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Executive Summary

This report presents the findings from an exploratory study of the Aspirnaut program in Maine. Specifically, this study examined the implementation of weekly STEM labs delivered to the classroom via video-conferencing (or "beaming").

To date, six different rural states have participated in some aspect of the Aspirnaut initiative, and four states currently participate in the "beamed" STEM lab program including: Arkansas, Tennessee, Maine, and Montana. During the recent 2012-2013 school year, 13 schools across the four states participated in the STEM labs, and five of those schools were located in the Maine communities of Otis, Surry, Milbridge, Dedham, and Deer Isle. STEM labs were implemented in grades 4-8, and our case study school expects to expand the program to grade 3 next year.

Using a qualitative case study research design, this study collected data through interviews, observations, and program documentation for one elementary school in Maine that implemented the program in fall 2012. Interviews were conducted with the program founders, principal, two teachers, and (through a focus group session) approximately half of the participating students from two elementary classrooms. The study investigated perceptions about the program goals, implementation, impacts for teachers and students, and suggestions for program improvement.

The long-term objectives of the Aspirnaut initiative are to improve student achievement in STEM (Science, Technology, Engineering, and Mathematics) areas, and to feed the pipeline for a robust workforce in STEM-related careers. To support those goals, the intervention seeks to increase student interest and excitement in STEM through hands-on inquiry activities guided by a Vanderbilt scientist. Participants agreed that the "beamed" STEM labs are designed to help students learn science from real scientists working in a broad range of STEM fields, and to get kids inspired to pursue STEM education and careers. Further, the program targets rural schools that have traditionally had fewer resources for STEM education.

The evidence from one case study school in Maine strongly indicated that the "beamed" STEM lab program was successful in achieving several objectives. By implementing this program, the school we studied had increased instructional time for science, the frequency of hands-on inquiry activities, the depth of science lessons, and the level of science expertise for guiding student learning. The program also increased students' interest in science in general, their enjoyment and excitement in learning about science, their awareness of different STEM disciplines and careers, and their aspirations to pursue science education in college and STEM careers. While students' comments during the observations and interview indicated they had learned some science content and vocabulary, we were not able to collect quantitative evidence of impacts on student learning and achievement. Further research is needed to explore the impact of the intervention on student learning.

Impacts for teachers were less clear. Both of the teachers participating in the STEM labs in our study school indicated they had learned more about using technology such as the video-conferencing equipment through this program, and that the program provided increased resources to deliver hands-on science inquiry more frequently than before. While this study could not confirm the impact of the program on teachers' content or pedagogical knowledge, there is great potential for the STEM lab program to improve teacher knowledge and instructional practice in science.

The principal, teachers, and students were largely very satisfied and enthusiastic about the quality and impacts of the STEM lab program from Vanderbilt. The teachers' suggestions for improvement were minimal. They requested more specificity on the type and quantity of supplies or materials needed for lab activities. They also suggested that the program developers adjust lab guides to ensure that the vocabulary and difficulty level is grade appropriate. While the labs were primarily developed for middle grade, some schools are implementing these labs below grade 5. Purchasing and organizing the supplies was somewhat of a burden for the teachers, and this may need more thought. Overall, students and their teachers were more excited about engaging in science inquiry and said they would like to have more time for science instruction.

In addition to the participants' suggestions, our study identified a few other areas for program improvement. One important recommendation is to incorporate discussion guides and assessment tools in the lab activities to guide instruction and provide teachers with more resources, as well as a method of measuring student learning objectively. Another recommendation is to incorporate more mathematics, technology, and engineering into the labs, as these areas received considerably less attention than science in the case we studied.

Introduction

At the request of the Maine State Legislature, the Maine Education Policy Research Institute (MEPRI) undertook an exploratory study to evaluate the Aspirnaut initiative in Maine. Faculty and staff from the University of Maine's Center for Research and Evaluation conducted this work during the spring of 2013. The purpose of the study was to better understand the goals of the Aspirnaut initiative, how the video-conferenced or "beamed" STEM labs component is currently implemented in Maine schools, and the perceived impacts for students and teachers. This report presents the findings from the study.

Overview of the Aspirnaut Initiative

The Aspirnaut initiative was founded in 2006 by Drs. Julie and Billy Hudson as a science education program and partnership between rural schools in Arkansas and Vanderbilt University Medical Center. The program has been implemented in six different rural states, and is currently used in four states: Arkansas, Tennessee, Maine, and Montana. The initiative's long-term objective is to assist in the development of a robust STEM (Science, Technology, Engineering, and Mathematics) workforce in the U.S. To support that goal, the intervention's more immediate objective is to support improved STEM education and achievement in grades K-12, primarily in rural schools that have traditionally had fewer resources for education, particularly STEM instruction. Dr. Julie Hudson explained in an interview for this study, "There are unique barriers and challenges for rural students in achievement in general, but in STEM in particular." For example, the Hudsons found that rural classrooms in Arkansas lacked adequate supplies or science kits and rarely conducted the kind of hands-on inquiry required by state standards.

The Hudsons also observed that it is difficult if not impossible for K-12 educators to stay current with STEM education given the rapid rate of innovation and new knowledge developing within science, and the broad range of science disciplines. A university-school partnership allows students and teachers to learn directly from scientists and helps to keep science education current as well as rigorous. As Dr. Billy Hudson noted, ". . . you're not going to turn teachers into scientists, and you're not going to turn scientists into teachers." The Aspirnaut initiative is based on the premise that students will learn more science content and be more inspired to pursue further science education and careers if they have the opportunity to learn directly from real scientists and to engage in fun, hands-on, inquiry-based investigations that have real-world relevance. Dr. Billy Hudson pointed out, ". . . one is hard-pressed to make the case that if one feels unsuccessful in an area, that one wants to spend a lot more time in that activity or pursuing that as a job or career."

The Aspirnaut initiative supports several different program components that together serve to feed the K-20 STEM pipeline. These include:

- Online STEM courses on school buses delivered daily via Wi-Fi and media screens (grades K-12); and supported by twice weekly community classroom sessions after school.
- Video-conferenced or "beamed" STEM labs in classrooms delivered weekly (grades K-8);
- Summer science immersion at Vanderbilt for teachers and students (grades 3-8);
- Accelerated/AP online courses with dual enrollment (grades 6-12);
- Summer research internships at Vanderbilt for rural high school students (grades 9-12);
- Guidance for high school students contemplating college; and
- Mentorship of students through interaction with science researchers (grades K-Post Doc)

In this section, we briefly describe the online courses delivered on school buses, video-conferenced or beamed STEM labs, and summer professional development for teachers.

Wi-Fi and Media Screen Buses

In 2006, the Aspirnaut initiative began piloting the Wi-Fi and Media Screen Buses in a rural school in Arkansas. This effort involved delivering online STEM courses to students via ipods or laptops on school buses. The idea was to engage students in STEM education during the long bus commute to and from their rural schools, five days a week. This would substantially increase the amount of instructional time students engaged in STEM education, and also deliver high quality instruction developed by scientists from across various STEM disciplines. Fifty semester-long online courses were completed with a score of 80% or higher during the three year pilot. A second iteration of the bus program was a one-year pilot, where ceiling-mounted media screens were installed and content was age-differentiated in three zones of the bus. Challenges in both efforts included delivering developmentally appropriate instruction to students across a wide range of ages on the bus, technology issues, and adequate technology support from the school district. This component generally has not been implemented in schools participating in the Aspirnaut initiative.

Video-Conferenced or "Beamed" STEM Labs

In 2006, Vanderbilt also initiated a pilot for video-conferencing hands-on, inquiry-based STEM lessons to rural school classrooms in Arkansas. These lessons were taught by undergraduate or graduate students and faculty in STEM fields at Vanderbilt University. The video-conferenced STEM labs program has been more widely adopted than the Wi-Fi and media screen bus program.

