Chapter 28

NASA Press Releases and Mission Statements: Exploring the mathematics behind the science.

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Abstract

NASA press releases contain a wealth of quantitative information and understated mathematics, which can be used to stimulate student interest in mathematics and science. Students are often curious about space themes, such as the search for extraterrestrial life, black holes, or space exploration. For this reason, press releases about discoveries in space make mathematics relevant and interesting to students beyond the mundane application problems so common in modern-day mathematics textbooks.

The overarching goal of the *SpaceMath@NASA* program is to assist students in seeing the mathematics behind the scientific discovery. We will describe this program and how we 'reverse-engineer' press releases to uncover the often simple mathematics suitable for on-grade-level learners in grades 3-12.

Key Words: Mathematics problems; space; astronomy; press releases; newspapers; applied mathematics; education; STEM curriculum

Bridging the science and math gap

In 2000, the National Commission on Mathematics and Science Teaching for the 21st Century published a provocative report '*Before it's Too Late*', which called the preparation of U.S. students in math and science unacceptable, and made the points that 1) If the U.S is to remain competitive in an integrated global economy, they must improve their math and science performance, and 2) the most direct route to improving student performance is through better teaching. This led, in 2001, to the No Child Left Behind Act (NCLB), which was intended to apply rigorous achievement goals to the nations schools. Schools that failed to meet the targeted test results (called Adequate Yearly Progress) in math, reading and science were subjected to increasing penalties. By 2014, all students in the United States must attain specific, challenging, math and science goals to be determined by each state. Each student will be subjected to frequent assessments, and teachers will be required to systematically improve classroom performance on these assessments while the performance goals continued to increase each year to meet the 2014 national deadline. But this test-based approach to excellence had its unfortunate, but perhaps inevitable, consequence. According to Cramond and Fairweather (This book, Chapter 24) *'…Educators caught in the push for basic skills and high-stakes testing lament that they cannot teach to the standards and [at the same time] teach students to be innovative too*"

As this environment of 'teaching to the test' became fully entrenched, some educators and scientists felt that it was actually adversely impacting student performance and understanding of science. Reading and math goals were comparatively easy to measure, but science is far more than just the memorization of facts. According to Tugel (2004, p. 1), NCLB has emphasized the performance in reading and math with the "…*unfortunate consequence of further marginalizing science in some districts, particularly at the elementary level.* According to Hazelwood (2005, p.9) the direct consequence of this trend is that *"Many schools are now looking for ways to bring science back into the spotlight and the core curriculum*". Many school systems have actually reduced their science content, and are now struggling to find ways to reintroduce science into the curriculum, but at the required levels mandated by NCLB (Lord, 2006).

One of the suggested ways is by connecting science with language arts to emphasize how science and literacy are interdependent (Tugel, 2004). A variety of popular classroom approaches to science education were analyzed by Fensham(2006), who identified a number of common elements. Students responded very well when science was presented as a 'story' involving people, situations and action. They particularly enjoyed the real-world situations that formed the core of the science or technology, and the science was clearly presented, and had a larger context. In 2006, the Programme for International Student Assessment (PISA) looked into the international context of student interest in science and found, not surprisingly, that the enjoyment of science in the early grades played a central role in their long-term career goals. (Ainley and Ainley, 2011). National surveys of parents and students are almost unanimous in their belief that demonstrating real-life applications in science can help make science education more interesting for U.S. students (Teaching with Contests, 2010), and that the internet should be used more extensively to make interesting science education materials available to teachers, and to help parents engage in their child's education. The challenge remains to find an inexpensive program that captures the positive elements of stimulating student interest, while complying with post-NCLB education standards that favor a cross-curricular approach to presenting subject matter.

The Sound of One Hand Clapping

Most scientists do not start out as mathematicians, but begin their formative years passionately pursuing some topic that interests them. These interests can include dinosaurs, rocks, insects, human anatomy, astronomy, space travel, science fiction, and yes even flying saucers! Yet, during the grade-school experience of most students and young scientists, mathematics is formally presented as a separate train traveling on different tracks than any developing curiosity about science topics. This dearth of mathematics in science-based topic areas changes rather dramatically when students suddenly encounter mathematics in high school chemistry and physics courses.

Despite the fact that students may have been operating at a very high level of sophistication in mathematics during their high school years, they had not been equally inspired to engage in the art of problem solving at a commensurable level. Even the problems they were assigned to puzzle over with their mathematical competencies were not even problems of their own choosing. They were problems assigned by a teacher or professor, and often contrived to lead to a specific answer in order to exercise a particular well-defined mathematics skill. As 'artists', they had acquired the finest oil paints, brushes and canvases, but never fully understood how mathematical problem solving techniques applied to the messy real world. They were certainly not encouraged to explore the art of problem solving on their own, so without the help of assigned application problems, students kept staring at blank canvases not really knowing what to do with their palette of mathematical tools.

