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A SATELLITE IN THE CLASSROOM: 2ND GRADE STUDENTS WORK WITH REAL-TIME SATELLITE IMAGES

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"A Satellite in the Classroom" pilot program began in September 2009, with second grade students at Academia Cotopaxi's International American school in Quito, Ecuador. Through real-time satellite images students are provided hands-on learning experiences which strengthen their understanding of space science and technology. The students are able to track real-time satellites on the globe, download live images, analyze the data, and share their findings with others. The program is based on the Delta operation mode of the HERMES-A/MINOTAUR Space Communications Gateway (SCG), built by the Ecuadorian Space Agency (EXA), and is possible due to its unique ability to act as a gateway between the Internet and the Earth's orbit. While the academic benefits of utilizing this new technological tool are immediately evident in the classroom, the long-term goal is also to inspire students to pursue an interest in space science as a life-learning process.

In this paper we discuss the teaching methodology as well as the actual classroom results from the utilization of the HERMES Delta virtual ground station at Academia Cotopaxi. Through rewarding educational experiences, accomplished with both guided instruction and cooperative groups, the students have interacted with satellite software, the computer and a SMART board. Additional activities carried out by the students have included observing anaglyph images, weather observation, creating weather stations, investigating maps, research, and recording data for the purpose of authentic learning experiences. As a result of this program, students have a greater understanding of technology, weather and geography; as well as an interest in the Earth's atmosphere and space science. The broader community, at all levels, has also taken an interest in the project.

By providing real-time satellite images in the classroom for educational purposes, we have encouraged an interest in science, technology, engineering and mathematics (STEM) in these young students. This teaching tool has increased the student's understanding of science, and has motivated them to learn more than they might have otherwise through more traditional methods of learning.

We provide several examples of student accomplishments and an overview of lessons learned in bringing a virtual ground station to the classroom. As the HERMES-A/MINOTAUR SCG is internet accessible, there is hope that the material in this paper will inspire other students and teachers around the world to also connect and bring outer space fully into the education and imagination of the next global generation.

I. INTRODUCTION

In September 2009 second grade students at Academia Cotopaxi in Quito, Ecuador, began a pilot program involving teaching and learning through the use of real-time satellite images in the classroom. This capability was made possible through the Delta operation mode of the HERMES-A/MINOTAUR Space Communications Gateway (SCG), built by the Ecuadorian Space Agency (EXA), since it serves as a portal between the Internet and the Earth's obit and provides images of South America; specifically between Cuba and the south of Chile [1]. The only materials needed for its execution are a computer, software (WxtoImg [2] satellite imaging and STK [3] satellite tracking); and, preferably, a projector and interactive SMART Board.

The participants included the second grade classroom teacher, second grade students, and training and support from both Ronnie Nader (EXA's ASM Commander) and Dr. Andrew Klesh (Japan Aerospace Exploration Agency, JAXA). As Academia Cotopaxi is an international American school, the makeup of the students consisted of children from a variety of origins including Ecuador, the United States, Argentina, Chile, Japan and Brazil. While classroom instruction was conducted in English, all students were bilingual; with Spanish being the other language of the school culture [4]. It is also an International Baccalaureate Primary Years Programme (IB/PYP) school, so inquiry is a natural learning approach of the school atmosphere [5].

The purpose of this pilot program was to introduce a relatively new and unique teaching tool into the classroom which had the potential to inspire students to pursue interests in science, technology, engineering and mathematics (STEM); and, more in particular, to also spark a curiosity regarding space exploration. The importance of encouraging such instruction in the elementary classroom is reflected in current educational trends in the United States, such as those noted in the Fall 2008 *Science Educator* article, "Models of Providing Science Instruction in the Elementary Grades: A Research Agenda to Inform Decision Makers" [6]:

- 20 percent of entering college students must take remedial science and math courses.
- The ability to respond to major policy issues, such as global warming and the energy crisis, is dependent upon public a "scientifically literate" citizenry being able to understand and evaluate scientific issues.
- Prior attempts at science education reform have made it clear that, to be fully effective, reform efforts must begin in elementary school.

Considering the rapid global growth in technology this past decade alone, preparing future generations to enter a new and ever-changing work force and society is of critical importance to any educator, policymaker and invested member of the public.

