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THE EFFECTS ON MATH ACHIEVEMENT AND ATTITUDES WHEN INCORPORATING SATELLITE EDUCATION IN A 4TH GRADE CLASSROOM

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During the 2012-2013 school year, a fourth grade classroom at Academia Cotopaxi's International American school in Quito, Ecuador, undertook the challenge of embedding satellite education into the regular curriculum for the purpose of enhancing mathematical achievement and attitudes with students. Satellite resources were attained through both the Ecuadorian Civilian Space Agency (EXA) and the National Aeronautics and Space Administration (NASA). Through EXA, students downloaded real-time satellite images in order to provide hands-on learning experiences, attained through the utilization of WXtoImg software and in conjunction with National Oceanic and Atmospheric (NOAA) satellites, which naturally lent themselves to authentic learning opportunities. The program was based on the HERMES-Delta operation mode of Ecuador's HERMES-A/MINOTAUR ground station, built by EXA, which acts as a link between the Internet and the Earth's orbit. This opportunity allowed for students to interact with satellite images in such a way that mathematics became immediately relevant and purposeful in their lives. Simultaneously, satellite education activities were integrated as part of NASA's Endeavor Science Teaching Certificate Fellowship Project and the Weather Data Learning Center (WDLC). The WDLC is an online resource that teaches 4th grade mathematics in the context of weather. Both satellite programs were grounded in applying US national math standards to real-life learning, and also aligned well to satisfying the science education objectives established in the *Next Generation Science Standards*. In this paper we discuss the teaching methodology as well as actual classroom results from the utilization of the virtual HERMES ground station within the Academia Cotopaxi classroom, in conjunction with the WDLC lessons. Through genuine educational experiences, the students interacted with satellite software, computers and an interactive SMART board. Targeted mathematics activities carried out by the students included the use of manipulatives, weather observation, inquiry-based lessons, data collection and analysis for the purposeful learning experiences. Additionally, both the US and Ecuadorian educational communities took notice of this innovative application for the elementary classroom – especially in light of the fact that Ecuador launched its first satellite, PEGASUS, in April of 2013 – and this interest also resulted in the creation of EXA's international and collaborative pilot program titled ASTERIA. Presented material in the final paper includes examples of student work, as well as an overview of satellite lessons and research-based teaching strategies put in place with the purpose of increasing student learning and performance.

I. INTRODUCTION

Weather satellite education is a means by which students utilize weather images taken by satellites in order to understand Earth systems, and this can be done through gathering, analyzing and interpreting data attained by these images[1]. As a veteran, fourth grade teacher at an international American school, Academia Cotopaxi, in Quito, Ecuador, I have been implementing weather satellite education in the classroom for three and a half years, beginning in September of 2009. This voyeuristic journey began as a pilot program titled, "A Satellite in the Classroom", and was initiated through collaboration with the Ecuadorian Civilian Space

Agency (EXA) [2]. Subsequently a paper, co-authored with Ecuadorian astronaut, Ronnie Nader, was presented at the International Astronautical Congress in Prague, Czech Republic in 2010; the focus of which was primarily on satellite education and its effects on academic achievement in the areas of geography and language arts.

Currently my school would like to infuse more critical thinking into its math curriculum, as well as augment math scores on the standardized Iowa Tests of Basic Skills (ITBS); especially in the area of computation [3]. As a result, the school will be transitioning to a new math program in September of 2013, from 1st through 10th grade; from a traditional math program to a more conceptually-based one. Since it is a goal for our school to improve upon both the students' standardized math scores and overall conceptual understanding of math, my investigation explores whether or not the satellite education which I embedded in my own 4th grade classroom had a positive correlation with math achievement and attitudes. The results of this investigation are not only of interest to my school and the Ecuadorian community, but can also contribute to the global body of work in this area to date. This investigation can provide information on how best to increase an interest in science, technology, engineering and mathematics (STEM) for our 21st century learners, as this is of global interest in the field of education[4, 5, 6].

II. LITERATURE REVIEW

The existing body of research indicates that embedding satellite education in the classroom helps to address US math and science standards effectively, promotes the use of constructive teaching practices, and increases students' positive perceptions towards math [1, 7, 8].

US High School graduates ill-equipped in math

Current research in the United States shows "large numbers of students graduate high school unprepared for post-secondary education and are ill-equipped for the labor force of the 21st century", so much so that college institutions find the need to re-teach concepts that should have been attained in high school (McCormick & Lucas, 2011, p.1) [9].Utilizing satellite education in the classroom is one way to counteract such deficits, especially in light of the fact that it directly addresses many US national math standards such as: learning about *numbers* (such as mean, median, mode, range, comparing and contrasting), *algebra* (patterns in weather and utilizing station models to understand quantitative relationships), *measurement* (understanding temperatures in Celsius and Fahrenheit, and measuring weather fronts), *data analysis* (collecting, organizing, analyzing and applying information)and *math processes* (problem solving, communicating and making connections) [7].

Satellite education satisfies the US Next Generation Science Standards

Supplemental satellite education activities also align well with the *Next Generation Science Standards (NGSS)* [10]. In addressing the specific disciplinary area of earth/space science, this methodology enhances learning in the following three dimensions:

- Practices: engaging, investigating, building models and developing theories of the natural world.
- Crosscutting concepts: thinking in patterns, similarities and diversity; cause and effect; scale, proportion and quantity; systems and models; and stability and change.
- Disciplinary core ideas: providing a key tool for understanding and investigating more complex ideas and solving problems; relating to the interests and life experiences of students, and connected to societal concerns that require technological knowledge; and being teachable and learnable over multiple grades at increasing levels of depth and sophistication.