Students are increasingly taught what might be consider ‘toolsmanship’ in mathematics, but are virtually left on their own to discover how to creatively solve real-world problems. Teachers call this ‘compartmentalization’ and remark , ‘*Why is it that my students can read a graph or ‘solve for X’ in Math Class, but one hour later in their science class they act as though they have never seen a graph or an equation before?*”

In fact, according to the very first sentence of the paper by Abbott and Nantz (1994, p. 22), '*In spite of much rhetoric and many adaptations of core curricula, one of the old problems still plagues us: students compartmentalize knowledge and fail to make lasting connections between subjects*." Clearly, compartmentalization of student's science and mathematics knowledge and skills is not surprising when viewed in this larger context. The challenge we face as educators is to find stimulating approaches that work in the classroom to break down these artificial walls.

The absence of math problems with obvious couplings to student’s interest in astronomy (or science in general) can be a hindrance to further development as a scientist. Students can fall into the trap of seeing mathematics as a rigid system of knowledge that does not easily map into the very messy and changing world around them. This fear of using mathematics playfully can make it difficult to understand how to launch a question and see a pathway to arriving at a mathematical answer, even in retrospect when the approach is very clear. There is nothing wrong with fitting data with an empirically-based regression formula, without any knowledge of the underlying physical reasons for that particular functional form.

For example, I recall in high school wanting to predict the position of a satellite of Jupiter on a given day from tabulated data provided in *Sky and Telescope* magazine. Even though a sinusoidal graph was provided in the magazine, I did not see how to extract the functional form of this sinusoid from the graph. My advanced math teacher told me it would require Fourier analysis; a topic that was understandably far beyond my skills at that time. Today I can look at that same graph and by simple visual inspection determine the amplitude, frequency and phase of the required sine function that adequately fits the data perfectly. I would have been thrilled to have had this insight available to me as a high school student. My teacher's advice was technically correct for an exact solution, but hopeless as a working first approximation, which was all I needed. Despirited in the apparent complexity of the problem, I put the project aside and never pursued creating my own ephemeredes for periodic astronomical events in our solar system. An important positive experience in the growth of an astronomer had been excised from my life.
How can you possibly teach this kind of a skill to children immersed in the modern teaching-to-the-test environment?

Following a long and happy career in astronomy, I had the luxury to return to these elementary issues as I began my second career at the National Aeronautics and Space Administration (NASA) as an ‘Education and Public Outreach Lead”. Doing more of the same science popularization at NASA seemed, quite frankly, a waste of my talents, especially at the elementary levels of discourse required to satisfy national education benchmarks in science. My unique skill as an astronomer was not that I could 'explain' stellar evolution or space weather to a middle school student. This could be done by reasonably articulate NASA educators without the benefit of a PhD in astrophysics. No, my unique skill was that I could easily see the mathematics behind the science content. It was this singular realization that completely re-directed my education efforts at NASA!

In 1997 we embarked on a program of creating math enrichment resources for students and teachers. The ones already available at NASA seemed to focus on below-grade-level learners, especially in middle and in high school. There seemed to be plenty of NASA education resources useful for math remediation, but no products for on-grade-level students, and certainly not at the high school level. We began to see how the modern situation in math and science education was strikingly parallel to what I had experienced first hand as a K-12 student over 40 years earlier. We were still teaching science shorn of its mathematical underpinnings in logic and data analysis, and conversely, mathematics shorn of the richness of its applications to science comprehension!

Through its many images, videos and on-line products, NASA has a huge resource base that can be called upon to stimulate student learning. What is astonishing is just how vast NASA's implicit mathematics resources are, and how very little of this has made its way into the hands of teachers. NASA primarily produces education resources to support science content education. Ironically for an institution such as NASA, where mathematics is so vital, the science content we produce for educators has been largely cleansed of its mathematical elements. This is often at the request of the teachers, themselves, who continue to be more interested in eye-catching and motivational products such as wall hangings. Ultimately, NASA tends to produce and distribute the products that teachers request. This continues to reinforce the idea that science and math are compartmentalizable subjects, which makes problem-solving that crosses the science-math threshold even more difficult to stimulate. Because problem-solving skills are so vital to student maturation as young scientists and engineers in STEM careers, a more aggressive approach may be called for. One of the best ways to get someone to learn a new skill is to ‘model’ that skill yourself!

In 1977, Stanford University psychologist Albert Bandura (1977) offered an interesting 'Social Learning' approach to learning and skill retention. In order for students to learn a new behavior, they must see that behavior modeled. *"Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do. Fortunately, most human behavior is learned observationally through modeling: from observing others one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action.* (Cherry, 2011). The impeccable logic of this observation appealed to me instantly.

Watching others carefully is, after all, how we learn to speak, dance and master thousands of other skills. Consciously or otherwise, we see how other people perform a skill, and then we mimic the behavior. A similar truism also applies to math education and problem-solving. We have to actively SHOW students the art of problem solving with mathematics before they 'get it', and make no mistake about it, problem-solving is an art form. It requires creativity, insight and inspiration to look into some aspect of the real world and parse what you see and know about it into a succinct, defining paragraph. It is also an art to turn a descriptive paragraph into a symbolic statement, and then to come up with the steps needed for solving the problem. Finally, problem-solving requires perseverance and constant checking, just as an artist spends hours getting a particular rose on a canvas to look exactly right. It is exactly in mastering this artistic skill of problem-solving that NASA can help the most!