During the piloting phase of the program, the video-conferencing happened only a few times during the year, but was gradually expanded into a program for the full school year. The full year program has been in place for the past three years. Schools can either conduct the labs as part of the regular school day or as an after-school program. During the recent 2012-2013 school year, 13 schools in four states participated in this program. Five of those schools were located in the Maine communities of Otis, Surry, Milbridge, Dedham, and Deer Isle. The 13 schools implemented the video-conferencing program in grades ranging from 4-8.

According to the Aspirnaut website, the beamed STEM labs program has two primary goals:

1. *To inspire K – 8 students living in rural locations to pursue higher education and careers in STEM fields; and*
2. *To augment the science curriculum offered in rural schools and improve student achievement in STEM subjects by providing hands-on science activities and weekly classroom conversations with undergraduate or graduate students in STEM concentrations, or faculty in STEM fields, at Vanderbilt University.*

Summer Science Immersion for Teachers and Students

In addition to beaming STEM labs to classrooms during the school year, the Aspirnaut program offers a two-day summer science immersion experience (or even up to a week or two) in June for participating teachers and their students. Participants get to spend time in Vanderbilt's lab facilities and meet the students or faculty with whom they've video-conferenced during the year. During their visit, teachers follow their students through science lab activities and observations, and get to see modern research technology and equipment. The workshop is pre-planned, with curricular elements that have defined goals and objectives for learning. While some schools have taken advantage of the two-day opportunity, none have pursued the longer immersion experience. The barriers for teachers and schools seem to be time and financial resources to cover travel expenses.

Focus of this Study

This study focuses on the weekly video-conferenced or "beamed" STEM labs, and the implementation of that program in one rural elementary school in Maine during 2012-13. The five schools in Maine participating in the Aspirnaut initiative are currently implementing only the video-conferenced STEM labs.

Evaluation Methods

This evaluation uses a case study research methodology with data collected through participant interviews, classroom observation, and program documents. Due to time and funding constraints for the study, the scope of the study was limited to one elementary school in Maine that implemented the beaming STEM labs beginning in fall 2012. The study explored four broad evaluation questions:

- What are the program goals?
- What is the design of the "beamed" STEM labs intervention program?
- How is the program currently being implemented?
- What are the perceived impacts for students and teachers?
- What suggestions if any do teachers, students, and the principal have for improving the STEM labs program?

The school selected for this study is a small, rural elementary school in Maine with an enrollment of approximately 100 students. The principal came to the school with prior experience using the beaming STEM labs and was a strong advocate for the program. Together, the principal and the school board viewed this intervention as a catalyst for strengthening science instruction and student learning, and for inspiring greater student interest in science and science-related careers. The school implemented the video-conferencing labs with Vanderbilt in fall 2012, with two elementary grades combined for the weekly STEM labs, with approximately 20 students and two teachers. The principal and teachers hope to continue the video-conferencing next year with Vanderbilt and also plan to extend the program to one additional grade below the participating grades.

Interviews were conducted with the Aspirnaut founders, the school principal, and each of the two teachers participating in the program. In addition, a student discussion group was conducted with ten students (about half) from the participating classrooms, six from one class and four from the other. (See Appendix A for interview protocols.) All interviews were recorded, transcribed, and de-identified. Information about the program goals and implementation were also obtained through the Aspirnaut program website and through collection and examination of lesson materials. The data were analyzed for themes related to the evaluation questions, and analytical tables were used to compare the perceptions of the different stakeholder groups. Any teacher names appearing in this report are pseudonyms.

Three classroom observations of the beaming STEM labs in action were conducted in April and May. Descriptive field notes were written during the observations and focused on how the activity was implemented, teachers' and students' actions and levels of interest during the activity, and instructional materials or guides used to support the activity.

Each stakeholder group was asked about the impacts of the intervention for students, and all groups except the students were asked about the impacts for teachers. For example, the interviews explored perceptions about the impact of the intervention on students' level of interest in science, aspirations to attend college and pursue a science career, and students' conceptions of science. Impacts for teachers' understanding about science and teaching practice were further investigated through the classroom observations. The interviews also probed participants' views about the hands-on lab activities and the video-conferencing with Vanderbilt scientists, to learn what is working well and which aspects could be improved.

Findings

In this section, we present the findings of the case study related to the broad evaluation questions outlined earlier. Our focus here is on the STEM lab program delivered weekly via video-conferencing.

Program Goals

We investigated the intended goals for the Aspirnaut initiative and the STEM lab component specifically through the interviews. The program founders said that the immediate goal of the program is to increase student achievement in STEM. They also hope this initiative will inspire students to continue with advanced courses in science and mathematics in high school and to pursue higher education and careers in STEM fields. Yet, Dr. Billy Hudson feels the most important aspect of the program is the ability to communicate to students and teachers a passion for science. And Dr. Julie Hudson described the broad goal of the Aspirnaut initiative in a similar way:

> One would hope that one of the deeper levels of impact is that it engages the students. That they find that we have conveyed that passion, that enthusiasm, this fascination that science is everything about them. It's all around them. It's in them. It's part of almost everything in their environment. . . . It's something far more integrated into their lives. And that does drive them to have a greater curiosity about these things going on around them constantly.

The Hudsons recognize that "science has moved so fast. . . . we have to find ways to have the scientists team up with those teachers out there, as a partnership, and share this responsibility and translate this knowledge of science to the kids."

In the Maine elementary school we studied, the principal felt that the major goal of the "beamed" STEM lab program was to expand the content knowledge of students and teachers by interacting with scientists working on STEM research, and to increase the material resources and opportunities for students to do hands-on science investigations in their schools. She commented, “We’re getting real science taught by a world class university. And the other piece is the technology.” In addition to supporting increased knowledge and learning in STEM, the principal agreed with the founders’ view that students and teachers can be inspired by the passion scientists communicate about their fields of expertise. The principal summarized it this way: “I get professional development, and student learning, and student engagement beyond belief. The excitement and the enthusiasm, and the idea that science wasn’t a textbook conversation.” She also saw the program as a way to raise aspirations for students in her rural community.

> I saw this right from the beginning as an opportunity to have career prep and aspirations conversations: ‘Well, you’re already going to Vanderbilt. You’re already in college.’ And in rural Maine schools, there are kids who don’t believe that they are going to be capable of that, either academically or financially. And so by saying, ‘You’re already there,’ you’ve opened a door for them that they can walk through later on.

Both of the elementary teachers we interviewed identified bringing hands-on science to elementary school students and raising career awareness for students as the two major goals of the program. One of the teachers, Cindy named an additional goal of showing students different educational uses of technology (e.g., using computers, cameras, video-conferencing, PowerPoint presentations, or YouTube videos). This teacher emphasized that in her small rural school, obtaining instruction via Skype was a novelty and “a big deal” for the students.

When asked what they hoped students would learn from the STEM labs with Vanderbilt, the teachers expressed somewhat different goals. Cindy wanted her students to learn and connect the vocabulary of their STEM labs with real life, and to participate in hands-on, experimental learning that promotes self-directed discovery and sparks students’ interest in science. Beth said she wanted her students to “put on their lab coats and be the best scientists they can be during the labs." She hoped that the students would participate in the pre-lab activities and share what they learned from the lesson after the lab.

When asked what their goals were for their own professional learning through participation in the "beamed" STEM labs, the teachers also had disparate responses. Cindy's goals were to become more comfortable using technology in the classroom, such as learning how to use the Smart Board and adjusting the camera for Skyping. She also wanted to be well prepared to teach the lesson in case the technology failed during a Skyping session. Beth viewed the program as an opportunity to learn new hands-on science activities that can be done with a reasonable number of materials.