In addressing US priorities, President Obama promised to train "100,000 well-qualified science and math teachers by 2020, and added a second, complementary goal with a workforce component to it, namely, to produce 1 million additional STEM graduates" (Science Magazine, 2012, para.1). Satellite education helps address all of these objectives, and in an innovative fashion.

Satellite education promotes best teaching practices

Additionally, satellite education allows for constructive teaching practices which include: *communication of content knowledge, questioning strategies, and student engagement* [8]. In a study in 2000, interviews and observations of a first grade classroom revealed high student engagement through problem solving tasks when collecting and manipulating weather data. Using technology tools to gather weather data stimulated relatable discussions among these students, and their teacher noted "high, sustained student interest levels" throughout their academic year [11].

Extensive research by Dr. Robert Marzano (2009), an expert in the field of student achievement, stated that "high-yield strategies" enhance student achievement through effective teaching techniques that include lessons involving the following: *new content that reflects on learning, practicing and deepening content that has been previously addressed, and cognitively complex tasks that generate and test hypotheses* [11]. Based on this definition, satellite education would be considered a high-yield strategy worth considering, as it creates authentic learning experiences which deepen student's understanding of math content.

Furthermore, incorporating this type of supplemental curriculum involves experiential and participatory inquiry methods which, when based in genuine learning, lead to self-discovery and ownership of the material learned; and this, in turn, leads to motivated students [13]. "The importance of science education by means of innovative classroom exercises that require active student and instructor involvement has been long recognized as an influential and effective pedagogical tool" (Moxey *et al.*, 2004, p. 391). This was also found to be true when utilizing real-time satellite imagery for K-12 classrooms in Florida, in 2001. Not only did the educators in this particular study find that using real-time imagery directly in the classroom *unsurpassed* utilizing Internet-based sources of data, but it was also their experience that this methodology promoted academic achievement in STEM and encouraged students to engage further in learning [14].

Satellite education increases self-efficacy in math

Another study conducted with 3, 259 upper-elementary students in California, from 2005-2007, revealed that math self-efficacy corresponds to positive predicted math performance. Self-efficacy is defined as "the degree to which a student believes that he or she is capable of performing specific tasks", and through surveys and standardized math performance scores it was revealed that students with higher math self-efficacy were able to: *persist longer on difficult math problems, are more accurate in math computations, and have better overall math performance* (Fast *et al.*, 2010, p. 729) [15].

When integrating weather satellite ground station technology into K-12 classrooms in Florida, surveys revealed that 81% of the teachers participating believed that the program and ground stations had a positive impact in their classrooms [1]. Among the one hundred six educators included in this two year study, positive impacts included: *positive changes in students' attitudes by connecting scientific events to the real world through the use of technology, increased interest in weather and space in general, readily available data for collection and interpretation, exposing students to computer-assisted learning, sparked interest from parents and "turned on" students with a previously low interests in science.* It is also important to note that in this study, 19% of the educators reported "no impact" for reasons including *lack of time* to implement the program, *equipment not being installed, no support and general computer problems*. At the end of the study, recommendations included allowing educators to *proceed at their own pace*, and for administrators to *provide training and technical support as needed*. On the subject of student feedback, it was found that success was attained when they were "provided with the power to explore realistic and scientifically relevant, real-world problems" and that they be "required to construct and reconstruct meaning as they frequently encountered unanticipated consequences and evidence that counter their understanding" (Graham, 1995, p.18).

A review of the published research on this subject matter reveals evidence to support the concept that the innovative use of weather satellite education may act as a catalyst to possibly motivate students, thereby increasing their overall achievement and self-efficacy in mathematics. Therefore, it would be beneficial to the educational community to have further research regarding the extent to which weather satellite education can have a direct and positive impact math achievement.

III. METHODOLOGY

Setting and participants

The study was conducted with 17 elementary students in a 4th grade core classroom (students ages 9 and 10), at Academia Cotopaxi; a private international, American school located in Quito, Ecuador [16]. This college preparatory school consisted of approximately 660 students, from pre-kinder to grade 12, and followed both the Primary Years Program (PYP) and International Baccalaureate Program (IB) [17]. While English was the primary language of instruction, elementary students received 45 minutes of Spanish instruction daily, and the majority of students spoke Spanish outside of the core and specialist classrooms (including PE, art, computers and music).

The students who participated in this study came from international backgrounds and all, at varying levels, spoke and understood both English and Spanish. All were native Spanish speakers, with the exception of one child whose primary language was English. With regard to nationality, 59% were from Ecuador, 24% from other Hispanic countries, 5% from the United States, and the remaining 12% from countries in Europe and Asia. Seven of the students received special services with Push-In and/or Pull-Out services, accommodations, or tutoring outside of school. It is also worth noting that 7 of the children in the study were previous students the teacher-researcher, two years prior while in second grade; and, thus, also had previous experience with satellite education at that time. The teacher-researcher who instructed the class had 18 years of experience, a Master's Degree in Education, and had for 6 years prior, embedded general aerospace education into her classroom instruction out of personal interest and to motivate her students in general regarding all curricular areas.

Additionally, two control groups were utilized, and consisted of 28 students from the other two, 4th grade classes at the same school. The control groups included the same and proportionate amount of students in need of special services, and the two teachers in the control groups followed the identical standardized math program, but did not supplement weather satellite education in their classes.