Training

This venture initially began with teacher support that was provided at the start of the school year, via emails and Skype communications, with Commander Nader and Dr. Klesh. This support network provided instructions and guidance concerning how to operate the

Figure A: Students track satellites on the STK software, while using two different 3D images.

Figure B: Students use WXtoImg software to download a real-time, live satellite image from HERMES Delta.

WXtoImg and STK software, with the purpose of creating a virtual ground station in the classroom. Once the classroom teacher had a solid grasp of the material, she then passed over the newly attained knowledge to her students with a two-fold purpose: 1) that the teachers and students would learn from one another with this new material, as no manual existed, and 2) to give ownership to the students from the start.

II. TEACHING METHODOLOGY

Both a student-centered and inquiry-oriented teaching approach was undertaken when piloting the Satellite in the Classroom Program. Research-based instruction that has proven to be successful was also implemented, such as: identifying similarities and differences, summarizing, reinforcing effort and providing recognition, cooperative learning, setting objectives and providing feedback, generating and testing hypotheses, higher-level questioning and wait-time [7].

Initially, through whole-class instruction, the students were taught how to navigate the two software programs until, within a couple of weeks, those students who grasped the concepts with the greatest ease were subsequently able to teach their peers, with minimal adult supervision (see figures A and B). Eventually, downloading satellite images on a weekly basis became a regular, non-intrusive part of the classroom routine and expectations; and, furthermore, the students came to anticipate and dialogue about expected results in advance.

The thrill of achieving the first real-time, downloaded image created such a buzz in the class that

Figure C: students use 3D glasses to view an anaglyph image that they downloaded.

the students naturally wanted to discover what more could be attained from this first image. This spark of curiosity led the class to begin experimenting with the various image enhancements that could be gained from the software until, after a few weeks of exploration, it was unanimously decided to focus on the following favorites: MCIR and MSA with precipitation, MB thunderstorm, sea surface, temperature and anaglyph (see Figure C). As neither instructions nor research yielded any significant revelations concerning the meaning of the image enhancements, the class began to analyze images in order to determine similarities and differences, as well as shed light on any inconsistencies discovered. For example, it was the students, rather than the teacher, that discovered that the MSA enhancements exhibited all the clouds visible in the images, while the MCIR enhancement only revealed some. This led the students to hypothesize that there might be a correlation between precipitation and the different enhancements viewed, and so the investigation for clarification continued.

As the students became adept at downloading information, they began to look for patterns in the satellite images. Coincidentally, during the first half of the school year, there was a drought in Ecuador; and, as electricity mainly arrived via hydroelectric power plants, frequent brownouts (a restriction of electrical power usage as set by the government) were imposed in order to conserve this energy. As the lack of electricity significantly affected all aspects of Ecuadorian and Latin American society during this time period, most notably in the classroom, the students quickly made a connection between the lack of this power source and weather prediction. Subsequently, the students wanted to know if, through utilizing the HERMES Delta virtual ground station, they could learn more about the state of affairs they found themselves is in and – better yet - begin to predict when the rains, and electricity, might return.

Seeking Answers

This journey of discovery proceeded through the use of a variety of approaches: hands-on learning, cooperative groupings, hypothesizing, problem solving and critical thinking. As the satellite images brought more answers, with them arose more questions and the children began to wonder: Why is the temperature so hot on the coast of Peru (the Sechura Desert)? Would this country be a good neighbour for Ecuador to ask if they can borrow some hydroelectric power? What other countries might not be suffering a drought and be able to sell us electric energy? Why do only some parts of Brazil always seem to have precipitation and not others (the Amazon jungle)? Could looking at the clouds in the playground give us clues as to whether or not it may rain on a given day? How did we accidentally get an image of Iceland??? Why doesn't it rain in Ecuador if we see clouds everywhere on a given day? Why is the sea warmer at the top of South America than at the bottom? Is the drought related to global warming? With the destruction in Haiti, will it rain today; and, if so, what does that mean for all the people living in tents? What can weather satellites orbiting other planets teach us about possibly travelling to them one day? How accurately can we predict the weather with the information that we've learned so far?

