A QUEST FOR TRUE INTEGRATION OF SCIENCE AND MATHEMATICS EDUCATION IN THE CONTEXT OF NASA-SPONSORED SPACE SCIENCE EDUCATIONAL OUTREACH. M. L. Urquhart[1,2], P. K. Kisunzu[1], and M. Hairston[2], [1]Department of Science/Mathematics Education, The University of Texas at Dallas (Mail Station FN 33, 800 West Campbell Rd, Richardson, TX 75080, urquhart@utdallas.edu), [2]William B. Hanson Center for Space Sciences, The University of Texas at Dallas (Mail Station WT 15, 800 West Campbell Rd, Richardson, TX, 75080, hairston@utdallas.edu).

Introduction: From the beginning, the formal education component of the Education/Public Outreach (EPO) program for the joint NASA/Air Force/UT Dallas Coupled Ion Neutral Dynamics Investigation (CINDI) [1] has been designed from the perspective of meeting the needs of teachers. However, like most educational outreach programs for NASA missions, the use of mathematics has been in the support of teaching science concepts rather than the other way around. Although teachers of secondary (middle and high school) science and secondary mathematics share some common goals, the approaches and needs of these populations often differ greatly. We are in the process of taking a new look from the mathematics education perspective at our current formal education resources and at how we design new materials so as to better serve both science and mathematics teachers and their students. By thinking about the needs of the mathematics classroom, we have an opportunity to engage mathematics students with the excitement of active space exploration, as has been done with the sciences.

A Legacy of Partnerships: The initial methods adopted by the CINDI E/PO team were a direct result of the partnership between the UT Dallas Center for Space Sciences and Masters of Arts in Teaching program in Science Education. By starting with the National Science Education Standards [2] and the Texas Essential Knowledge and Skills for Science [3] and the questions 'What do students need to know?' and 'What do teachers need?' in the grades in which Earth and space science are generally taught in our home state of Texas and the nation at large, we essentially adopted a backward design approach [4]. Although we acknowledged the strong ties between science and mathematics in the activities adapted and created for the CINDI curriculum materials and educator workshops, we did not take into account the perspective of the mathematics teachers who might also be interested in our materials.

Thinking About Mathematics: Initially, we thought about mathematics entirely from the perspective of science teachers, focusing on what supporting mathematics skills students could be expected to have by a particular level in school. We did included alignment with the state and national mathematics standards, but only after the middle school activities were created. The reliability of the transfer of skills and concepts from the mathematics classroom into science classrooms has long been a concern in curriculum development and inplementation. Repeatedly we at UT Dallas hear from inservice teachers in our programs that the concepts and skills their students are taught all too often don't make the transition across the the hall from the mathematics classroom to the science classroom, and vice versa.

Traditional separations between the disciplines at all levels is likely to be at least part of the issue with crossover of mathematics and science content. In the experience of the first author in previous space science curriculum development projects [5], little coordination or communication existed between the middle school science teachers and the mathematics teachers covering overlapping material. To quote two Master Teachers (former directors of science and mathematics in local school districts) in the UTeach Dallas [6] secondary science and mathematics teacher preparation program: "based on a combined twenty six years of observing grades 4-12 science and mathematics classrooms, we observed no planned effort to intergrate mathematics into science in a way that tried to highlight mathematics as a part of science that went beyond simple coincidence of topics" even with curriculum department encouragement and support. [7]

Certainly efforts have been made at breaking down traditional silos in K-12 education and reformers in STEM (Science Technology Engineering and Mathematics) education are aware of the challenges for teachers. A long term professional development project with this goal notes that despite the rich context science can bring to mathematics, without experience in integration of the disciplines, teachers "are unlikely to teach integrated curricula in their classrooms".[8] Recently in the state of Texas, recommendations from the Science Teachers Association of Texas to change language in the state science standards for middle school to align with language in mathematics (such as using mean in place of average) were included in the recent decadal revisions.[9] Although alignments in language may not at first glance seem significant, Mireles [10] argues that in correlating mathematics and science, misconnections can occur due to differences in language that hamper student learning. In the UTeach [11] program, originally created at the University of Texas at Austin (and for which UT Dallas is a replication site), integration of future science and mathematics teachers in certification coursework is both purposeful and thoughtful. Our involvement in the UTeach replication process, and new levels of interaction between mathematics education and science education faculty, have spurred the current effort to re-examine the design of our CINDI E/PO program.

Opportunities for Teaching Mathematics: Space science content can provide rich opportunities for linkages to mathematics beyond the traditional connections to science with measurement and word problems. Scale modeling, for example, a highly utilized component of the CINDI E/PO materials, involves quantitative and proportional reasoning. The inclusion of metric units and very large numbers inherent to space sciences can broaden and make relevant instruction typical to the mathematics classroom.

Units and large numbers are mentioned explicitly in descriptive text in the *Principles and Standards for School Mathematics* in middle grade levels [12]: “Work in the metric system ties nicely to students' emerging understanding of, and proficiency in, decimal computation and the use of scientific notation to express large numbers.” – p 241. However, these topics are more often than not neglected in the context of mathematics instruction, despite their importance to science. Students may encounter large numbers associated with distances in the solar system as early as third grade, but may be provided with little context with which to develop number sense with regard to such numbers in their mathematics classes. Helping teachers of mathematics see the value and relationship of such topics to their own instructional needs may assist students in getting the foundation necessary to build reasoning and understanding in both fields. Findings of outcomes of major curriculum reform efforts emphasize that “[o]f particular relevance to teachers are requirements related to what is taught, how it can be taught, and how it is assessed.” [13] If our formal education resources are to authentically integrate science and mathematics instruction, then the requirements placed on teachers in both disciplines must be taken into consideration.

How Big is a Million? To assist teachers and students in developing number sense/quantitative reasoning with regard to very large numbers, we have created a resource to aid in conceptualizing numbers beyond the realm of everyday experience but which appear frequently in space science and in other sciences. “How Big is a Million?” uses a powers of ten approach with one thousand tally marks, made in sets of five, copied onto one thousand numbered pages of double-sided paper and bound into a volume. The one million marks made with one ream (500 sheets) of paper is a starting place for using reams and boxes of copy paper as units to build number sense of ever larger numbers. The first guided activity, designed for upper elementary, uses mathematics manipulatives to strengthen the development of number sense and the concept of sets. We intend to use the “*How Big is a Million?*” resource along with our existing scale modeling activities to aid middle grade level students in understanding of underlying mathematics concepts in our curricular materials in a way that meets the requirements of mathematics teachers as well as science teachers.

High School Connections. While connections between high school physics and mathematics are readily made, again the differing needs of instruction in both disciplines should be considered. We are examining the role our resources for physics teachers can play in strengthening high school mathematics instruction. For example, a laboratory demonstration device we recently filmed for inclusion in instructional videos on the CINDI E/PO website shows the interaction of a beam of electrons with electric and magnetic fields. The mathematics behind this interaction is ideal for development of quantitative and proportional reasoning and algebraic thinking.

Conclusions: We are just beginning our quest for true integration of science and mathematics in the context of our NASA-sponsored educational outreach activities and professional development for teachers. The goal of the CINDI E/PO team has, from the beginning, been to use the excitement and real-world application of the CINDI mission to engage students and their teachers in meaningful educational experiences. Including this new perspective – that of the mathematics educator – in our work can only serve to strengthen our efforts to make useful and relevant contributions to space science education.

References:

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