Materials and procedures

From September 2012 to June 2013, the students in the core classroom were given supplemental weather satellite lessons and activities, which focused on providing hands-on experiences connected to the Virginia State math standards and benchmarks for grade 4. This was accomplished in two ways: through students downloading live weather images of South America in the classroom, made possible through the Ecuadorian Civilian Space Agency's (EXA) ground station, and simultaneously receiving targeted math lessons provided by NASA's online Weather Data Learning Center [18].

The virtual ground station in the classroom utilized free WXtoImg online software [19], a VRS Remote Monitor [20], laptop computers, an (optional) interactive SMART Board [21], and the HERMES - Delta operation mode of EXA's HERMES-A/MINOTAUR ground station. The Delta operation mode of this ground station acted as a gateway between the Internet and the Earth's orbit, thereby providing real-time weather images that students could interact with and manipulate. Students selected image enhancements that showed cloud cover, precipitation, land temperature, water temperature and 3-dimension visuals. Signals from the National Oceanic Atmospheric Administration (NOAA) satellites #15, 18 and 19 were used as they passed above EXA's ground station, located in Guayaquil, Ecuador (see Figure 1) [22].

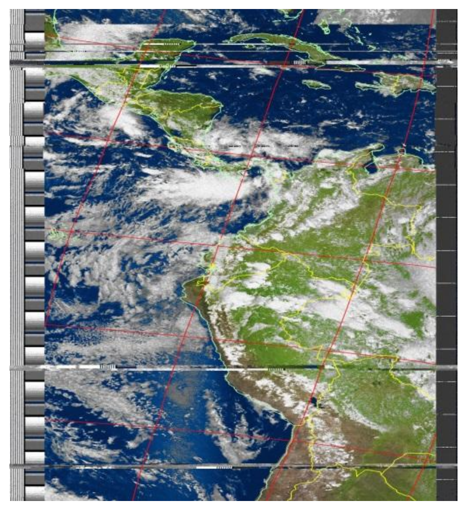

Fig. 1: A real-time, student download of NOAA 18. The image shows cloud cover over Central and South America.

Approximately once a week, and depending on how relevant the images were to the curriculum topics being addressed at any particular time, the students set up the satellite software in the morning and wrote the times that the satellites would pass on a small whiteboard; on display for all to see and be mindful of during the school day. When the passing time for the NOAA satellites approached, students would take turns to monitor the download session, which took approximately 15 minutes, in case the signal needed to be reconnected at any time. Once adept with this process, it was easy for the students to take turns with both the set-up and downloading procedures, and complete them in such a way that no interference took place with the regular functioning of the classroom setting. Afterwards, students would be asked to make any verbal observations in relation to what they noted from the day's download, and the images would then be used as part of the WDLC weekly math lessons (see Figure 2).

Fig. 2: Interactive whiteboard. Students label and analyze cloud formations, and make connections with high and low air pressure.

As part of NASA's Endeavor Science Teaching Certificate Fellowship Project [23], the students and teacher-researcher had access to the Weather Data Learning Center's 4th grade math activities; which were taught through the context of weather by using a teacher's manual, individual workbooks and online activities. Students applied math concepts to weather maps and engaged in problem-solving activities, with the added benefit of using their own local satellite images to apply the concepts learned. In this way, the lessons were meaningful and immediately relevant to the students. In order to embed these lessons into the curriculum, the teacher-researcher either substituted these satellite lessons in the math curriculum program being used, and/or prioritized other curricular objectives during the school week in order to allow time for these lessons. An example of making a math lesson meaningful through the use of weather data involved having students download a live satellite image, record the temperatures of five specific countries, and then utilize those numbers for the purpose of discovering the mean, median, mode and range of temperatures for the day. Through such authentic educational experiences, accomplished with both guided instruction and cooperative group learning, the students gained experiences with manipulatives, weather observation, inquiry-based lessons, data collection and analysis.

Examples of lessons taught through using EXA's images in conjunction with the WDLC activities included: exploring *types of weather satellites* (the geostationary orbit of some satellites in relation to Ecuador's heliosynchronous PEGASUS satellite orbit), becoming familiar with *cloud formations and forecasting* (from both above and below the cloud lines), *measuring real-time temperature changes*, *making connections* between dew point data from outside temperatures versus information from Station Model maps, *reading temperature maps* to find averages and ranges, using *authentic weather data* to determine the median and mode, understanding and *applying their knowledge* of air pressure, *measuring the movement* of weather fronts, and creating *Station Model Maps*. To assist in making their learning more meaningful, after analyzing their downloads, the students also shared their work with the global community by posting their images on the *Worldwide Satellite Links* portion of the satellite website created by the AWTY International School in Texas, USA [24].

<u>Data collection</u>

The purpose of this study was to reach beneath the surface of our current understanding of math achievement in elementary school students, and illuminate how implementing weather satellite education might positively impact their content understandings. With this objective in mind, both qualitative and quantitative approaches were used, as studies showed that a mixed methodology "for the elementary classroom gave insights that neither type of analysis could provide alone" (Hoepfl, 1997, p. 48) [25]. It has also been discovered that "the mixing of methods shed light on trends in patterns of student responses" [26]. Additionally, to avoid pitfalls that can arise from qualitative research, both breadth and depth of data collection were implemented. Qualitative sources included a student survey, a parent survey, journal reflections, one-on-one interviews, photos and field observations; while the quantitative sources used were the Virginia Standards of Learning (VSOL) [27] mathematics assessment and the Iowa Tests for Basic Skills (ITBS) for grade 4.