In comparing the different perspectives, we found that the founders, principal, and teachers identified several major goals of the Aspirnaut STEM lab program. They all agreed on the potential for students to be inspired by the opportunity to interact with university scientists. Yet, the founders and the principal emphasized the potential to convey a sense of passion or interest in science and to subsequently increase knowledge and student achievement in science, while the teachers focused more on the opportunity to conduct more frequent hands-on science activities and incorporate more technology into the classroom.

Program Design

In this section, we describe the general design of the video-conferenced or "beamed" STEM lab component of the Aspirnaut initiative, outlining what it is, how it is typically delivered to classrooms, and who facilitates or delivers the instruction.

The program is structured in such a way that it makes the students feel like they are already in college. The STEM labs effectively turn classrooms into an extension of a university science laboratory. Students and teachers wear white science lab coats embroidered with the

Vanderbilt name, and they work with Vanderbilt researchers under the supervision of the classroom teachers.

The classroom video-conferences with Vanderbilt via Skype and the video is projected onto a large Smart Board in the classroom. Students work in small groups as the Vanderbilt scientist provides some background information about the science concepts involved in the activity, leads them through each step of the activity, and facilitates discussion through questioning. Science content is delivered both through mini-lecture from the scientist as well as through visual aids such as videos or pictures on the handouts. The entire session is conducted weekly in one hour sessions.

There is also a brief non-science portion of the video-conferencing that typically takes place at the beginning and end of each session. This is a time when the Vanderbilt scientist greets students in the classroom, asks them about their activities or interests, and allows students to ask questions about how the facilitator chose his/ her science field and what educational preparation they needed to pursue their career. The purpose of this brief social exchange is to inform young students about a range of careers in science, and to inspire them to pursue their interests through post-secondary education.

The program strives to provide 25 videoconferencing labs to each participating school over the course of the school year. Typically, before the school year starts, volunteers from Vanderbilt work with participating teachers to coordinate available STEM lab activities with teachers' lesson plans for the semester/year. The topics focus on various areas of science and engineering, with some technology and mathematics incorporated into activities. The Aspirnaut program has created a series of activities around central, foundational concepts of science, such as electricity, magnetism, or energy. Teachers select topics and lab activities based on their state standards and curriculum requirements for the particular grade levels. Lessons also incorporate discussion or demonstration of how the science concepts are found in the real world or applied to help solve real-world problems.

For each lesson, Aspirnaut provides an activity guide for teachers and written handouts for students. The STEM lab activities are generally developed for the middle school level, but can be adapted for lower grade levels if the facilitator adjusts the vocabulary or mathematics involved in the activity. Schools can purchase lab kits directly through the Vanderbilt program or buy the materials independently. In general, most of the materials are inexpensive household items that are available from the grocery store or local hardware store. Occasionally some items are more difficult to obtain.

The Aspirnaut program typically recruits undergraduate students pursuing science majors but also involves graduate students and faculty who volunteer through an existing program called "Vanderbilt Student Volunteers in Science." The volunteer service program had existed for about ten years before the Aspirnaut program began a collaboration. The volunteer program put undergraduate students from STEM disciplines into area classrooms to support science instruction.

Scientists volunteering to facilitate the STEM labs are matched up with activities based on their area of expertise and are trained prior to delivering the lab to classrooms. They attend meetings with program staff, consult with experienced facilitators, and learn how to communicate with younger students. They are video-taped and evaluated on their facilitation skills before they video-conference with real classrooms. The Aspirnaut program solicits feedback from classroom teachers and the Vanderbilt volunteers after each session. The program currently does not include any assessment measures to determine what students have learned or retained from the lab sessions. Teachers have discussion guides that they may use for post-lab questioning if they wish.

Program Implementation

In this section we describe how the Aspirnaut program has been implemented in one elementary school in Maine, the general format for the "beamed" STEM labs we observed, the activity and content for each of the three labs, and finally some thoughts about the labs we observed.

STEM Lab Scheduling and Mode of Delivery. Over the course of the 2012-13 school year, the school in our study participated in approximately 25 STEM labs through video-conferencing. The majority of these sessions occurred during the spring semester. The hour-long labs were conducted during the final class period on Friday afternoons, combining two elementary grades in one classroom. Prior to the STEM labs, the teachers combined their classes and spent approximately 30-45 minutes "pre-teaching" concepts that would be covered in the lab activity. We did not observe a pre-teaching lesson, and do not have data on how those lessons were conducted or aligned with the Vanderbilt lab activity. We also did not collect any evidence about the post-activity discussion or debriefing with students, although the teachers said this typically occurs after the lab through informal questioning.

The implementation of the Aspirnaut STEM labs may have increased the amount of instructional time scheduled for science each week in this school. In the school year prior to the program (2011-12), teachers in the observed grades spent approximately 60-120 minutes each week delivering science instruction. After the program was implemented, teachers spent approximately 90-120 minutes each week on science. Therefore, the time spent on science was either the same or slightly increased from the previous year after adding the Aspirnaut component.

Format of the "Beamed" STEM Labs. The STEM labs in the school we studied followed the general format described by the program founders and outlined in the written lab guides. In preparation for the session with Vanderbilt, the teachers brought students together into one classroom. Students were seated in groups of five or six. The two teachers and students proudly donned their lab coats, and assembled the required lab materials for each desk group. Depending on the activity and availability of supplies, students either worked with a partner or with a larger group. Students worked with partners during one of the STEM labs we observed, while the other two activities were conducted in bigger groups of five or six students sharing a common set of supplies. Teachers assigned students to different groups over the course of the year.

Once the students were settled into their groups, one teacher, typically Cindy, initiated the Skype call with the Vanderbilt facilitator for that week's lesson. The three labs we observed followed a similar format, which we describe here. First, the facilitator took a few minutes to greet students, ask questions, or share information about his/her background and research interests with the students. The facilitators we observed were friendly and enthusiastic in their communication with students via video through Skype. In two of the labs we observed the facilitators were undergraduate students, and in a third lab the facilitator was a graduate student. One of the program founders greeted the students during the final session of the year.

After the initial greetings, the facilitator gave a quick overview of the day's activities and asked students questions about what they knew about the day's topic. Then the facilitator provided some basic, introductory information about the topic and science concepts for the activity. This included some background information such as vocabulary terms or explanations about the content. In one lab we observed, some of this information was communicated through two short videos, while the other two labs relied on verbal commentary from the Vanderbilt researcher.

After the preliminary introduction to the science concepts, the facilitator guided the classroom step by step through the planned activity. Although students could see the Vanderbilt researcher in his/ her own lab setting, the facilitator did not demonstrate how to set up the materials or how to do the lab activity in any of the three labs we observed. When the teachers or students had questions about how to set up some lab materials or the quantity of a material to use, they asked the facilitator for clarification. The facilitator could observe the students as they worked in the classroom. The two teachers circulated around the classroom to assist students during the activity. The principal assisted with one of the labs we observed, and a custodian assisted with another lab. Sometimes students were asked to record their observations on their lab sheets, but we only observed the students doing so in the third lab we observed.

Throughout the lab activity, the Vanderbilt scientist took an active role in leading the questioning and discussion around the concepts and vocabulary terms. We observed this occurring at several points—typically in the introduction to the activity, during the activity, and after the inquiry activity was completed. The classroom teachers sometimes asked students questions, but more often simply restated students' questions or answers so the Vanderbilt scientist could hear them. In our three observations, students were generally attentive and quiet during the discussion, although they were most attentive at the beginning of the lab, before they got involved in the activity. They were eager to respond to the facilitator's questions at the beginning and end of the lab session, as indicated by the large number of hands eagerly being raised. Teachers generally called on students as the facilitator would not know students' individual names. Students were less attentive to the facilitator or often did not respond to the facilitator's questions during the middle part of the activity, when students were highly engrossed in working with the physical models or materials and communicating ideas with their teammates.