Although children often profess an interest in space science, especially black holes and the search for 'aliens', ironically, mathematics textbooks only offer about 4% of their application problems in space-related subject areas. For example, the book *'Pre-Algebra'* by Glencoe Publishing has about 420 application problems of which only 12 are space-related, which is a space-related share of about 3%. Similar problem counts and percentages persist among algebra (4%) and calculus (4%) textbooks. The vast majority of the applications problems found in common US textbooks are in economics or other consumer-based topic areas. Since more than 2/3 of the US economy is based on consumerism and not on scientific or space research, this poor showing by space science in applications problems is perhaps not surprising. It does, however, reinforce the notion among students that scientists do not really need to know mathematics. This could directly support a misconception that claims made by scientists about, for example, global climate warming, evolution theory, or even big bang cosmogenesis are possibly not based upon a solid mathematical and logical foundations. All topics in science are, therefore, subject to linguistic debate as though science were an extension of a comparative literature class. Some students, and adults, may even subscribe to the extreme idea that science is ‘just another’ belief system. This stealthy misconception, that science and math are different enterprises, should be a real concern among science educators. Despite a passion for science as a highly-motivated child, a student can travel a long way in the curriculum and come into contact with virtually no examples of mathematics applied to science is a believable way. A similar 'desertification' of mathematics in space science persists today in the 21st century!

A Brief History

In 1997, the NASA, Imager for Magnetosphere to Auroral Global Exploration (IMAGE) satellite education program decided to create math enrichment resources for students and teachers rather than the traditional posters, bookmarks and other science content products. Initially, they began by developing math guides for middle school students covering topics in space weather; the area of research covered by the IMAGE mission. Between 1998 and 2003 the program produced *Solar Storms and You, Northern Lights and Solar Sprites,* and several other guides combining space weather topics with elementary math and geometry. The popularity of these guides soon led to the idea of posting a new math problem each week covering a different area of solar and space research. This online resource, *Space Science Problem of the Week,* featured unusual problems for middle school students in solar science, auroras, magnetic storms and occasionally astrophysics and planetary science topics too. The problems in a one-page format were eventually collected together into annual math guides beginning with *Exploring Space Science Mathematics*, followed by *Space Math I, Space Math II, Space Math III* and so on through *Space Math VII* in 2011. Teachers and NASA mission educators soon began to request collections of problems on specific topics to support their particular mission, so math guides such as *Solar Math, Earth Math, Black Hole Math* and other topics quickly followed.

Growing teacher interest and support for mathematics-related, real-world problems, has recently collided with the evolution of more test-oriented classroom environments even in middle school classrooms. In response to this trend, the IMAGE mission's *Space Science Problem of the Week* was redesigned after the loss of the IMAGE satellite in 2005 to include more targeted math resources. These resources involved 'one-page' math problems spanning the entire topic space of pre-Algebra and high school on-grade-level instruction, while offering an interesting science topic as the problem's theme.

The education program of the US/Japanese Hinode spacecraft stepped-in to continue this popular program. So, beginning in 2005, the Weekly Space Math program was officially re-named '*Space Math @ NASA*', with an entirely new website and domain name (http://spacemath.gsfc.nasa.gov). With the ending of the Hinode education efforts in 2009, *SpaceMath@NASA* became solely funded by NASA's Science Mission Directorate (SMD) through a series of 3-year education grants in 2008 and 2010.

By working in partnership with other missions, and with content areas in other NASA Directorates beyond SMD, we have succeeded in developing a broader spectrum of mathematics subject areas than what SMD missions normally consider. Currently, *SpaceMath@NASA* has incorporated images and data from SMD missions such as the Solar Dynamics Observatory, Mars Global Surveyor, Spitzer Space Telescope, Hubble Space Telescope, in addition to data on various aspects of radiation effects to humans (Exploration Systems Mission Directorate) and technology (SMD, Space Systems Mission Directorate, and the Aerospace Systems Mission Directorate).

Figure 1 about here

SpaceMath@NASA does much more than merely create ad hoc mathematics problems to articulate a specific science principle. Instead, we work closely with one NASA resource that is updated daily, and that has an enormous public distribution - its press releases! Thankfully, NASA press releases such as the one shown in Figure 2 are not stripped of their mathematical or quantitative content unlike the many other press releases and announcements that you might find in the news media. In addition to provocative and inspiring quotes from the researchers themselves, NASA press releases often contain numerical information, occasional graphs in many forms, and of course the dazzling imagery returned by its many satellites, spacecraft and astronauts.

Insert Figure 2 about here

All that one needs to do to couple the excitement of science discovery and space exploration with mathematics is to essentially reverse-engineer NASA press releases! There is good reason to think that this approach might be viable in bridging the gap between math and science education.

Can Newspapers be a Magic Bullet?