In an attempt to gain knowledge on students' perceptions regarding math in general, in February and June of the school year they were given surveys with questions adapted from the Patterns of Adaptive Learning Scales and included the following questions: How sure are you that you can learn everything taught in math?; How sure are you that you can do even the hardest work in your math class?; How sure are you that, even if a new topic in math is hard, you can learn it?; How sure are you that you can figure out the answers to problems that your teacher gives you in math class? [28]. Students were then ask to respond based on a 5-point scale (1 = *not* *at all sure*, 3 = *somewhat sure*, and 5 = *very sure*). A comment section was also placed at the bottom of the survey, in order to encourage students to give more specific feedback should they choose. Once the surveys were collected, the scores were reviewed so as to determine the percent of math self-efficacy evident; and comments were read with the purpose of seeking out emergent patterns. For comparison, the survey was also anonymously given to two control groups; however the experimental group results weren't anonymous, as the student's identification would be important for later comparison with their respective parent's survey results.

To help clarify and provide further illumination of the students' responses on the survey, the class was then asked to self-reflect about their perceptions by responding to the following journal prompt: "What do you most and least enjoy about math, and why? What do you most and least enjoy about weather satellite activities? Please explain." As some journal entries left specific questions unanswered or provoked further inquiry, a semi-structured interview session was then held individually with certain students; during which time the teacher-researcher took notes of the responses given and clarified with each child if the interpretation of their responses was accurate before concluding each interview with member checks. Returning to question the children through one-on-one interviews helped to verify the accuracy of whether or not students' self-efficacy towards math was affected through incorporating satellite education in the classroom [29]. In addition to conducting surveys and interviews, photos and field observation were also looked at independently for emergent themes.

As for ethical considerations, all students involved in the study had Parental Release Forms signed regarding the release of their images, with the understanding that names would not be published. Thus, the cyclical nature of using multiple data sources to delve deeper into students' responses served to add coherence and credence as to whether or not supplemental satellite education impacted student's achievement in math.

As "social support perceived from parents was associated with school achievement", a parent survey was also conducted with the experimental group only (Leyla & Sayil, 2006, p. 297) [30]. The parent survey, which also included a comment section, was based on a 5-point scale as well, and included the following questions: How familiar are you with the weather satellite activities your child has been doing in class?; How much do you value the incorporation of satellite education in your child's classroom this year?; and To what extent do you believe that your child is interested in math as a result of the satellite education supplemented in your child's math curriculum this year? By matching the parent survey results with that of their child's on the student survey, further emergent patterns addressing the inquiry question could be taken into consideration.

Lastly, quantitative data was attained through both the VSOL and ITBS for grade 4, with the purpose of noting the percentage of growth which occurred throughout the 10-month school year. The VSOL was given at the beginning, middle and end of the school year, and provided questions to *all* the math standards that the students should know *by the end* of the school year in June; hence, this quantitative resource was mainly utilized to note math achievement as it related to *growth*. The ITBS, however, was only given at the end of each school year. Additionally, the two control groups were included in the quantitative data for comparison purposes, as was also done with the student surveys mentioned earlier. Including quantitative data in the study provided an additional means by which to "gauge student's progress overall" in math, in order to note if any differences occurred as a result of embedding satellite education with the experimental group (Hoyles, 2005, p.235).

Utilizing a triangulation of data, which included an independent analysis of each source for the purpose of seeking emergent themes, increased the probability that the research would be rigorous; and, equally importantly, that the results of the analysis would potentially be influential. A variety of sources were also utilized when looking for emergent themes, and this included completing member checks with the students and debriefing with colleagues. Academia Cotopaxi peers who assisted in reviewing the methods data analysis of this study included the Curriculum Director and the high school IB math teacher. Additionally, the instructor and peers in the Action Research Course, as part of NASA's Endeavor Science Teaching Certificate Project, gave helpful feedback and suggestions as well. Through gathering and analyzing a variety of data, and then utilizing several sources for analysis, the study was then assured a solid and credible foundation on which to report common findings.

IV. FINDINGS

Data analysis

Analysis of the data revealed a positive impact when embedding satellite education in the math curriculum for fourth grade students, specifically with regard to achievement and self-efficacy. The analysis involved seeking out emergent themes from each of the data sources independently, with the purpose of ultimately discovering common themes across all data sources. The five main themes that emerged from the data revealed the following: students displayed a *high rate of self-efficacy in math*; a *correlation existed between parent support of satellite education and students' attitudes* towards math; students were *motivated and engaged*; both students and parents viewed math and satellite education as being *meaningful*; and *positive academic achievement in math* was evident.

A high rate of student self-efficacy

High rates of self-efficacy in math were evident in the data found in the student surveys, journals and interviews. The overall trend that emerged from the student math survey, given at the end of the school year, was that the vast majority of students, including those in Special Services (SS) and English as a Second Language students (ESL) programs, perceived themselves somewhat to very capable in math overall. Furthermore, when comparing with the control groups, the experimental group displayed a 17% increase in mean scores, in 3 of the 4 questions asked on the survey. With the exception of one student, all participants rated themselves as being somewhat sure to very sure regarding every question asked. This is to say that the students felt they could *learn everything taught in math*, *do even the hardest work*, *learn a new topic even if it was hard*, and *figure out the answers to problems* presented by the teacher (see Figure 3).