Content of STEM Labs. The school in our study participated in science labs that covered a wide range of topics including: biology, anatomy, and physiology; chemistry, acids, and bases; physics; geology of Earth and solar bodies; and geothermal concepts and fossil fuels. We observed three STEM labs: one in early April and two in late May. Our last observation was the final STEM lab of the school year. We describe each of these lessons briefly here.

***First Observation*.** The first STEM lab we observed focused on how fossil fuels develop deep within the earth and how they are found through exploration and drilling of core samples. The central topics were geology and the process of decomposition of plant matter. This lesson was facilitated by a male graduate student from Vanderbilt, and had two distinct lab activities.

In the first activity, students worked with a partner to assemble a type of aquarium that, over time, would simulate the process of decomposition, development of fossils, and fossil fuels. They placed water, sand, dirt, twigs and leaves into a Ziplock bag inserted into an empty soda bottle. Over the next few weeks, they would add more sand and observe the decomposition of the plant matter. Students were quite interested and engaged in this activity. Many students stood up while assembling the materials and they all had opportunities to work with the materials.

In the second activity, students worked in groups of five to assemble layers of the earth using different colors of Playdoh, where white represented oil deposits. The models were then reassigned to different groups and students took turns inserting a straw to simulate oil exploration with core samples. The facilitator said to students: “So now you guys are all engineers and you need to do an expeditionary trip to see where the oil is. Imagine this is a huge oil field and you have to see where the oil is. So you’re going to use a straw to drill a core sample.” Students were interested and engaged in this activity, although there were fewer opportunities for all students to get their hands on the materials, given that they were sharing one set of the materials with a larger group.

In between the two hands-on activities the facilitator showed two short YouTube videos via video-projection. The first video had animated representations of an oil rig and oil drilling, and the second video showed real oil experts and workers at an oil rig. Students were quiet and attentive during both videos, but were more attentive and interested in the real videography of oil drilling. The facilitator questioned students about fossil fuels and the real-life uses of oil at various points in the hour-long session, and also offered background facts and information about fossil fuels.

Second Observation. The second STEM lab we observed involved building models of roller coasters to observe the differences between potential and kinetic energy. Thus, the lesson focused on two fundamental concepts of physics-- energy and motion. A male undergraduate student from Vanderbilt facilitated the activity, which had two separate but related parts.

The first part of the lab was conducted as a whole group demonstration and discussion. The facilitator asked two students to hold a piece of plastic track at a declining angle while they let a toy car roll down the track. The other students observed, standing and moving closer with interest. The facilitator then guided discussion by asking students questions about what they observed, such as: "When is the car going the fastest?", "What happens just before?", and "Why is the energy being lost?"

After the brief demonstration and introduction to the concepts, students worked in groups of five to construct a model rollercoaster that met certain specifications. Students used a piece of clear tubing for the track and held one end up in the air or taped it to a fixture in the room. They debated with their teammates how to make three "hills" in their rollercoaster. Students then observed small metal ball bearings sliding through the tube to see where they sped up or slowed down. The activity was framed as a "contest," and the group with the most height in their roller coaster model scored first.

This lab activity was the most lively of all three that we observed, with students standing, actively constructing the model, testing the model, and moving around the classroom to find different places to hang the top end of the clear tubing. Students debated different ideas for constructing the rollercoaster, and acknowledged and complimented their peers' ideas. Although students were highly engaged and excited about the lab activity, it also required a good deal of cooperation among teammates and social skills to allow each student to contribute in some way. The facilitator asked students questions about their observations at the end of the activity, reinforcing the central concepts and vocabulary of the lesson.

***Third Observation*.** The third lab investigated how comets form and the difference between comets and asteroids. This activity tied in to the broad science topic of Earth and the solar system, focusing specifically on the composition of comets and their impact on Earth's geology and environment (i.e., presence of carbon and nitrogen). The lesson also demonstrated how vapor forms, as with the visible "tails" of comets that begin to melt during their orbit around the sun.

Since this was the final session of the school year, one of the program founders, Dr. Julie Hudson, greeted students and engaged in a brief exchange with them. Dr. Hudson asked about students' summer job plans, and she congratulated students on their learning during the year. She said she hoped students saw how fun math and science could be. A female graduate student who had facilitated some of the STEM labs during the year then greeted students. However, the facilitator for this lab was a female undergraduate student who had just graduated and was headed for medical school. Students were encouraged to ask her about her college and career plans, but did not do so. This exchange took about 10 minutes of the 60 minute session that day. There was one lab activity for the day.

The facilitator then quickly launched into the lesson, beginning with questions probing students' general knowledge about the topic for the lab, such as: "What are comets?", "What shape does a comet orbit in?", and "Does anyone know why the Earth orbits around in space?" The facilitator alternated between asking questions and providing background information about what comets and asteroids are, how to distinguish between them, and what their composition. One student mentioned the prediction that a meteor would pass close to Earth that evening. This introductory segment took about 10 minutes and left about 40 minutes remaining to do the activity. The facilitator directed students through the steps for the lab and continued to ask questions and offer information throughout the lesson. Unlike the other two facilitators we'd observed, this facilitator held her lab guide and referred to it often throughout the lesson.

Students worked in groups of five or six sharing a common set of materials. They were instructed to wear gloves and safety goggles because of the ammonia and dry ice involved in the lab activity. Students scooped a little sand and dirt into their Ziplock bags, while the teachers distributed the water, charcoal, and ammonia, and a custodian handed out bits of dry ice. They watched and waited for the ice to freeze the materials into a lump resembling a comet. While they waited, the facilitator used the opportunity to ask questions about what dry ice is, the temperature at which water freezes, what charcoal is, and also provided information about how vapor forms, and the temperature in space. When the expected reaction did not occur, the facilitator suggested adding a bit more water. Students became less attentive to the facilitator's questions and commentary during this activity, as they were focused on trying to get the materials to freeze. After adding a bit more dry ice, the desired reaction began to occur. Students observed bubbles forming and, in one group, students were surprised and startled when the gas built up inside their Ziplock bag creating a sudden small pop. The facilitator also asked students from each group to blow on a piece of ice inside a beaker to observe how vapor moves.

Because of the extra time for the preliminary greetings and the difficulty getting the comets to freeze, this lesson went about 10 minutes over the scheduled hour for the video-conference. Near the end of the session, the comets finally formed into a solid and students were able to take them out of the bag to examine their composition more closely. The facilitator urged students to write down a description of what the comet looked like, on the back of their lab handout. Students also looked at a small sample of a meteorite in a tiny plastic box that was passed around the room. The facilitator explained that meteorites are the same thing as asteroids, and that they have sometimes landed on the Earth. She explained how they differ from comets. The session concluded and students cleaned up.

Reflections on Observed Labs

In this section, we offer some reflections and observations on the STEM labs we observed and the program implementation in the study school. We describe both positive aspects of the lessons as well as some areas that could be improved.

Student Engagement. In all three observations of the “beamed” STEM labs, we were struck by the high level of student interest, engagement, and excitement in the hands-on portion of the lessons. This was also confirmed by the focus group interview with students and the interviews with the teachers and principal. Students loved being actively engaged in their learning and getting a chance to touch the lab materials, build something, test their models, and reflect on what they had done. The roller coaster activity was the most engaging as it involved constructing a physical object and moving parts. Overall, students were most engaged during the time they were immersed in conducting their experiment or activity, but were also eager to respond to the facilitator’s introductory questions and final observation questions. Students were less responsive to questions and less attentive to commentary from the facilitator while they were busy working on the activity and interacting with peers. During that time, they generally did not look at the video projection of the facilitator.

Facilitation by Vanderbilt. In all three labs we observed, there was a friendly, positive rapport between the students and the young Vanderbilt scientists with whom they interacted through Skype. The facilitators seemed interested in the students, and conveyed a sense of excitement and interest in the topics of the labs. Students were not shy about asking questions or offering observations, and the facilitators responded to students’ comments. Overall, we felt the facilitators used effective questioning strategies to probe students’ understandings and to reinforce learned concepts. They generally had a balance between questioning and commentary, though at times we felt perhaps the commentary/ background information may have taken a bit too long and students started to lose interest and get restless.