One common way in which students and parents come into contact with science is through the newspaper, or its electronic equivalent. The use of newspapers in the classroom is not, however, a new idea. Students who participate in these 'Newspapers in Education' (NIE) programs show a marked increase in reading competency, the ability to discriminate facts from opinions, and a heightened interest in current events (Rhoades and Rhoades, 1985 and Alex, 1988). A variety of Internet sites now provide extensive suggestions about how to use newspapers in the classroom in topics spanning the entire curriculum. Teachers increasingly find that newspapers help bridge the gap between the classroom and the 'real' world. They are extremely flexible and adaptable to all curriculum areas and grade levels, and they make learning fun. According to Vockell and Cusick (1995, p. 359), '*Newspapers give students the opportunity to apply skills used in the classroom and to be exposed to more up-to-date information than that found in textbooks"*.

DeRoche (1991) has also found that by 1990 approximately 3 million students and 16,000 schools were participating in the Newspapers in Education program, which is supported by nearly half of all domestic newspapers in the U.S.. Moreover, students have a measurably improved performance in reading, vocabulary development and content awareness as a result of frequent access to newspapers. '*On average, students who use newspapers in school scored 10 percent better on standardized reading tests, and a 29% increase in test scores was found among low-income, non-English speaking or minority students*" (Bruder, 2006, p. 1).

A few of the suggested math activities recommended by Newspapers in Education include having students locate 10 items in newspaper as and calculate the difference between the regular and sales price, have them scale up recipes for larger serving sizes, and follow stock activity by graphing daily share prices (NIE, 2011).

The *SpaceMath@NASA* program was expanded in 2009 to include mathematics problem supplements to many NASA press releases, based on previous successes with disseminating 'one-page' math challenges since 2004. By building on existing programs, and scientific data from across NASA's Science Mission Directorate, we have also succeeded in creating a new generation of space-related math problems and resource guides that support and enhance mathematics instruction. More importantly, *SpaceMath@NASA* dramatically shows students that mathematics is the key to a universe of new opportunities for thinking about the world around them.

Extracting Mathematics from Press Releases

Although originally designed to provide enrichment math problems in space science and heliophysics (our IMAGE legacy), NASA's involvement in space, and student's interests, are much broader in scope. *SpaceMath@NASA* has fully evolved to provide math problem content that covers the full spectrum of humanity's interest in the cosmos.

As described by Odenwald (2011,2012), problems are derived from a variety of 'breaking' topic areas and are often coupled directly to press releases posted on the NASA front page (http://www.nasa.gov) as shown in Figure 2. Once a press release appears, it is carefully read for content and a math problem is developed based on information or science content provided in the press release. These problems can include verifying quantitative information in the press release. No two press releases offer the same mathematical topics, so one has to be creative in reading these documents and deciding what the math element might be. We also take advantage of NASA videography, often posted on YouTube (http://www.youtube.com) to create problems related to speed and displacement, such as the one shown in Figure 3 involving the highly-publicized launch of the Space Shuttle Atlantis.

Insert Figure 3 about here

For other press releases and discoveries, it helps to be an astronomer to sort through the bewildering field of science and math concepts. There can be many different math principles camouflaged in the same news story, which is a boon to math and science teachers looking for 'extension' activities for more advanced students. It can also benefit students to see how one topic progressively leads to another! Here are a few elementary examples:

Problem 425: NASA Dawn Spacecraft Returns Close-Up Image of Asteroid Vesta

July 18, 2011 – "…*After traveling nearly four years and 1.7 billion miles (2.8 billion kilometers), Dawn also accomplished the largest propulsive acceleration of any spacecraft…*" Analysis: This is a simple speed = distance/time problem that students can solve to get an average speed for the Dawn spacecraft of 700 million km/year. This can be further converted into kilometers/day (1.9 million km/d) or kilometers/hour (80,000 km/hr) and compared to the Space Shuttle orbital speed of 28,000 km/hr.

Problem 402: NASA finds Earth-sized planet candidates in the Habitable Zone

February 2, 2011 - "…*The findings increase the number of planet candidates identified by Kepler to-date to 1,235. Of these, 68 are approximately Earth-size; 288 are super-Earth-size; 662 are Neptune-size; 165 are the size of Jupiter and 19 are larger than Jupiter. Of the 54 new planet candidates found in the habitable zone, five are near Earth-*

sized. A total of 156,435 stars were surveyed…" Analysis: Students can bar-graph the data by planetary size, then determine the percentage of Earth-sized planets in the full candidate sample (1235) that were in the Habitable Zones of their stars (5) to get 0.4%. As an extension, if it is assumed that the Milky Way contains 40 billion stars similar to the ones in the Kepler survey, students can estimate from (40 billion/156435)x0.004 that there are 1 million Earth-sized planets in the Milky Way that are in their Habitable Zones.

Problem 397: NASA Research Finds 2010 Tied for Warmest Year on Record

January 12, 2011 **–** "…*To measure climate change, scientists look at long-term trends. The temperature trend, including data from 2010, shows the climate has warmed by approximately +0.36 F per decade since the late 1970s*." Analysis: From the graph that accompanies the press release, students can determine the slope of the linear regression line through the data from 1970 to 2010 using a ruler, or the two-point formula. They can then determine the units for this slope in degrees Celsius per decade, then convert this to degrees Fahrenheit per decade using F = 9/5 C + 32 to confirm the value in the press release of +0.36 F/decade. As an extension, they can extrapolate this rate to the year 2050.