Very quickly, the students began constructing their own scientific paradigms as a result of the virtual ground station they were able to manage and manipulate at will. In this manner a domino affect took place, and the momentum and curiosity that was evoked branched the students off to other relevant areas of academic interest – both scientific and social.

In order to answer their question, students often needed to look to other sources in order to begin to make connections. Cloud wheels were downloaded [8], cloud graphs and 3D glasses constructed, and weather prediction graphs were sought out. Soon the students began to make precipitation graphs in order to compare them to weather predictions graphs attained on the Internet [9], as well graphs on EXA's website [10] indicating the previous year's results (see Figure D). This assimilated information then gave the children insights into the importance of weather prediction and, furthermore, it caused them to take action; specifically with result to water conservation, both at home and at school.

For example, when Commander Nader made a visit to the classroom and filled a glass of water to the top - in order to teach the concept of water surface tension - a student quickly took initiative and commented , after the

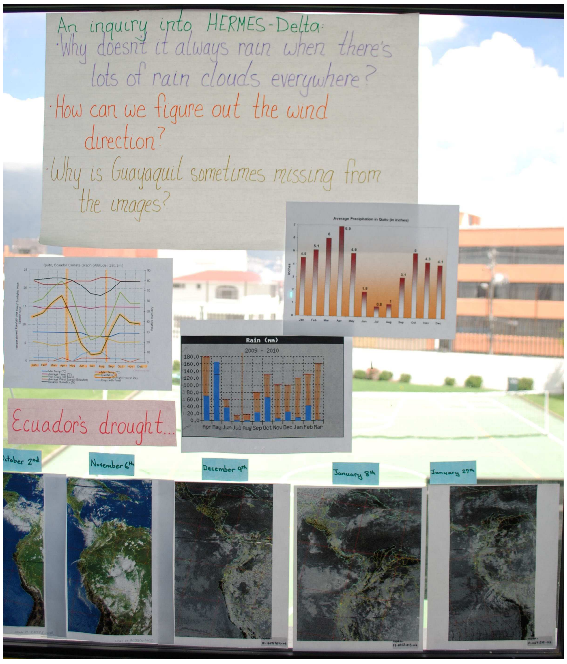

Figure D: Weather pattern and prediction graphs for Ecuador, a chart of inquiry questions and monthly satellite image downloads.

experiment took place, that the contents should be shared with the plants outdoors in order to not waste this valuable resource.

As the much delayed rains began to return towards the end of the school year, the class would become elated at viewing satellite images which showed precipitation within the vicinity; and the students were also quick to report these results to any school members that crossed their paths on any of these given days. At this point in the school year, the students would record the cloud types viewed outside the classroom window and, while making connections to the satellite image of the day, and predict the amount of rain that might be expected in Quito.

Learning Opportunities

In order to fulfill the academic standards and benchmarks required for both the school's IB/PYP and math curriculum, satellite activities were designed to align with these goals. The grade 2 IB/PYP objectives were met for the following Units of Inquiry: How the World Works (weather), How We Organize Ourselves (mapping), and Who We Are (global contributors) [11]. This satellite project also helped the students to embody the PYP/IB learner profiles, which encourage the students to be: inquirers, knowledgeable, thinkers, communicators, principled, open-minded, caring, risk-takers, balanced and reflective [12]. As for math, the standards that were enhanced included graphing, temperature, probability, time, patterns and number concepts [13].

Some of the educational learning opportunities that were conducted included the following: homemade weather stations that incorporated a thermometer, rain gauge and wind gauge (see Figure E); recording weather and interpreting graphs; creating biospheres for viewing the water cycle; a Weather Word Projects (investigating weather words and creating a final product); tracking the NOAA satellites 15, 17, 18 and 19 on the globe; ongoing show-and-tell items; space-related read aloud books; current events linked to space exploration; student spacecraft inventions (drawn and simply constructed prototypes); viewing video clips about weather prediction and space weather [14] ; and air rocket launching with math extension activities.

III. RESULTS

Professional Teacher Development

As a result of the high accessibility of EXA as a resource, the teacher was able to learn new material and problem-solve with relative ease. The educator was able to learn how to track satellites, as well as download live images and manipulate them. Most valuable was the trial-and-error method of learning, which proved most effective in mastering the material.