We wondered why the facilitator did not demonstrate some aspects of the activity, which would have made some of the steps more clear for teachers and students. The facilitators could have pointed to or held up a model for the class to see, but instead relied on verbal description and instructions, and the written text on the lab handout. For students who may be more visual learners, having pictures or models to point to would help to make it clear what students were supposed to do or the ideas being conveyed. In the three labs we observed, students saw facilitators sitting in their labs, but the facilitators did not point out any "cool" equipment, experiments, or models in the Vanderbilt labs.

Science Content. The STEM labs we observed and the other labs students received over the year were rich in content and fundamental concepts covering a range of different areas of science. Students learned about basic principles of biology, chemistry, physics, geology and other disciplines. There was much less emphasis on engineering, and very little attention to mathematics and technology. Sometimes engineering and technology were mentioned during a lab in the way of connecting the concept to real-world applications. Technology was primarily represented as a tool to deliver the lab instruction (i.e., the video-conferencing). Mathematics was seldom incorporated into the lessons we observed, other than basic measurement of liquids, lengths, or recording of data. Further, a classroom teacher typically performed these tasks for students, limiting students' opportunities to use mathematics within the activity.

To truly capture the intent of a "STEM" lab, we felt more effort could be made to incorporate concepts and tasks from engineering, mathematics, and technology. However, we were also aware that the labs we observed were being conducted with two elementary grades (below grade six) and that the curriculum choices were influenced by the state guidelines for this particular grade span. Perhaps engineering, mathematics, and technology are better represented in the STEM labs conducted in grades seven and eight.

The leveling of the content also depended on the ability of the facilitator to adjust the level of vocabulary in the information and commentary they shared with students. Sometimes the facilitators we observed assumed the students were in sixth grade, as the STEM labs are primarily written for the middle grades. In one lab we observed, the students corrected the facilitator as to their actual grade levels. Teachers also commented in the interviews that they would appreciate more effort to level the lab handouts and activities if they are going to be used below the middle grade level.

STEM Lab Guides. The printed handouts for students and the lab guides for teachers identified the science concepts, vocabulary, and goals for the lab lesson. They listed the materials needed and outlined the step by step procedures for the activity. Yet, we found some inconsistencies, a lack of specificity, and missed opportunities for including information to support student and teacher learning.

Two of the three handouts we collected included pictures or drawings to help students understand the material. The handout on fossil fuels also included a brief section of text on the age of fossil fuels, but did not actually explain how they form. The handouts for the roller coaster activity and for comets did not include any background information or explanations. Only the handout on roller coasters/ energy conversion included an "observation sheet" which consisted of questions for students to respond to in writing. We did not see students writing observations for this lab, but they did write some observations on the back of the handout for the comet activity. The guides for teachers did not appear to include questions for pre- or post- activity discussion and debriefing, assessment tools to measure learning and retention, or additional resources for reading or instruction. Thus, there were several aspects of the lab handouts or guides that could be more consistent and better developed to support and reinforce learning.

In addition, the list of materials was not always specific enough. For example, the comet lab required "one container of sand/ dirt," and "one container of charcoal," but did not specify the exact quantity needed. The lab guide for the fossil fuel activity was similarly vague about the type and quantity of materials needed. For example, the list specified "three straws" for the oil exploration with Playdoh. However, it did not specify that these should be clear straws so students could see the different colored layers of "Earth" or "oil" inside their "core sample." Students struggled to cut their colored straws open to see the contents. The lack of specific information about the materials required for the labs was a constant frustration for the students and their teachers throughout the year. The consequences were that the school ended up buying more sand, ammonia, etc. than they needed, and students and their teachers had to improvise on the spot as they were doing their labs.

Mentoring Opportunities. One of the primary intended goals of the Aspirnauts initiative is to allow younger students the opportunity to interact with college or graduate level students, and sometimes faculty, to learn about post-secondary education and careers in science and other STEM areas. Students are encouraged to ask the Vanderbilt researchers about their educational paths and career choices. Yet, we did not observe students or facilitators talking about education or careers. In fact, none of the three facilitators we observed identified their area of expertise and how it related to the topic of the lab activity in the session we observed. It is possible that one or two of the facilitators had shared this information in a previous lab session earlier in the year. In the final session, which occurred at the end of May, a pre-med undergraduate student led an activity for the first time, dealing with geology (comets), and we wondered what expertise she had in that area of science. Thus, there were some missed opportunities for mentoring, and part of that may have been due to the fact that they only had one hour to conduct the activity and convey information to students.

Another missed opportunity for mentoring was that the facilitators were sometimes vague about the quantity of materials to use, and did not always follow the measurements listed in the handout. Since much of science involves attention to accurate measurement, the facilitators seemed to convey the idea that measurement does not matter. If the amount of materials did not matter in some aspects of the activity, then facilitators could have explained why it didn't matter. When more precise measurement was required, the facilitator could also explain why. Moreover, asking students to accurately measure materials would have incorporated more opportunities to use math skills.

Role of the Classroom Teacher. In the three labs we observed, the classroom teachers (and sometimes the principal), served the role of providing support to students in assembling the materials to begin the lab, handing out materials when needed, measuring materials, and recording data. They also assisted by calling on students who had their hand raised to respond to the facilitator's questions or to share comments. And teachers also helped to get students' attention when the facilitator wanted to share information or ask questions as students were engaged in their activity. Overall, the Vanderbilt facilitator took the lead instructional role, and modeled for teachers effective strategies for probing students' understanding through questioning, and guiding them through the activity but allowing students the opportunity to explore and discover. Teachers acted as the lab assistants, helping with the physical materials and classroom management to make the activity successful within the one hour timeframe.

One of the teachers, Cindy, took a more active role in moving about the classroom and assisting students with their lab materials. She measured out and distributed the required quantity of water or other materials, helped students measure the height of their roller coasters, converted centimeters to inches, and recorded measurements on the board at the front of the classroom. We wondered about this active role in measuring and recording data, and saw this as another missed opportunity to actively involve students in using their math and language skills to measure and record results for their team or teams within the classroom as a whole. The lab guides for teachers could offer some guidance about the teacher's role in the labs, and encourage more student involvement in measurement and data tasks.

Perceptions of Impacts for Students

To explore the impacts of the STEM labs for students, we analyzed the interviews to examine several areas of potential impact as indicated by the intended goals of the program. These areas of impact included:

- Students' understandings or conceptions about science
- Students' interest in science/ STEM
- Students' aspirations to attend college
- Students' aspirations to pursue a STEM career

Within in each of these areas, we compared the perspectives of the program founders, the principal, the two teachers, as well as the students we interviewed in the focus group (about half of the participating students). We identified similarities or differences in the participants' views, and recurring themes in the comments they made during the interviews.

Students' Conceptions about Science. We were curious to know if students' engagement in hands-on science inquiry and interactions with university researchers had changed their understanding of what science is, broadly speaking. Although we had no preintervention measures or quantitative measures available, we asked participants about this in the interviews.

The program developers talked about students learning science concepts and the process of investigation, but also learning the notation and terminology used in science. They also emphasized the rapid developments made in science today, and the opportunity for students (and their teachers) to learn about current research and knowledge in a wide range of science disciplines by hearing directly from experts in those fields. So from their perspective, the program increased students' awareness of the wide range of science disciplines and research, as well as the real-world applications, and taught students the procedures and notation for conducting science inquiry.

Neither the principal nor the two teachers described specific ways the program has impacted students' understandings of science or STEM, although the teachers commented that they would like to know if the program is increasing students' learning of science concepts. Overall, the principal emphasized the aspirational aspect of the program more than the science learning aspect. When asked how the program benefits students she said, "Increased capacity for science knowledge, and application." She said they are also learning about technology through the Skype sessions, and how to handle unexpected problems when the technology fails.