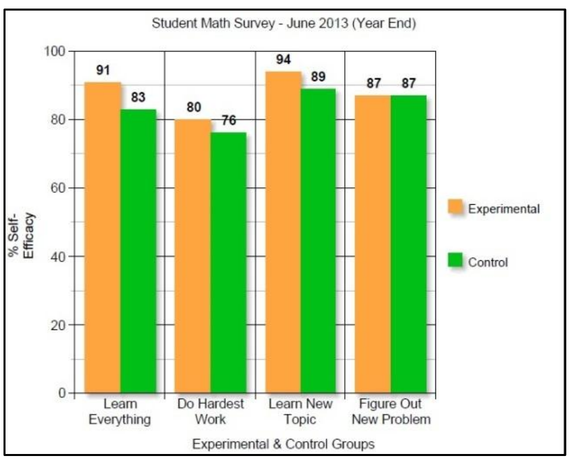

Fig. 3: Results from the student survey at the end of the school year. Students in the experimental group showed an average gain of 17% over the two control groups.

The students' journal entries revealed exceedingly positive responses on the subject of math perceptions, and students commented that they enjoyed multiplication and division (two standards recently covered and mastered by the majority of students) and learning new things. Responses included statements such as, "I like multiplication because I know how to do it!"; "I always am looking forward to doing Challenge Math"; and "In math I feel safe to express (myself) and solve problems in different ways".

Student interviews also revealed positive perceptions towards math, such as when one child wrote, "For me math is an extension of your mind. Math is a weapon that you always use in the field of work. The difference between writing and math is well…there is no difference. And that is what I like about math" (see Figure 4).

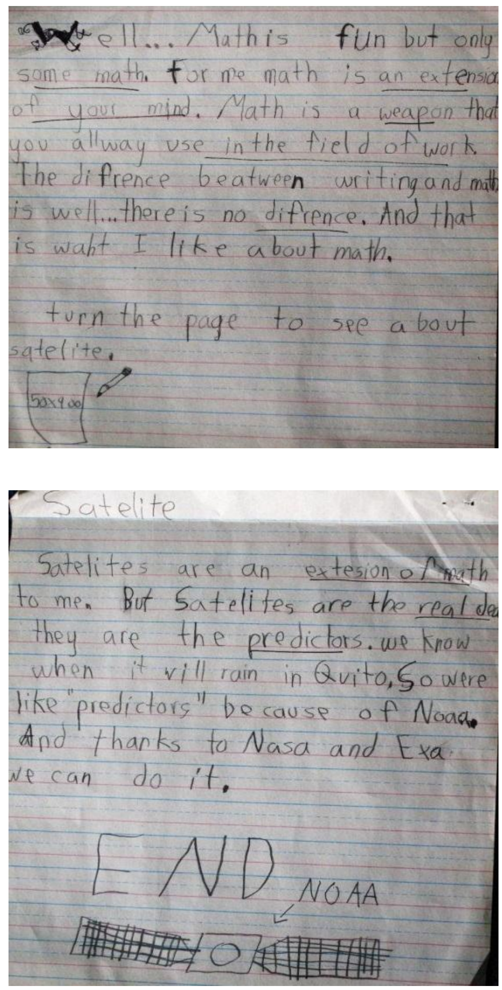

Fig. 4: A Special Service student's journal entry regarding his perceptions about math and satellite education.

It also became evident that positive self-efficacy was tied to optimistic feelings of having *surmounted perceived obstacles* as they related to understanding math and satellite content. This theme was evident with written responses such as, "I like to express my thinking (and) also having the emotion of finding the answer to problems and helping others". Although several students wrote that what they least enjoyed about math was when problems were hard to figure out, they also consistently added that when they were able to figure out a math or satellite problem, they subsequently experienced a feeling of satisfaction. This affirmative attitude towards math also correlated with the high scores that the students self-reported on the specific survey question about their perceived ability to learn a new topic.

A correlation between parent support of satellite education and students' attitudes towards math

All class parents responded to the parent survey, with 78% stating that they felt familiar with the satellite activities in which their child had been participating in class during the first semester, 96% perceiving satellite education as having value within the core classroom, and 84% believing that their child's interest in math was the result of including satellite education in the curriculum (see Figure 5).

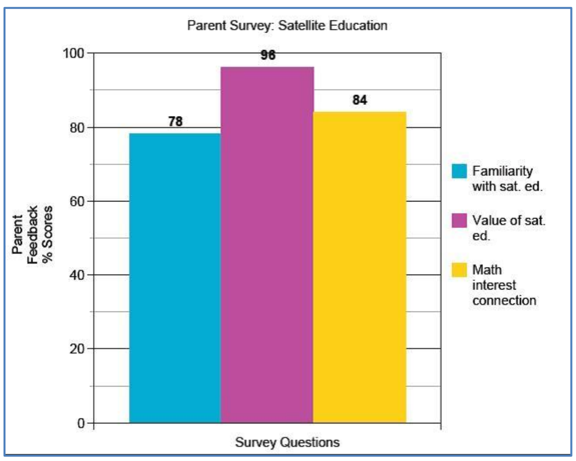

Fig. 5: Parent survey results.

With only one parent questioning the effectiveness of the methodology used in the core classroom, all parent comments were exceedingly positive. The high level of overall parent support in general could likely be attributed to the fact that the teacher-researcher conducted parent education on a regular basis in order to foster parent support and interest, as research elicits as a vital component to student achievement [1, 30]. Parent education took place either weekly or on a bi-monthly basis, and informed the parents of satellite activities that were occurring in the classroom through newsletters, emails, photos, conferences and/or personal conversations. Parent feedback included comments such as, "(Our child) has been very excited about the satellite activities. It has helped him to keep a very concrete focus on issues that otherwise would have been too abstract to grasp. His increased interest in math and science has a lot to do with satellites. Last but not least, there is a strong sense of pride in him because of satellite education. Summarizing: Only benefits, and very significant ones!!"