Academic Student Achievement

Through the use of live satellite downloads in the

Figure E: Homemade weather station

classroom, students were provided with real-world learning experiences in all areas of STEM; and this, in turn, motivated the children to want to learn more in these areas than had been observed by the classroom teacher in her previous 15 years of teaching elementary students.

Evidence of overall academic student success was also apparent in the year-end assessment scores. In reading, the Qualitative Reading Inventory (QRI) revealed that, while 38% of the students were below grade level at the beginning of the school year, while at the end of the academic year only 1 student (on an Accommodation Plan) was reading below grade level and 81% of the class was *above* grade level (see Table 1)[15].

8 = Instructional 1st grade	
9 = Independent 1st grade	
10 = Frustration 2nd grade	Above
11 = Instructional 2nd grade	
12 = Independent 2nd grade	At
13 = Frustration 3rd grade	
14 = Instructional 3rd grade	Below
15 = Independent 3rd grade	
16 = Frustration 4th grade	Grade level
17 = Instruction 4th grade	standards

August 2009 Previous grade level (1st)	November 2009 – QRI results (2nd grade)	June 2010 – QRI results (2nd grade)
14	14	15
14	15	17
13	14	17
11	11	13
11	11	14
11	12	14
11	11	14
11	11	14
11	11	14
10	11	16
9	11	14
9	11	12
9	11	12
8	11	(moved)
8	11	13
8	11	14
8	8	11

Table 1: Qualitative Reading Inventory assessment results during three periods of the school year.

In math, all but one student passed the Harcourt year-end common assessment; with the majority attaining scores between 83-100% (see Table 2) [16].

Student	*Year-End Summative Math Results*
1	100%
2	95%
3	91%
4	91%
5	91%
6	91%
7	91%
8	91%
9	87%
10	87%
11	87%
12	87%
13	83%
14	70%

Table 2: Year-end summative math assessment results for second grade. Two students did not take the test due to the stipulations of their Accommodation Plans.

As for vocabulary development, all students received scores at or above grade level on the Words Their Way assessment (see Table 3) [17].

At grade level — Above grade level

Syllables and Affixes - Middle	2
Syllables and Affixes - Early	2
Within Word Pattern - Late	5
Within Word Pattern - Middle	7

Table 3: Words Their Way year-end vocabulary assessment results.

Regarding geography, the students were given a blank world map to fill out, in December and then again in June of the school year, and asked to note any recognized body of water or land. The overall average gain for the year in this assessment was 7 points, and the median was 10 points (see Table 4). When compared with a control group, the other second grade class, scores reflecting geographic recognition in June showed that the control group had and average gain of 15.6 points and a mean of 14, while students in the satellite

Students in satellite program	January 2009 scores	June 2010 scores	*Overall points gained*
1	42	76	34
2	3	19	16
3	6	21	15
4	8	23	15
5	7	20	14
6	11	25	14
7	11	24	13
8	15	26	11
9	13	22	9
10	5	11	6
11	12	16	4
12	22	26	4
13	5	8	3
14	2	3	1
15	22	23	1
16	5	5	0

Table 4: Geography results for students in A Satellite in the Classroom program.

Students in control group	June 2010 scores
1	40
2	31
3	20
4	18
5	17
6	17
7	15
8	15
9	14
10	14
11	12
12	11
13	10
14	10
15	8
16	8
17	6

Table 5: Geography results in June for the control group.

program had an average gain of 21.7 points and a mean of 22 (see Table 5). On a more personal level, students emerged with a better concept of how science and intercultural respect and understanding are related as well. Case in point, students considered the effect of weather on Haiti's earthquake aftermath and how they might be able to help as a result. The students also took into account the importance of considering geographic locations before requesting hydroelectric energy from nearby countries.

Concerning student engagement, through observation it was evident that the students were highly engaged, their interest in overall learning increased, fewer students were off-task, and many children exhibited a desire to learn more about space exploration, weather and meteorology (see Figure G). Additionally, it was evident that through increased exposure to technology, the children felt at ease with the tools employed and enjoyed using the software and interactive SMART Board for learning purposes [18]. When presented with inevitable, technological challenges, their problem-solving improved; and, indirectly, their self-esteem.

