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A DESIGN FOR INSPIRING STUDENTS WITH NEAR-SPACE EXPLORATION

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Introduction

The prevalence of overseas success in engineering education represents a significant threat to the United States. Once the dominant force in advancing technology, the U.S. is seeing significant amounts of research and development work moving overseas. U.S. competitiveness and increased productivity requires demand for high-value-added products (Porter & Rivkin, 2012) such as those designed and developed by those with advanced training in science, technology, engineering and math (STEM) disciplines. The U.S. economy, thus, depends on the production of skilled scientists and engineers – not just to sustain American leadership in science, but to sustain its national economy.

STEM education across all academic levels is critical to the production of these scientists and engineers. However, the United States' educational system is under siege by diminished budgets, which have lead to increased class sizes, diminished teacher time on a per-student basis and reduced teacher support (McCord et al., 2009). These effects are particularly pronounced in less affluent areas (Freelon, Bertrand, & Rogers, 2012) where, in addition to contending with resource issues, students are facing declining science instruction in deference to a focus on national reading and math standards (Johnson & Fargo, 2010); these areas are also among the most severely impacted by budgetary issues (McCord et al., 2009).

A new approach is needed to allow the United States to reclaim educational leadership. This approach must not be disruptive and must be easy for educators to adopt. It should not be perceived as a threat to educator employment. It should make use of educational best practices, identified both domestically and worldwide. It must engage students and inspire them to pursue additional education and careers in STEM fields.

Outer space, an area of clear American leadership, can be this inspiration source that drives STEM interest and retains students in STEM fields (Robbins, Delaney, Conaty, & Gabrys, 2012). However, in order to be successful, space must be presented as more than video recordings and textbook exercises. It must be made to be hands-on. High altitude balloons (HABs), which reach the outer edges of Earth's atmosphere, allow students to experience a near-space environment. Students must deal with the unique challenges and constraints posed. These challenges would push them to learn and excel.

This paper presents an inspirational educational program to teach students STEM knowledge, skills and abilities. It begins by providing background related to three areas: pedagogical techniques, middle school education and prior use of high altitude balloons in middle schools. Next, an overview of the proposed program is provided; this is followed by a discussion of the specific educational content units incorporated. Finally, a qualitative evaluation of program benefits is conducted.

Background

Three areas of research are relevant to the proposed program. First, the pedagogical background for this program will be reviewed. Subsequently, the present state of knowledge in the field of middle school education is reviewed followed by a review of the prior use of HABs in middle school curriculum.

Pedagogical Background

The United States economy, its technical superiority, its military might and – in fact – its long term viability as a high-standard-of-living nation are quite literally dependent on the innovations created by the graduates of its colleges and universities that decide to pursue STEM fields. Floersheim and Johnston (2010) suggest, however, that many students who may have an interest in pursuing STEM education are lost far before they enter (or even prepare to enter) the collegiate system. They contend that students discontinue pursuing STEM subjects when transitioning from elementary to middle school. These students, they note, fail to transition from the concrete material of elementary school to having the ability for conceptualization required for more advanced learning.

Despite the United States having among the best funding and facilities, the cognitive abilities of students lag behind those from many Asian countries. Many of these countries benefit from a level of curriculum integration not seen in the United States. They also cover less topic breadth per year – but still cover more material (41 topics not covered by U.S. schools) through diminished repetition (Floersheim & Johnston, 2010).

Degenhart, et al. (2007) evaluated the impact of providing interaction with a STEM-field college student on middle school students. In this case, a NSF Graduate Fellow was assigned to each experimental classroom and student attitudes towards STEM were measured before and after this school-year-long association. The NSF fellows had approximately 10 hours of interaction with the middle school students each week (for the majority of an academic year) including co-teaching inquiry-based classroom lessons. The fellows were also presented as role models and attempted to correct misperceptions about STEM fields and stress their importance. Degenhart, et al. proffer that the interaction with the NSF Fellow caused students to develop "a positive belief in their abilities" and an "increased willingness to persevere and work toward educational goals in that subject" (2007). As Degenhart, et al.'s study failed to include a control group, it is not possible to ascertain the impact of this student placement relative to other contributing factors. However, this study presents anecdotal evidence that college student involvement with students enrolled in lower grade levels is beneficial.