Notably, the parent who questioned he effectiveness of satellite education in correlation to math achievement gave herself one of the lowest scores on the parent survey, as did her child on her respective survey; despite her child's successful math scores on various assessments throughout the school year, and including a 20% growth on the VSOL. In summary, there was a 70% correlation between parent-student survey results; where student's self-efficacy mirrored that of their parent's attitudes towards satellite education and its relationship to math in the classroom; thus, indicating a link between parent support and student self-efficacy in math.

Student motivation and engagement

Another theme that emerged from the student surveys, journals, interviews and class observations was that the students enjoyed incorporating satellite education into the math curriculum because it was *interesting* and made them *feel special*. The student surveys included statements such as "I love, love, love, love math and learning new math things."; "I feel good." and "I love math. It is so cool!" While there was one outlier with a comment that said, "It's boring (math)", it is also worth noting that this student was currently undergoing a psycho-educational evaluation for admittance to special services for ongoing challenges in school.

Motivational journal responses included the following examples: "I like (satellite education) because we are some of the only kids in the world doing this, and it makes me feel special"; "What I like the most of downloading satellite images is that I can see the weather and how it changed", and "(I like knowing) more than other 4th graders".

One student noted in her journal that she liked satellite education because it "helps you learn more…it helps me feel more confident in myself. I think that when I am confident that helps me do more stuff at a higher level. I think this is great because it helps me push myself and helps me be a better student. I will keep looking forward to satellite education". During her interview, this particular student was asked to expand upon her desire to challenge herself, and she replied as follows: In 4th grade I'm more open to ideas than I was in 3rd grade. When we learn about space, it gives me more ideas, so I'm not a person who says 'math is boring'. I don't give up when I don't understand something, but I also don't show off either. I want to do my best because it's fun and I'm eager to learn.

Photos taken during satellite embedded math lessons supported the fact that the students were positively engaged, motivated, worked cooperatively and applied math standards and benchmarks in an authentic manner (see Figure 6).

Fig. 6: Satellite data analysis. In addition to applying math concepts in an authentic manner, students also applied other skills such as geography and language arts.

These findings support and contribute to the body of knowledge with respect to satellite education and its positive impact on interesting students in weather and space, turning students on to learning, and affecting overall positive changes in students' attitudes by connecting scientific events to the real world through technology [1].

Students view math and satellite education as being meaningful

A recurring theme when conducting interviews was that all students, including ESL and Special Services students, viewed math and satellite education as being meaningful in their lives; both in the present and future.

Interview #1.

When one Special Services student was verbally asked to clarify what he meant in his journal when he wrote that math is like a "weapon", he responded as follows: It's like you can use a sword to fight, or use it like a butter knife. You can also use a knife as a weapon, or to cut and peel things. Math is the same, because you can use it all the time. For example, you can "estimate" how much time you have to look at different things and keep from getting distracted and losing time.

This same student was also asked to explain what he meant when writing that "satellites are an extension of math to me". He clarified this statement in the following fashion:

Satellites depend on math. For example, scientists need to figure out how fast satellites should rotate around the earth so that they don't fall and crash, or not crash into other satellites; for example, the Direct TV or NOAA satellites. Also, if we do satellite education then we'll get better at math. When I did math in third grade, multiplication was hard, but with the WDLC it's easier because we do it in different ways, like with word problems.

Interview #2.

A second student was asked to clarify her journal comment which stated that she felt math could help her with her life goals, and she proceeded to explain that she wanted to be a veterinarian when she grew up and that she knew she'd need to use math everyday with her job, "like when I need to measure animals or see how many patients I need to meet with".

Interview #3.

In a third interview, the student was asked what he wanted to do when he grew up, and he replied that he'd like to work in offices where you can "roller skate and play the drums, like in the video you showed us (about Google offices)". He added that he'd like to work for businesses like Apple, or invent an X-Box Touch game; for which he explained that understanding math concepts would be crucial for him to succeeding in those occupations.

The interview responses supported the extensive research conducted by Dr. Robert Marzano, which reveal that student achievement can be attained when lessons involve new content that reflect on learning, and when concepts are applied at a deeper level; as both are with satellite education [12].

Students showed academic achievement in math

The math section of the Virginia Standards of Learning (VSOL) and Iowa Tests of Basic Skills (ITBS) were utilized for the purposes of quantitate data, to show both growth in math achievement over the entire school year.

With regard to growth in mean scores, the experimental group showed an overall increase of 3% over the combined average of the two control groups on the VSOL (see Figure 7). When breaking down the subject areas of this assessment, the percent increase of the experimental group was as follows: computation & estimation (7%), number & number sense (2%), measurement & geometry (7%),

VSOL Mean Scores June 2013	Computation & Estimation	Number & Number Sense	Measurement & Geometry	Probability & Statistics	Patterns, Functions, & Algebra	Overall Mean Scores
Experiment group	80%	83%	79%	86%	84%	82%
Control Groups A and B	73%	81%	72%	84%	83%	79%

Fig. 7: Year-end results on the math portion of the Virginia Standards of Learning (VSOL) standardized assessment.

probability & statistics (2%), and patterns, functions & algebra (1%). With regard to the ITBS, scores which were compared over a one year period, there was an overall increase in mean scores (growth) of 4.23% for the experimental group, when compared with the combined averages of the two control groups.