Similarly the teachers had few comments that focused on the potential for improving students' knowledge of science. Cindy commented that sometimes there is no single correct answer or result for an experiment, which suggests this is something she would like students to take away as an understanding about science and science research. Like the principal, Cindy also talked about how students have learned about technology because they are using Skype, the Smart Board, a computer camera, and other technology during the video-conferencing. Beth said that the program allows students and teachers to learn from science experts. She emphasized that she wants students to be involved in gathering data, doing activities, discussion, and learning from others.

It was also somewhat difficult to get students to talk about the science concepts they had learned about, or how their views of science had changed through the STEM lab program. When asked to name topics they had learned about this year, they focused on the activities or materials used in the lab—the vehicles for learning—not the science concepts. For example, students said they'd learned about "volcanos," "prosthetics," and "roller coasters," instead of: geothermal dynamics; robotics; anatomy; energy and motion; and gravity. They also mentioned learning about "vision," "chemical reactions," "chemistry in a Ziplock bag," "dipping strips of paper in shampoo," and building things with jello or marshmallows and then shaking them to simulate an earthquake. Overall, students focused on how a discrete thing works, rather than the foundational concept that was involved and that applies to other things as well.

However, there were a few comments that were an exception to this—where students mentioned a scientific principle or concept they had learned. In describing an activity where students tested shampoo for pH-levels, one girl commented: "I kind of learned a lot about it, but like we used strips, and we learned about neutral and like positive and negative, neutral." In reflecting on a series of related labs, one boy said:

> Um, the one we just did, the rollercoaster, I think that one really, it helped me with the understanding of, partly of the last one [lab] and this one, because the one we did before that was Newton's laws. And I felt like it kind of connected because you had to have so much velocity and force for the BB to go all the way through. And it really showed me how an object can keep going over all these, as long as it has enough kinetic energy.

In addition to students' comments about science concepts they'd learned, we also found evidence that students had developed a greater appreciation of how science investigation is conducted in research. They talked about how the Vanderbilt STEM labs involved bigger projects, and were more like doing real science than what they had done in school prior to the program. One girl explained,

> I think that we definitely get a lot more out of when we do it with our [Vanderbilt] professors over Skype, because sometimes we do projects with our teachers, but not as big of projects. We kind of just like dumb it down. But when we're doing it with the professors, we do it like a big project . . .

A male student agreed:

> When we first did science, the first time we ever did like, really big science was in second grade. And the only thing we did in science was like we would color in pictures and learn things, little facts. But, now that we do Vanderbilt, it's like so much bigger than what we did in third grade! And it's so much fun, because the activities, from going on a sheet of paper to something that touches the ceiling down to the floor . . . And it's just really cool to do the, like they're just big, big projects for us.

Students also acknowledged that the program helped them to appreciate the wider scope of science than they had been aware of previously. By interacting with the Vanderbilt scientists, students were not only learning about a wide range of science disciplines, but they were also learning about the technology involved in science research and engineering and about the real-world applications of science discovery. One boy commented, "Before we started doing the science, like I didn't know there was so much to science. There's kind of something for everyone in it."

The students agreed with the program founders that they had more opportunity to learn about science in a deeper way by hearing directly from science "experts" and asking them questions. One boy said,

> I like talking with the scientists because it's one of the cool things, because you get to talk with them and they're like, it's almost like they're there. It's like the next best thing besides them being in the room. And . . . it's neat that you could like ask them questions and they can answer it . . .

A girl commented,

> I think it's better to talk with a real scientist than have your teachers go to school and learn science, because scientists have actually, I think that they have gone to school for most of their live. But they have wanted to be a scientist, so they know more than what our teachers can learn.

When asked to give a one word descriptor of what science is in their view, students offered the following ideas: "fun," "a way of life," "learnful," "educational," "discovery," "learning new things," "animals," and "amusing." These terms all convey a positive view of science, and some get to the heart of science that is "discovery" and "learning new things."

Students' Interest in Science. While the STEM lab program does not have a formal tool to measure the program's impact on students' interest in science, they do ask teachers for feedback after each session. The program founders said that the feedback from participating schools indicates that students are highly engaged during the STEM labs. The founders also hope that the program has a deeper impact by helping students to realize that science is everywhere around them, and inspires a greater curiosity about science.

The principal in our study school emphasized that students are very excited and engaged during the STEM labs. She commented, "Students are so engaged . . . our students are . . . rejuvenated into that [mindset of] 'Let me show you what I know! Let me show you what I can do!'" She also noted that for one student who does not always excel in school, the labs have really inspired an interest in science and provided him an opportunity to really shine.

Both teachers felt that students liked the program and were excited to do the hands-on science activities. They emphasized the program's ability to engage students and keep their attention, although they didn't talk about whether or not students were more interested in science as a result of the program. Cindy said both the STEM lab facilitators and the content were successful in "drawing students in" and keeping their attention, specifically when students were given the challenge of designing and creating as part of the activity, for example when making rollercoasters or prosthetic legs. Beth felt that students were making connections between previous and current lessons, and extending the connections to their learning in other subjects, like social studies. She also mentioned that the program is "magical" for hands-on students who are not "paper and pencil learners."

Students' responses during the focus group interview indicated that the program has greatly increased their interest in science and other STEM fields. Their responses emphasized that the program is a significant departure from the science lessons they received in previous years, in terms of the STEM labs' wide range of content, hands-on approach, bigger activities or projects, more challenging tasks, more frequent science instruction, and relevancy to real-life problems. The opportunity to do more "big projects" and to interact with "real scientists" from a leading university has changed students' outlook on science and science class, making it something they look forward to because it is fun, interesting, and real. The following are some representative comments from students:

> I really look forward to this program because, not only is it different from what we had last year, it's kind of cool to feel like you're actually a real scientist, where they send you the lab coats . . . (boy)

> Before we started the Vanderbilt program, I wasn’t really that into science, because I really didn’t get much of it. And then starting the Vanderbilt [program], it’s got me more interested in science, and it has me more looking forward to going to work on the Vanderbilt labs, instead of, ‘Oh yeah, it’s Friday, we have science class . . .’ (boy)
>
> The first time we ever did really big science was in second grade, and only thing we did in science was we would color in pictures and learn things, little facts. But now that we do Vanderbilt . . . It’s so much bigger than what we did in third grade. And it’s so much fun, because the activities, from going on a sheet of paper to something that touches the ceiling down to the floor, and it’s just really cool to do. They’re just big, big projects, for us. (boy)
>
> Before Vanderbilt . . . I really hated science. I did not like it. But it’s really encouraged me, and I kind of want to go to Vanderbilt to learn science. (girl)
>
> I think it really has helped us like science more, and it kind of makes us want to set a career on that, if you like it. . . . and I really hope that we’ll be able to do it next year. (girl)

One boy said that he didn’t really like to read much before the STEM lab program. Once the program started, he started to look up books on topics related to the lab activities, and began reading more and learning from those books.

Students’ Aspirations to Attend College. The program founders believe that if successfully implemented, the program will increase students’ interest in science and active engagement in science learning, which will lead to improved science achievement and aspirations to continue studies in science. The program founders also hope that by providing frequent opportunities for students to interact with Vanderbilt students and faculty, students will have a better appreciation of the importance of education for STEM careers. The Aspirnaut initiative has attempted to collect data about students’ college attendance from high schools participating in Aspirnaut programs, but this has proved to be difficult. They would like to develop a way to better track this information. Students at the elementary and middle levels are still several years from making any firm decisions about college.

The principal viewed the program as an opportunity to reinforce the idea that all students can go to college, which she felt was critical for the students in her school. She emphasized the potential of the program to raise aspirations for students. The teachers did not talk about the program impacting students' aspirations to attend college.

