scheingruber, H., and Shouse, H., eds. 2007, *Taking Science to Schools. Learning and Teaching Science in Grades K-8*, Washington: National Academy of Sciences.

Friedman, T. L. 2006, *The World is Flat*, New York: Farrar, Straus and Giroux.

Goodstein, D. L. 1993, "Scientific Elites and Scientific Illiterates," *Proceedings from Sigma Xi Forum, Ethics, Values, and the Promise of Science*, Research Triangle Park, NC: Sigma Xi, The Scientific Research Society.

Lopez, R. E., and Schultz, T. 2001, “Two Revolutions in K–8 Science Education,” *Phys. Today,* 54, 44.

Manduca, C. A., and Mogk, D. W. 2003, *Using Data in Undergraduate Classrooms*, Northfield, MN: Science Education Resource Center.

McNeill, K. L., Lizotte, D. J., Krajcik, J., and Marx, R. W. 2006, “Supporting Students’ Construction of Scientific Explanations by Fading Scaffolds in Instructional Materials,” *J. Learn. Sci.,* 15, 153.

Mumford, G. 2008, “Astronomy@Home,” *Astron. Educ. Rev.,* 7, 103.

Naisbitt, J., Light, G., Weder, J., and Bartlett, L. 1984, *Megatrends*, New York: Warner Books.

National Research Council 1996, *National Science Education Standards*, Washington, DC: National Academies Press.

Partnership for 21st Century Skills 2007, *Learning for the 21st Century*, Washington, DC: Partnership for 21st Century Skills.

Slater, T. F. 1998, “Using Real-Time Earth and Space-Science Data in the Classroom,” *Leading and Learning with Technology Journal,* 26, 28.

Slater, T. F., and Beaudrie, B. 1997, “Using the Internet to Bring Authentic Science Investigations to the Classroom,” *Leading and Learning with Technology,* 25, 28.

Slater, T. F., Beaudrie, B., Cadtiz, D. M., Governor, D., Roettger, E. R., Stevenson, S., and Tuthill, G. F. 2001, “A Systemic Approach to Improving K–12 Astronomy Education Using NASA’s Internet Resources,” *Journal of Computers in Mathematics and Science Teaching,* 20, 163.

Slater, T. F., Slater, S. J., Bailey, J. M., and Williams, J. P. 2008, “Transforming an REU Program from Good to Great: Lessons Learned from External Evaluation,” oral presentation (31.05) presented at 211th Meeting of the American Astronomical Society, Austin, TX, January 2008, *Bulletin of the AAS*, 39.

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