SpaceMath@NASA also develops problems outside the NASA press release pipeline when the particular story has considerable public interest. The British Petrolium Gulf Oil Spill of 2010 led to several problems for estimating the amount of oil generated by using the published live video stream from the oil well. These timely problems were extensively used by teachers to show how simple math can be used to make important estimates several weeks in advance of the official government-sanctioned numbers. In the aftermath of the Japan Tsunami of 2011, a number of problems were developed related to radiation issues including dosimetry, half-life and the hazards of interplanetary travel.

Although individual problems are published to the *SpaceMath@NASA* website through out the academic year (September-June), individual special-topic books are also designed concurrently. These books include end-of-the-year compilations of posted problems, as well as an increasing variety of special-topic books on topics as diverse as black holes, remote sensing and astrobiology. In many instances, these books have been requested by specific NASA education programs.

Insert Figure 4 about here

For example, the math resource book *Astrobiology Math* shown in Figure 4, was requested by the NASA Astrobiology Institute and will now be re-printed by them to serve the needs of their teacher workshop participants and interested students. *Transit Math* was requested by the Sun-Earth Day program to support their Transit of Venus theme in 2012. *Space Weather Math* was requested by the Challenger Learning Center to support their teachers and students in their continuing simulation of space operations experiences with technical accuracy in space weather forecasting.

Video

Recognizing that students are immersed in a multimedia world, in 2010, *SpaceMath@NASA* partnered with *NASA eClips* to create a series of video programs supplemented by math content. The *eClips* program has nearly 200 short-segment video segments lasting three to four minutes, and available online (http://spacemath.gsfc.nasa.gov/media.html) covering all aspects of NASA science and technology development and innovation. Thirteen episodes have been featured in a series of modules that identify math extensions to the video content in each program. Students are exposed to a topic presented with conventional fast-paced and visually interesting content, and are introduced to math problems that build upon one or two aspects of the program content. For example, the program '*Kepler: Earth-like Worlds*' describes the excitement of the search for earth-like planets, while the associated problems cover the statistics and elementary physics behind the exoplanet discoveries.

Insert Figure 5 about here

Impact

The popularity of *SpaceMath@NASA* has grown dramatically since 2008 as the figures below illustrate. We employ two monthly statistics to gauge the activity of the *SpaceMath@NASA* website: The number of unique Internet Provider addresses (called IP Addresses) and the number of PDF documents downloaded. Unique IPs, presented in Figure 5, is a measure of distinct identifiable visitors using separate computers, each with their own web address and is very helpful in assessing how large the population of visitors is. However, different people using the same computer are counted as one visitor, which underestimates the number of students visiting the website if only one or two computers are available in the classroom. The number of PDF files served is a direct measure of the activity of the website because the vast majority of the website consists of

434+ PDF files and over 30 PDF-formatted books. Figure 6 shows the number of monthly PDF files downloaded since 2008.

Insert Figure 6 about here

The trends clearly show that the number of users and downloaded documents increases by about 50% each year. In terms of cumulative problem requests since 2004, in February 2011, the 3 millionth PDF problem file was downloaded from this website. This was followed in September, 2011 by the 4 millionth.

We can also gauge visitor interest by assembling a list of the 'Top-20' items in each category. Table 1 lists the most popular individual problems in terms of the cumulative number of downloads between 2008 and 2011. The total number of downloads represented by these top-ranked problems is 215,619. This is about 9% of all one-page, individual problem PDF files downloaded from at *SpaceMath@NASA* during the same time period.

Insert Table 1 about here

Table 2 lists the most popular book-length files ranked by their cumulative downloads between 2008 and 2011. The total number of downloads represented by these top-ranked books is 467,494. This is about 84% of all book-length PDF files offered at *SpaceMath@NASA*. Since 2010, book-length resources have overtaken and surpassed the downloads of the top individual problems (compare Table 1 and 2).

Insert Table 2 about here

The rankings and 'shares' occupied by the problems and books indicate that visitors have a relatively narrow interest in math skills from unit conversion and scientific notation exercises, to problems involving distance, time and speed. However, the most popular problems only account for 5% of all problems offered, so taken as a whole, visitor interests really do span the entire gamut of math abilities and topic areas from basic numeracy and fractions to advanced calculus. In terms of book-length products, it is clear that the annual collections of the previous-years individual problems are very popular. This reflects the fact that it is more convenient and efficient to download the past-years problems in one batch (about 10 megabytes), rather than the 50-80 individual downloads. Moreover, the problem books all contain extensive explanatory text that provides additional science content information not found in the individual problems. It is of particular interest that, although the Algebra 2 book was only available in 2011, its cumulative downloads and ranking already exceeds book products such as *Black Hole Math,* which have been available since 2008. Clearly the creation of this high-school-level math guide with over 200 space and astronomy application problems was a significant and ultimately wise decision, and one that will be replicated in an upcoming pre-Algebra product for grades 6-8.