In the focus group, most of the ten students indicated they had already been thinking about attending college prior to the STEM lab program. When we asked if the program had made them made them want to go to college even more, nine of the ten students raised their hands and a tenth student also agreed but was shy about raising her hand. Some comments made it clear that the program did help the students feel more inspired and increased their thoughts about college attendance. One boy said the program "prepares you for college," while another said: "I found it would be like cool to Skype with somebody from a real, actual like college who studies science, and actually figure out real-life stuff." A third boy smiled broadly and summed up the impact of the experience for the group this way: "It's just an honor. I mean, we're talking with Vanderbilt! One of the top 15 most prestigious colleges! It's just awesome! It's an honor. I love it!" Overall, the students made little reference to attending college during the focus group, but had more to say about different kinds of careers that interested them, which all implied a need for higher education. Given that students were in elementary school, we were not surprised that they weren't yet focused on college.

Students' Aspirations to Pursue Science or STEM Careers. The developers see the program as a way to help students think about and understand how the world around them works. Through this opportunity to explore, they also hope students will become interested in pursuing science or STEM careers, which is the long-term objective of the Aspirnaut initiative.

The principal touched on this topic briefly in her interview by recognizing how important the “aspiration component” is for students participating in the program, in that it helps students widen their own perceptions of where they can take their lives. Both of the teachers commented about how students have talked about pursuing science careers since they’ve started the STEM lab program. For example, one boy asked the principal if he could work on a cure for cancer. Cindy noted that the program has prompted students to think about STEM careers, with some students identifying the kind of work they would like to do even though they are not sure yet sure what the career titles would be. Beth also felt that the program has increased career awareness for the students.

We were surprised to find that all ten students we interviewed in the focus group indicated they were considering careers in science or STEM fields, and that they largely attributed their interest to the STEM lab program. When we asked if they were thinking about science careers before the program, only one student said he was “sort of” open to the idea at that point. Yet, when asked if they were more interested in science careers now because of the Vanderbilt program, all ten students indicated that they were. One boy said, “Before we started Vanderbilt . . . I didn’t know what I wanted to do, but now I think I want to become a physicist, or something like that, and . . . that sounds really cool, and that’s what I think I’m going to do.” A girl commented, “I’m one of the people who aren’t sure yet. I love science, but I love other stuff too. But it has probably made a really big improvement.”

We also asked students what type of science careers interested them. Some students expressed an interest in one or more science professions. One boy said either math or physics, one boy said sports science, three boys indicated an interest in engineering, one boy said he was interested in being an engineer for prosthetics, two boys indicated an interest in electronics or technology, one girl indicated an interest in being a nature biologist, and one girl said she was interested in being a marine biologist.

Still, the STEM lab experience was only one of many factors influencing students' views about science, college, and potential career paths. Some students said they had been thinking about attending college or pursuing a particular career because of a parent's or grandparent's career, or because of some other experience they had. For example, one girl had visited a marine museum in Florida and began to think about being a marine biologist. A boy explained that both of his grandfathers were engineers, so he wanted to attend the Maine Maritime Academy and become an engineer and after that become a physicist. Another boy said his dad was in the service, so he'd like to help design the weapons or amour to help those in service. We recognized that these students were still quite young and it is unclear at this point how their career interests and paths may change over time.

Perceptions of Impacts for Teachers

Although the broader goals for the Aspirnaut initiative focus on students' science achievement and students' aspirations to pursue science education and careers, the program also seeks to influence classroom teaching by modeling inquiry-based pedagogy through the video-conferenced STEM labs and through the summer immersion experiences available to teachers. The founders emphasized the importance of university-school partnerships to bring the latest in science knowledge to schools, and to expand and support the science curriculum. As Dr. Billy Hudson commented,

> . . . you have wonderful people out there who want to do the right job. But science has moved so fast . . . we have to find ways to have the scientists team up with those teachers out there, as a partnership to share this responsibility and translate this knowledge of science to the kids . . .

Similarly, the school principal viewed the STEM lab program as a catalyst to improve the rigor and focus on science (STEM) in her school, and increase students' excitement about learning through hands-on activities. She also recognized the value of the program as a vehicle for teacher professional development in science and science pedagogy, particularly for a small rural school with limited fiscal resources. She commented, ". . . they're getting that professional development at the same time the students are learning the core content. And I think we need to use all the resources we can lay our hands on to get our kids ready for life." Like the program founders, she acknowledged that teachers cannot know everything about all areas science, and that students might learn more from experts in STEM fields. She explained,

> We don't have the same instructors every week. If we're doing the human body, we have people from the medical department. If we're going chemistry, we have people from a different department. . . . And that enhances things enormously, especially for staff. You can't teach what you don't know.

The principal said she wanted students and teachers in her school to begin to see that "everybody's a teacher, everybody's a learner."

Our interviews with the two classroom teachers focused primarily on impacts for students and sought teachers' feedback on the program. However, we did ask teachers what their goals were for their own learning through this program, and what they viewed as the most positive aspects of the program. In thinking about their own learning, both teachers emphasized the positive impact of introducing more technology into the classroom through the video-conferencing equipment. They felt good about learning how to use these tools, and said students were also getting more comfortable with them. Although they noted there were sometimes glitches with the Skyping technology, they wanted students to learn how to deal with the unexpected. Cindy said she'd accomplished her goal of ". . . being more fluent when it comes to technology and setting up the Skype program, using the SmartBoard, the camera, adjusting the camera." Beth said, "We had to learn how to position our camera, that kind of thing, and we did . . . sometimes at the last minute, you know, things kind of go wrong. . . .We troubleshoot and it works."

Beth also appreciated the ability to obtain resources in her school to conduct more frequent hands-on science activity. Although she said she had been doing hands-on activities prior to the program, her school did not have a sufficient budget to buy science kits and materials. She said she appreciated having "more hands-on science, things that are doable with a reasonable number of materials." The STEM lab program helped to support this effort, although the school did have to purchase the materials for the labs. An anonymous donor provided funding for the supplies, if they were purchased locally.

We were somewhat surprised by the absence of any comments about what teachers might have learned about different areas of science or teaching science through hands-on inquiry as a result of the program. Exploring the program impacts for teachers' knowledge and classroom practice would be valuable research and would require additional fieldwork over time.

Feedback for Program Improvement

The school principal, teachers, and students largely had very positive views about the STEM lab program through Vanderbilt, and emphasized the positive impacts of this program, particularly for students. They did offer a few suggestions for improvements, which we will share in this section.

The dominant theme centered on the acquisition of materials for the STEM labs and the clarity of the materials lists provided to schools. The teachers explained that while kits could be purchased for the STEM labs from Vanderbilt, that it was less expensive for the school to purchase the materials locally. However, the choice to purchase the materials locally meant that the teachers had to spend their own time driving to hardware stores or other vendors to find the necessary supplies, and then they also needed to organize and prepare the materials for groups to use in the labs. The lab on making a comet required dry ice. When this was not available locally, a custodian had to scramble and drive some distance to purchase the dry ice. The responsibility to purchase and organize lab supplies on a weekly basis put an extra burden on teacher and staff time. They would have preferred the school to purchase the kits directly.

A related problem was the lack of specific information about the quantity of supplies to purchase. When the activity guide was too vague, the school ended up purchasing too much of something (and then paid more than they needed to or had too much leftover to store), or too little of something (and then did not have enough when the activity was underway). Sometimes the materials list was not specific about the type of material needed, and the wrong type was purchased. In the activity making comets, the teachers had purchased the wrong type of safety gloves and had to scramble to find a different type just before the lesson. In the activity on fossil fuels, the wrong type of straw made it difficult for students to see what their "core sample" contained.