As *computation* was an area that the school wanted to focus on improvement, it is worth noting that the experimental group showed an increase of 7% in mean computation scores on the VSOL, over the combined control group scores, and a 12.68% increase with that particular standard on the ITBS. Thus, the quantitative data supports positive academic gains in mathematics (see Figure 8).

ITBS June 2013	Computation	Overall
Experiment group	19.55%	9.31%
Control Groups A and B	6.87%	5.08%

Fig. 8: Mean Score growth percentage in math, on the Iowa Tests of Basic Skills (ITBS) from June 2012 (grade 3) to June 2013 (grade 4).

DISCUSSION

This action research addressed the question as to whether or not embedding satellite education in the curriculum helped increase achievement and attitudes in fourth grade students with regard to math. The students in the study felt that they were somewhat sure to very sure that they could learn all math content, do even the hardest work, learn a new topic that was difficult, as well as figure out answers to math problems posed to them; and, when compared with two control groups, the experimental group also showed a 5.63% gain in the area of perceived confidence (self-efficacy) in math content.. Strong parent support for satellite education was likely the result of ongoing parent education, and also likely contributed to the high self-efficacy scores evident with the experimental group. Furthermore, the data supported the fact that these children were highly engaged and motivated when incorporating satellite education in the core classroom, and also viewed math as being meaningful in their lives. Lastly, quantitative data revealed positive gains with regard to math achievement; with a 3% increase in mean math scores on the VSOL and a 4.23% increase on the ITBS, when compared with the control groups.

Overriding themes revealed the importance of providing parent education for the purposes of cultivating parent support; which educational literature acknowledges is a key factor in student achievement [1, 30]. Journal entries and interviews also brought to light that students' perceptions of their math ability were strengthened when experiencing success in overcoming math challenges. A *sense of accomplishment* and increased ability were reported through *overcoming perceived math obstacles*, and a *sense of pride* was also evident in having participated in a program that was perceived to be unique and special. These positive attitudes, evident with both students and parents, were potential factors related to the increase in math achievement observed in the quantitative data. Educational research consistently validates the fact that academic achievement and perceived abilities are increased when students are engaged and motivated through hands-on, authentic learning, which was observed throughout this study [8]. In the publication, *Balance is Basic: A 21st-Century View of a Balanced Mathematics Program*, by C. Seeley, educational investigations show that "there is a difference in knowledge that is useful for an exercise in a mathematics textbook and knowledge that is needed to solve authentic, multifaceted problems in other contexts", and satellite education satisfies this need in an innovative fashion (Seeley, 2009, p. 2) [31].

Also worth noting is how the Ecuadorian and global communities became engaged in satellite education, once Ecuador launched its first nanosatellite, PEGASUS, in April of 2013 [32]. The unique ability of this satellite to share live, onboard video gave the students – and the world – free access to an innovative technology tool that broadened educational possibilities, as well as brought the media into the classroom [33, 34]. Unfortunately, almost a month later, space debris sideswiped the satellite and, although it was still "alive" and transmitting a signal, its changed orbit no longer allowed the public to access its video [35]. Nonetheless, this feat inspired the Ecuadorian nation and, most importantly, its children, to step into the world of space science for the first time. Pegasus also inspired the development of ASTERIA, a collaboration of three Ecuadorian schools – including Academia Cotopaxi – to pilot and develop methodologies with which to immerse satellite education into the classroom. Igniting this new awakened passion is the anticipation of the launch of Ecuador's second nanosatellite, Krysaor, expected at the end of 2013.

CONCLUSION

Both the quantitative and qualitative data attained in this action research affirm the idea that embedding satellite education in a fourth grade class helps increase achievement and self-efficacy in math. The findings help contribute to the body of knowledge in mathematics and aerospace education, as few action research projects have been conducted in educational settings where a virtual ground station exists in the classroom.

Limitations of this action research were evident in three areas, the first being that only one school year was spent on collecting data; thus, further research is needed to verify the findings in this study. Secondly, a pre-assessment of both the student and parent surveys, at the beginning of the school year, would have been ideal in analyzing any changes in attitudes that might have taken place during the time of this project. Lastly, although students and parents were instructed to respond specifically to "satellite education", some responses may have been intermingled with other, ongoing aerospace activities which regularly took place in the classroom as well.

From the teacher-researcher perspective, there were also challenges inherent in promoting an initiative such as the one proposed, the most prominent being the *lack of time* a typical classroom teacher would need to learn and implement a satellite education program. For this reason, it is highly recommended that any institution considering piloting a satellite education program be prepared to support the teacher with the *professional development* necessary, *extended preparation time* (especially the first year), and *technology support;* as previous studies have also shown these to be important ingredients to consider when implementing a satellite program[1]. As is educationally appropriate, a satellite initiative should also be utilized as a means to *go deeper* into the math content; rather than add additional standards and benchmarks to an already taxed curriculum.

The findings of this study support the notion that satellite activities align well with the US *Next Generation Science Standards*, through developing and using models, planning and carrying out investigations, analyzing and interpreting data and using mathematical and computational thinking. As this methodology also supports the US National math standards, it behooves educators and administrators to pursue further investigations in this rarely tapped STEM area [8, 9]. Ongoing research in mathematics would not only benefit students, but also educators, parents, administrators and the community on an international level. Cultivating a generation of STEM graduates is a worldwide objective for our 21st century learners, and satellite education is an innovative step in the right direction to attaining this goal [6].