Assessments:

Since 2008, the Technology For Learning Consortium has conducted teacher and student evaluations using on-line surveys and written/email surveys targeted towards workshop participants. Multiple methods of data collection were utilized to assist in the evaluation of the *SpaceMath@NASA* project during the period from 2008-2011. The *SpaceMath@NASA* website web statistics were analyzed for usage, teachers utilizing the math books were surveyed, students whose teachers were utilizing the *SpaceMath@NASA* problems in the classroom were surveyed, and conference attendees were surveyed and interviewed.

The majority of educators who download application problems from the Internet are getting the ones they utilize directly from the *SpaceMath@NASA* website. The website has also improved users' impression of NASA's support of STEM education in a significant way. Consistently, users praise *SpaceMath@NASA* as a valuable and accessible resource.

We learned that teachers plan to use *SpaceMath@NASA* problems to introduce a math concept or science concept, for group problem solving in class, and as curriculum extensions. They report that the problems they have looked at so far will improve the math skills featured in the problem, help them be more effective in teaching STEM topics, align well with what they teach, increase their students' interest in STEM, and encourage student exploration, discussion, and participation.

Students reported they would like to do more problems of this kind, that it was easier to do the math problems because of the science content, and that they felt inspired to learn more about the math. As one student shared, "*Definitely worth having and completing for a greater understanding of space science and mathematics.*"

Most of the 300 educators who responded to the Annual Surveys since 2008 reported they are science teachers who use the problems to emphasize science content. About a fifth of the educators described themselves as math teachers and an additional one-fifth of the respondents indicated that they were informal educators. More than half of the teachers reported using the problems a few times a month, and that their students are productively challenging by *SpaceMath@NASA* problems. In particular, the educators noted in the surveys that their students enjoy the application problems and the topics they presented. The students were also asking questions about the problems that demonstrated curiosity and interest. There was also considerable anecdotal evidence in the surveys that students improved their academic performance as a result of working these problems, and were actually looking forward to exploring new problems! Perhaps just as importantly for the longevity and impact of *SpaceMath@NASA* is that all of the surveyed teachers reported sharing the problems with at least one other educator during the year.

Conclusions

Amidst the hubris of modern education practice and theory, it is sometimes helpful to consider the simple principles that stimulate learning. As an astronomer who had matriculated through the conventional K-12 system in the United States, I recognized the sources of stimulation to my own learning process. Through SpaceMath@NASA, we have created a resource that brings students into contact with thrilling, and timely, instances of genuine scientific discovery. These moments, captured in NASA press releases, are then used to explore relevant mathematical topics. The use of 'newspapers in education' has scored dramatic successes in other educational areas. We are hopeful that a similar approach using NASA press releases will ultimately foster the same kinds of successes in science and mathematics education.

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Figure 1 - The Home Page of SpaceMath@NASA showing some of its many features. (http://spacemath.gsfc.nasa.gov). Teachers may register at the website to gain access to over 25 space-related problem books, and over 400 individual math problems, all provided with answer keys to facilitate immediate classroom use.

Figure 2 - Front page of NASA (http://www.nasa.gov) dramatically showing a news announcement about the discovery of a planet orbiting two stars (September 16, 2011). SpaceMath@NASA published a series of math problem about this discovery three days later.

Space Shuttle Atlantis (STS-135) Launch Speed 8

This sequence of images shows the historic launch of the Space Shuttle Atlantis (STS-135) on July 8, 2011 at 11:29 a.m. EDT, from launch pad 39A at the NASA Cape Canaveral Space Center.

From bottom to top, the image times are 11:29:15.0, 11:29:16.0, 11:29:17.0, 11:29:18.0, and 11:29:19.0. The length of the space shuttle orbiter (not the red fuel tank) is 37 meters.

The launch sequence can be seen in the video located at:

Problem 1 - Using a millimeter ruler, what is the scale of an individual image in meters/mm?

Problem 2 - Measure the height in meters between the tip of the red shuttle fuel tank and a fixed location near the bottom of each frame.

Problem 3 - Graph the height of the fuel tank versus elapsed time beginning at T=0 in the bottom (first) image.

Problem 4 - About what was the average speed of the Shuttle in the top image in A) meters/sec? B) miles per hour?

Space Math http://spacemath.gsfc.nasa.gov

Figure 3 - An example of a math problem (Problem 431) from *SpaceMath@NASA* showing the simple science content and how appropriate math problems are derived. The answer key for this problem is provided as a second-page to the PDF file, which may be

accessed through the Educators-side of the website after a simple user registration process.