Another theme that surfaced less often related to the grade-leveling of the STEM lab activities and materials. The teachers were aware that the STEM labs were developed with the middle grades in mind, and they said that sometimes the terminology could have been adjusted more for their elementary grade levels. They suggested that the labs be leveled for additional grade levels. When asked about the lab activities and lab handouts, Cindy said,

> On occasion they're a little tougher for fourth and fifth graders than, I mean the scientist teaching the lesson today thought they were sixth graders! . . . . there's some math on there that is very challenging. We stumble through it, but it can be hard.

Both students and teachers said they would like more time for science instruction beyond what they have now in the school schedule. While they appreciate the increased time with the implementation of the STEM lab program, they feel more time is needed for the pre-teaching and for debriefing afterwards. The hour long labs sometimes felt rushed and jam-packed with substantive information. There was little time to process and reinforce this information afterwards. When asked for their suggestions on how to improve the program, one student in the focus group said "more time," and the other students all chimed in with agreement. Also, students liked having labs that were linked conceptually and wanted more of that, and more time to conduct their hands-on explorations.

Conclusion

The evidence we collected through interviews and observations strongly indicated that the "beamed" STEM lab program was successful in achieving several of the goals for students. By implementing this program, the small, rural school we studied in Maine had increased instructional time for science, the frequency of hands-on inquiry activities, the depth of science lessons, and the level of science expertise for guiding student learning. The program also increased students' interest in science in general, their enjoyment and excitement in learning about science, their awareness of different STEM disciplines and careers, and their aspirations to pursue science education and careers as adults.

We were not able to collect objective evidence about the impact of the program on student learning, given that our study design did not include pre- and post- measures of student achievement in science, and the program itself does not include assessment measures. Certainly, students and teachers attested to the positive impact of the program for student learning in their interviews. But without objective measures, it is difficult for us to confirm what students learned or retained from their STEM labs. This is one area that deserves further research, with an experimental or quasi-experimental study and valid assessment measures. That is, a study comparing student learning for students who received the STEM lab program with students who did not receive the program, and pre- and post- measures. Measurement of impacts for learning has been a stumbling block for the program in general. The program's focus on rural schools with small numbers of students per grade level hinders the collection of data for a sufficient number of students to confirm the positive impact of the program intervention.

Similarly, there was evidence from the interviews that the program had a positive impact on the college and STEM career aspirations of students. However, given the young age of these students, and the absence of a method to track their paths over time, we could not verify the extent or persistence of the positive impacts on college and career aspirations. Again, this would be a worthwhile subject for further research and would require the collection of longitudinal data for individual students. It may be more feasible to do with students who participate in the STEM labs in grades seven or eight.

In addition to potential positive outcomes for students, we believe there is great potential for the STEM lab program to improve teacher knowledge and instructional practice in science. Again, we were not able to confirm this without assessment and other data collection measures. A larger study could explore the impact of the initiative for teachers and classroom instruction.

Our study indicated that the program may emphasize science but has less emphasis on the other STEM areas (engineering, mathematics, and technology). We observed opportunities for more attention to these fields within the science labs, and encourage the program developers to incorporate more opportunities for students to actively engage in math tasks and to also interact with data and technology. These areas may receive more attention in the upper middle grades than in the elementary grades we observed.

The content of the labs and activity guides were generally of high quality and covered important concepts and content in different fields of science. However, we noted some areas where the activity guides could be improved. In particular, the guides need to be more specific and clear about the materials needed for the lab, include more instructional or background information about the key concepts of the lesson, include questions for discussion, and suggested reading or other resources both for teachers and for students. Further, if the STEM labs are going to be implemented in grades lower than grade six, then some grade-range leveling or adjustment in the vocabulary and tasks may be required for successful implementation and optimum impact.

Finally, the problem of purchasing supplies for the labs may be a barrier for many schools. While the Aspirnaut initiative targets rural schools to bring more resources and opportunities to these schools, the limited financial resources of these schools may make it difficult for many rural schools to afford the supplies, and their isolated location may make it difficult to obtain the lab materials locally. While teachers may be excited about the program, they may find the extra time to purchase and organize supplies to be a burden. This is a piece that may require more thought.

Appendix A

Protocols for Interviews

Interview Protocol for Principal

When did your school become involved in the Aspirnaut program?

What are the primary, intended goals of the program?

Tell me about how your school became involved in the program.

What were the reasons your school adopted this program?

What goals do you have for your teachers through this program?

What goals do you have for the participating students through this program?

How well has the implementation gone so far?

What feedback are you hearing from your teachers?

Have you had any feedback from parents about this program?

What do you feel has been the most positive impact of this program for your school so far?

Are there any challenges in implementing this program? Please describe.

What suggestions for improvement if any do you have for the program designers?

How long will your school participate in this program?

If this program ends, would you consider pursuing similar partnerships with other universities or science institutes?

As you know, we'll be asking students about the program in a focus group interview. What would <u>you</u> like to know from students' perspective? What questions should we ask?

Interview Protocol for Teachers

Tell me how and when you became involved in Vanderbilt University's "Aspirnaut" program.

What do you feel are the primary goals of the program?

What goals do you have for your own learning or teaching by participating in this program?

What goals do you have for your students from their participation in this program?

How well has the implementation gone so far?

What is working well with the video-conferencing sessions?

What could be improved with the video-conferencing sessions?

What is working well with the hands-on science activities led by Vanderbilt?

What could be improved with these activities?

Do you have any suggestions regarding the activity guides prepared by Vanderbilt?

Has Vanderbilt provided any other resources to teachers to support these activities?

What topics have you covered so far this year? How many sessions in total this year?

What have you noticed about students' reactions to these sessions? Does it vary for different students? (Explain)

To what extent has this program facilitated student learning of science concept? (Examples)

Has there been any assessment of students' understanding or retention of the science concepts covered in the activities? (Explain)

Have you had any feedback from parents about this program? (Describe)

What do you feel has been the most positive impact of this program so far?

What suggestions for improvement if any do you have for the program designers?

If this program ends, would you consider pursuing a similar partnership with other universities or science institutes?

As you know, we'll be asking students about the program in a focus group interview. What would you like to know from students' perspective? What questions should we ask?

Interview Protocol for Program Designers

Tell us about how you developed the Aspirnaut program, and what your primary goals were?

When did the first school pilot this program and where was that?

Where is the program used currently (how many states, how many schools)?

Please describe the major components of this program, such as the video-conferencing for classrooms and hands-on science activities, number of sessions, how they are planned with school curricula.

What feedback have you received from schools and teachers about this program?

Have you made modifications in the program based on this feedback?

Does the program include any assessment of students' understanding of the science concepts covered in the activities? Or retention of learning?

Does the program include any supporting instructional or assessment materials for teachers?

Does the program include any professional development for teachers other than the modeling implicit in the video-conferencing/ activities?

Have you collected any data, or do you plan to collect data, to track students' college majors for those who have participated in the program?

Have you collected any other kinds of data to assess the impact of the program in other ways?

As you know, we'll be asking students about the program in a focus group interview. What would you like to know from students' perspective? What questions should we ask?

Focus Group Interview for Students

You’ve been doing some hands-on science activities with the Vanderbilt program. What have you been learning about this year with Vanderbilt? (e.g., science topics, concepts)

Which activities did you like the best? Why?

Which activities did you like the least? Why?

(Probe: positive/ negative aspects, challenging/ easy, interesting/ boring, and suggestions for improvements)

Are these activities helping you to understand science? How?

What happens when you don’t understand something?

How are these activities similar or different from what you normally do with your teacher when you work on science?

What is it like to Skype with a scientist from Vanderbilt University?

(Probe: positive/ negative aspects, and suggestions for improvements)

Are the Skyping sessions and activities helping you to understand better what scientists do? How?

Have you changed your ideas about science because of the Vanderbilt program? How so?

If you could think of one word to describe what science is, what would it be?

Have you become more interested in going to college because of this program? Explain.

Have you become more interested in a science career because of this program?

What kinds of science careers interest you?

What should Vanderbilt change to improve this program?