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REFERENCES

1. Graham, S. (1995). Integrating weather satellite ground station technology into the K-12 classroom. http://www.met.fsu.edu/orgs/explores/Steve/thesis.html.
2. Ecuadorian Civilian Space Agency (EXA, 2013). Ecuadorian Civilian Space Agency announces the program "A Satellite in the Classroom" for giving real time access to weather satellites in schools in Ecuador. http://exa.ec/index-en.html.
3. The University of Iowa College of Education (UICE). 2013. Iowa testing programs. http://itp.education.uiowa.edu.
4. Forbes Magazine (2012). America desperately needs more STEM students: Here's how to get them. http://www.forbes.com/sites/forbesleadershipforum/2012/07/09/america-desperately-needs-more-stem-students-heres-how-to-get-them/.
5. McNeely, C.L. & Hamm, J. (2009). The global chase for innovation: Is STEM education the catalyst? *Global studies Review.* http://www.globality-gmu.net/archives/2972.
6. Science Magazine (2012). Obama's budget shuffles STEM education's deck. Science Insider. http://news.sciencemag.org/scienceinsider/2012/02/obamas-budget-shuffles-stem.html.
7. National Council of Teachers of Mathematics (NCTM). 2013. Math standards and expectations. http://www.nctm.org/standards/content.aspx?id=4294967312.
8. Stronge, J.H., Tucker, P.D., & Hindman, J.L. (2004). Handbook for qualities of effective Teachers, Alexandria, VA.
9. McCormick, N. & Lucas, M. (2011). Exploring mathematics college readiness in the United States. *Current Issues in Education*, 14 (1).
10. Next Generation Science Standards (NGSS). 2013. http://www.nextgenscience.org.
11. Gallagher, S. (2000). Collecting and manipulating weather data: using technology tools in a first-grade classroom. *Computers in the Schools*, 16 (3/4), 167-175.
12. Marzano, R.J. (2009). Setting the record straight on "high-yield" strategies. *Phi Delta Kappan*, 91 (1), 30-37.
13. Everett, S. & Moyer R. (2007). "Inquirize" your teaching: A guide to turning favorite activities into inquiry lessons. *Science and children*, 44 (7), 54-57.
14. Moxey, L., Tucker, C., Sloan, J. & Chadwick, J. (2004). Introducing real-time AVHRR-APT satellite imagery in the classroom environment. *Journal of Science Education and Technology*, 13, (3), 387-394.
15. Fast, L.A., Lewis, J.L., Bryant, M.J., Bocian, K.A., Cardullo, R.A., Rettig, M. & Hammond, K.A. (2010). Does math self-efficacy mediate the effect of the perceived classroom environment on standardized math test performance? *Journal of Educational Psychology*, 102 (3), 729-740.
16. Academia Cotopaxi (2013). American International School. http://www.cotopaxi.k12.ec/home/.
17. International Baccalaureate (2013). http://www.ibo.org/.
18. Weather Data Learning Center (WDLC). 2013. http://www.us-satellite.net/wdlc/.
19. WXtoImg (2013). Software to decode APT and WEFAX signals from weather satellites. http://wxtoimg.com.
20. NCH Software (2013). VRS Remote Monitor. http://www.nch.com.au/vrs/remote.html.
21. SMART (2013). SMART Board Interactive Whiteboards. http://smarttech.com/smartboard.
22. NOAA (2013). National Oceanic and Atmospheric Administration. http://noaa.gov/satellites.html.
23. NASA Endeavor Science Teaching Certificate Project (2013). http://www.us-satellite.net/endeavor/about.cfm.
24. AWTY International School Weather website (2013). Weather satellite images recorded at Houston, TX, USA. http://wx.w0mm.com/.
25. Hopefl, M.C. (1997). Choosing qualitative research: A primer for technology education researchers. *Journal of Technology Education*, 9 (1), 47-63.
26. Hoyles, C., Kuchemann, D., Healy, L. & Yang, M. (2005). Students' developing knowledge in a subject discipline: Insights from combining quantitative and qualitative methods. *Int. J. social Research Methodology*, 8 (3), 225-238.
27. Virginia Department of Education (2013). Standards of Learning (SOL) & Testing. http://www.doe.virginia.gov/testing/index.shtml.

28. Bocian, K.A., Bryant, M.J., Cardullo, R.A., Fast, L.A., Lewis, J.L., Rettig, M. & Hammond, K.A. (2010). Does math self-efficacy mediate the effects of the perceived classroom environment on standardized math test performance? *Journal of Educational Psychology*, 102 (3), 729-740.
29. Gerdes, D.A. & Conn, J.H. (2001). A user-friendly look at qualitative research methods. *Physical Educator*, 58 (4), 183-193.
30. Leyla, A.K., & Sayil, M. (2006). Three different types of elementary school students' school achievements, perceived social support, school attitudes and behavior-adjustment problems. *Educational Sciences: Theory & Practice*, 6 (2), 293-300.
31. Seeley, C.L. (2009). Balance is basic; A 21st-century view of a balanced mathematics program. *Math Solutions*, 104.
32. Worldwide Tech & Science (2012). Ecuador to launch its first satellite "Pegasus". Students' desks will become spaceships. http://worldwidegadget.blogspot.com/2012/08/ecuador-to-launch-its-first-satellite.html.
33. Ms. Margot's Class – Student Authors (2013). Through a variety of audiovisuals, Lower School students journal about their class experiences. http://msmargotsclass.blogspot.com/
34. Margotmania (2013). The adventures of an educator in aerospace education! http://margotmania.blogspot.com/.
35. BBC: News Latin America & Caribbean (2013). Ecuador Pegasus satellite fears over space debris crash. http://www.bbc.co.uk/news/world-latin-america-22635671.