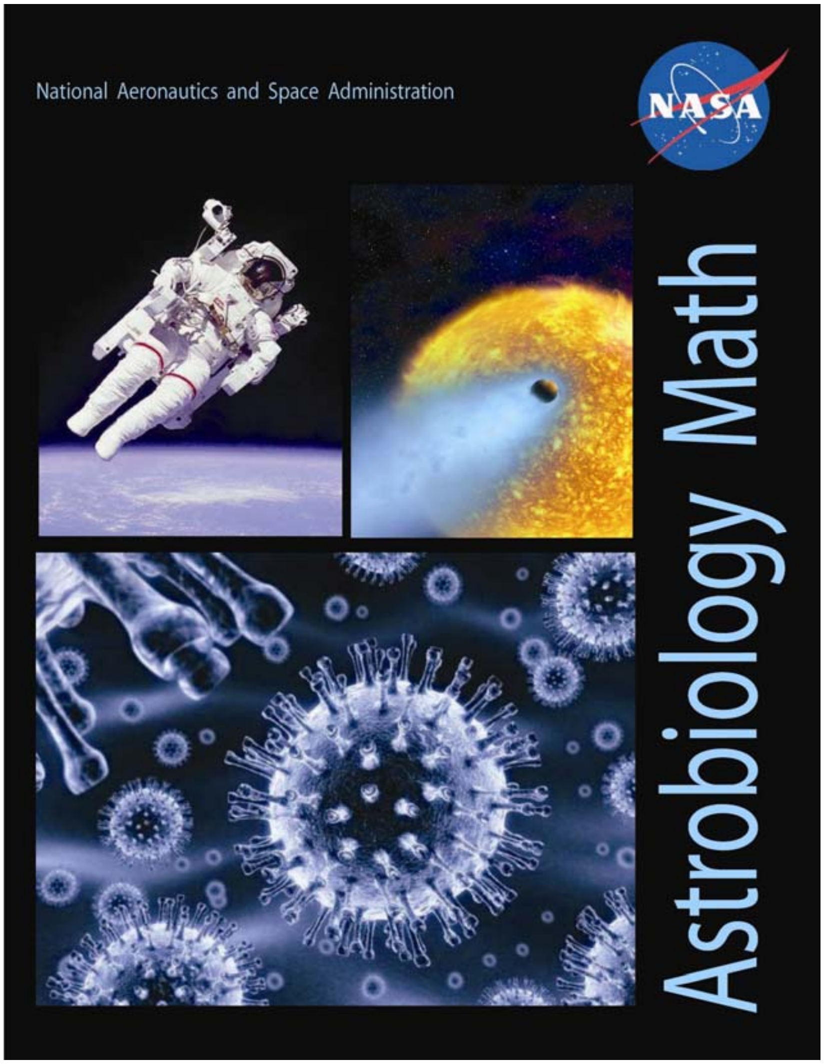

Figure 4 - The cover of the problem book 'Astrobiology Math' published in 2011. This book was requested by the NASA Astrobiology Institute and contains 50 problems covering the search for Earth-like planets, basic biology and chemistry, and Drake's Equation.

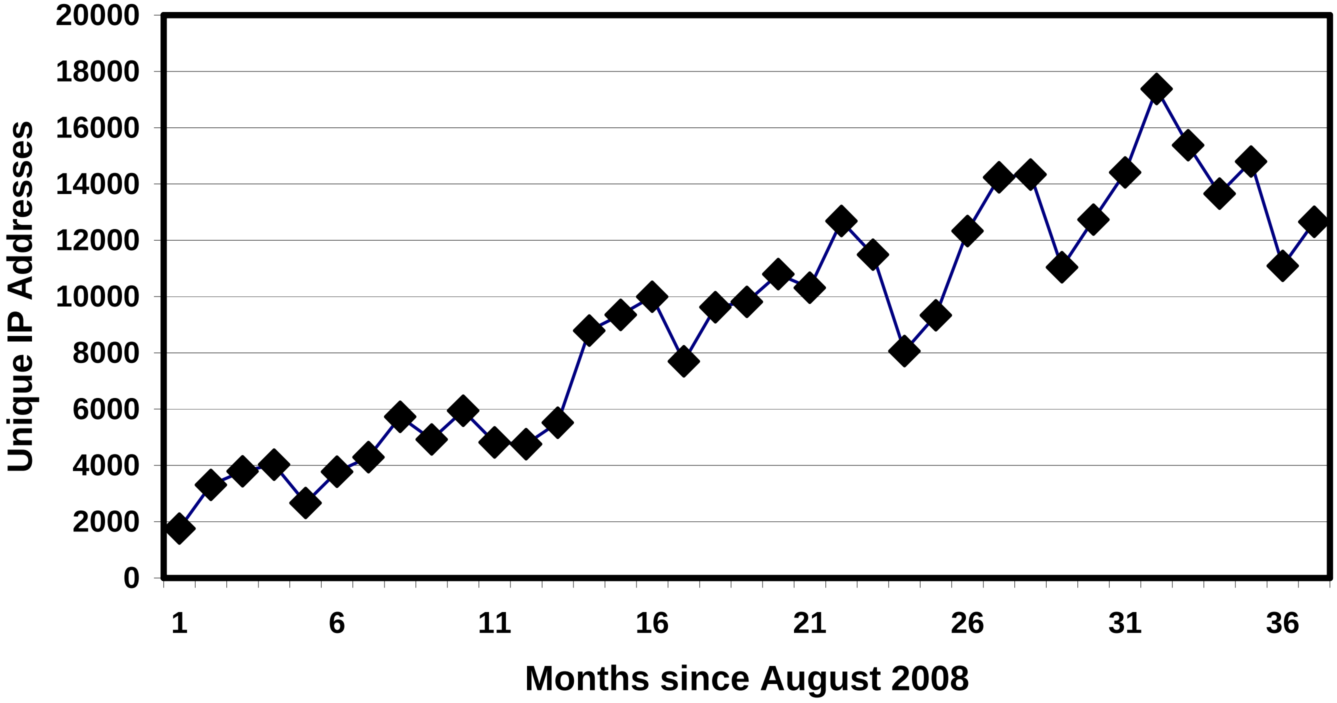

Figure 5 - Graph of monthly changes in unique IP addresses between August 2008 and August 2011. The periodic dips between July-September are correlated with summer vacation when formal educators and students are predictably less active users.