Most importantly, as the students made connections between satellite images and weather, they emerged with an improved sense of global responsibility; specifically, the significance of human action – or inaction - and its direct impact upon the environment and our global society.

Figure G: Show-and-Tell rockets and space port for launching satellites.

Community impact

High interest in learning more about the Satellite in the Classroom Project was exhibited both in and outside of the classroom environment.

Within the school, the following activities were shared: students gave demonstrations for peers at both the elementary and high school level, information was communicated with class parents through parent-teacher conferences and emails, information was published on the class website [19], as well as the school community's electronic flyer and website.

Beyond the school community, information was shared via the following opportunities: student accomplishments were published on a University of Michigan website, You Tube [21] and the World Space Week website [22]; the classroom teacher gave workshops and presentations (at the Association of American Schools of South America in Chile;
t he Universidad San Francisco, Quito, as well as to local private and public school teachers and administrators in a variety of venues); the students did a demonstration for a local school, the press and a delegation of EXA representatives; and the school nominated Commander Nader for the Global Citizen Award in recognition of the contributions he and EXA's satellite program made for the school community [23].

Lessons learned

Much of the success of this pilot program was due to a combination of teacher motivation and easy access to Commander Nader for feedback and problem solving. In order to share this technology with other educators in the future, professional development support would be essential and could possibly be provided in three ways: initial training on the part of EXA, a well-constructed manual, and/or an ongoing resource support professional that educators and administrators could contact when unsolved questions arise.

In addressing the classroom teacher, it would be advised to consider initiating the Satellite in the Classroom Program by first training those classroom teachers who are most motivated to pursue this new technology; and then, in time, use these skilled individuals as resources within each particular school for the future growth of the program. Since much time is needed for initially implementing the HERMES Delta virtual station in the classroom, it would also be highly recommended for administrators to provide extra preparation periods for training and practice purposes. Lastly, while the program can be conducted simply with any computer, the potential for student growth and motivation is greatly increased when the use of a projector and/or interactive SMART Board are utilized.

IV. CONCLUSIONS

The Satellite in a Classroom Program proved to be highly effective in encouraging academic gains, as well as stimulating an interest in STEM - specifically space exploration – both within and outside of the school community, by providing a sense of adventure. Teacher support and student ownership also were essential elements for the success of the program. Likewise, utilizing the HERMES Delta virtual ground station, and its accompanying interactive technology, was shown to be an effective teaching and learning tool in preparing a generation of future scientists, technicians, engineers and mathematicians…a critical consideration when striving to develop the imagination of lifelong learners for the benefit of humanity.

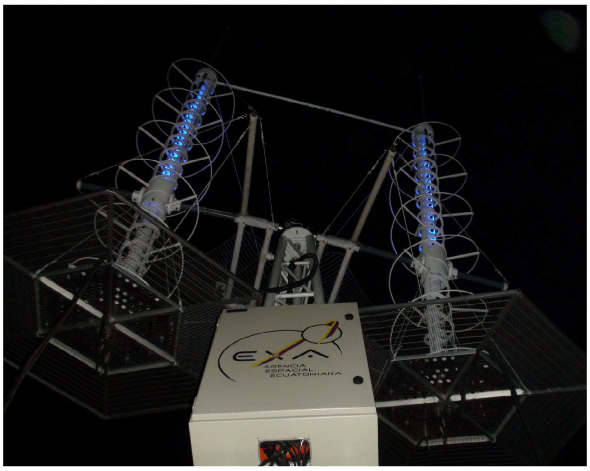

Figure H: HERMES ground station in Guayaquil, Ecuador.

V. ACKNOWLEDGEMENTS

The impressive accomplishments attained for both international students and the Ecuadorian community were possible due to the generosity of time and resources donated by the Ecuadorian Civilian Space Agency (EXA); without whose dedication and investment in aerospace education, none of these achievements would have been possible (see Figure H). Furthermore, much gratitude would like to be bestowed upon the following individuals and organizations: Commander Ronnie Nader for his overall extensive investment in the HERMES Delta project, Dr. Andrew Klesh for providing valuable training and feedback, the Academia Cotopaxi community for its extraordinary support for the project, as well as NASA for its resources provided to the public.

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