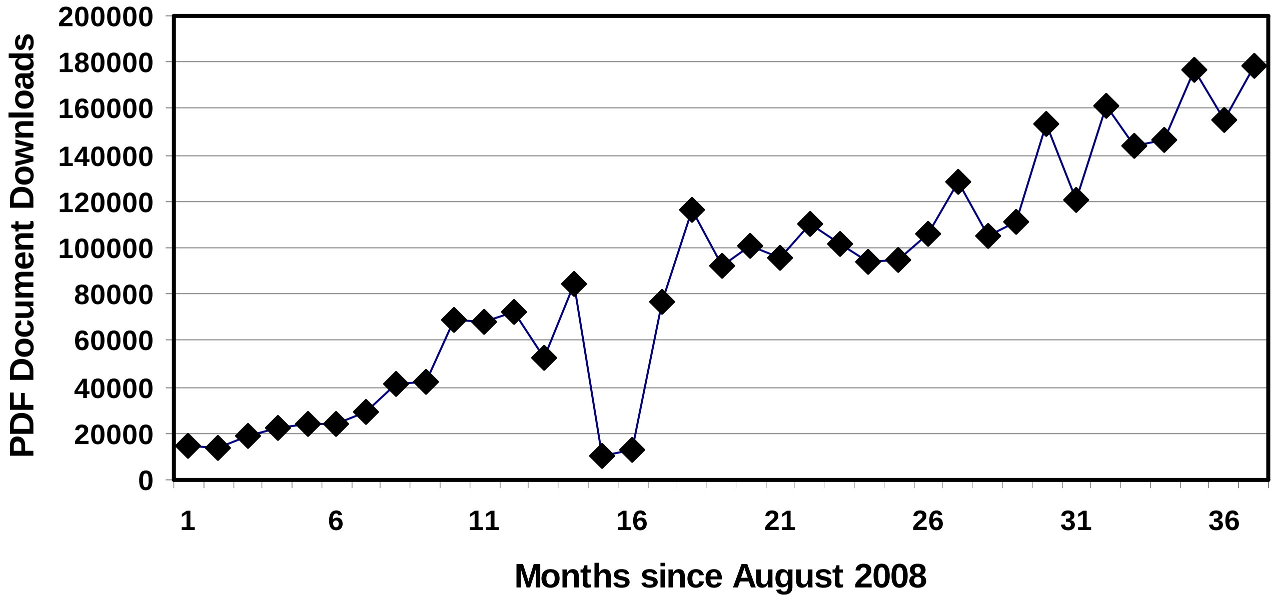

Figure 6 - Graph of the number of monthly problem downloads between August 2008 and August 2011.

Table 1: Top-20 ranked individual math problems according to title

Rank	Downloads	Title of Problem
1	17,795	Unit Conversion Exercises - I
2	14,973	The Relative Sizes of the Sun and Stars
3	12,421	How fast does the sun spin?
4	11,453	When is a planet not a planet?
5	11,367	Space Shuttle Launch Trajectory
6	11,001	Scientific Notation - An Astronomical Perspective.
7	10,807	Time Zone Mathematics.
8	10,782	Unit Conversion Exercises - II
9	10,780	Exploring Distant Galaxies
10	10,478	Radon Gas in the Basement
11	10,266	Time Zone Math
12	10,225	Scientific Notation - I
13	9,826	The International Space Station: Follow that graph!-
14	9,721	The Solar Tsunami!
15	9,490	CME Kinetic Energy and Mass
16	9,435	Solar Eclipses and Satellite Power
17	9,358	Angular Size and velocity-
18	9,276	Are the Van Allen Belts Really Deadly?
19	8,405	An Introduction to Space Radiation
20	7,790	Super-Fast Solar Flares!!

Table 2: Top-20 ranked math resource books according to title

Rank	Downloads	Book Title
1	116964	Space Math Volume 1
2	60574	Exploring Space Mathematics
3	44124	Space Math Volume 5
4	30258	Space Math Volume 2
5	28335	Space Math Volume 3
6	23420	Magnetic Math
7	18753	Space Math Volume 4
8	17970	Earth Math
9	17728	Space Math Volume 6
10	14756	Electromagnetic Math
11	12289	Northern Lights
12	11684	Algebra 2
13	10223	Space Weather Math
14	9520	The IMAGE Satellite - Introduction
15	9323	Solar Math Volume 1
16	9319	Black Hole Math
17	9037	The IMAGE Satellite - Data
18	8510	Solar Math Volume 2
19	7478	Lunar Math
20	7229	Tracking a Solar Storm