Cantrell, et al. (2005) looked at the use of engineering activities in a middle school classroom to close achievement gaps between various student populations. In this study, groups of 2-3 middle school teachers developed a module that was subsequently presented in all team member classrooms. Three engineering modules were produced. The first had students design, fabricate and test a hot air balloon. The second looked at minimizing recoil from vehicular collisions. The third looked at the construction of a balsa wood bridge. Cantrell, et al. (2005) found that the project/problem-based learning experience had a positive effect for students with special needs. It also closed the achievement gap for Hispanic and Black students, while widening it for Native American and White students. They also note that male students seemed to outperform female students in the exercises; however, this may be attributable to the students' pre-exercise concept/vocabulary/tool familiarity. They do note that "teachers reported student excitement at higher levels than normal when the engineering modules were taught" (Cantrell et al., 2005).

Kroeger, et al. (2004) looked at techniques that could be utilized to retain at-risk students. Their study involved including students in a program that focused attention on the students. Katz (1997), who proffered that a single adult showing a level of belief in the student may be enough to prevent the student's drop-out, is cited as a key motivator for the research. Only anecdotal results are presented; however, it appears that some combination of the added attention and the "photovoice" activities produced a positive impact in the six middle school students' lives.

Ricks (2006) studied the impact of an informal summer science education program for 7th and 8th graders. This program is run by undergraduate student counselors and features a combination of laboratory exercises, short lectures and demonstrations from STEM professionals and faculty members. Utilizing a pre-test / post-test experimental design, it was shown that students' science knowledge and attitude towards science were enhanced by the experience. A longitudinal study focusing on participants during a period ranging from 6 to 12 years prior to the study date indicated that, for 73.5% of those responding, participation in the program influenced their "future goals or career choice" Science knowledge or interest was identified by 49% of respondents as being enhanced by the program.

The Present State of Knowledge in the Field

The middle school curriculum is designed to be challenging, integrative, exploratory, and relevant (North Dakota Department of Public Instruction, 2006). Middle school teachers are encouraged to challenge students to utilize higher-order thinking skills. It is essential that teachers create curricula that allow students to delve into more critical thinking and decision-making opportunities. The proposed work provides the opportunity for students to become 'young investigators', which is well aligned with the needs of middle school students.

Middle school teachers are encouraged (Powell, 2011) to utilize innovative instructional strategies that actively involve the student in the learning experience. The use of discovery or inquiry learning must be coupled with the basic knowledge and comprehension to enhance information retention. This leads to a curriculum that sustains interest and thus, motivates students intrinsically.

It is important to consider that the early adolescent brain is developing at very rapid rate and it is for that reason that young individuals are highly influenced by their surroundings. The standards-based curriculum (North Dakota Department of Public Instruction, 2006) encourages them to explore a multitude of topics. This exploration results in a tendency for students to particularly appreciate and thus gravitate toward specific courses (e.g., science or mathematics). An interactive, hands-on experience, like the proposed, in a middle school science or mathematics classroom could likely influence the career direction that students pursue in high school and beyond. This has been demonstrated by the work of Ricks (2006) and others who have demonstrated a longitudinal connection between early STEM experiences and later choices.

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Evidence also suggests that the process of teaching/mentoring lower grade-level students can be beneficial for the higher grade-level students as well. The work performed by Takehara (2012) has shown that pre-service teachers lacked recall of science concepts taught at the middle school level. Even for higher grade-level students that do not intend to pursue teaching careers (or teaching careers at a given educational level), forcing recall or re-learning after an extended period of time should strengthen the memory and understanding of these concepts (Toppino & Cohen, 2009). Previous work (Cortese, 2005) has also demonstrated that teaching is an excellent way for the instructor to internalize an understanding of the concept being presented.

The proposed program, thus, is poised to provide both benefit to the higher and lower grade-level students that it will involve. While it is anticipated that most undergraduates that will be involved in this trial will be pre-service teachers with a particular topical interest in STEM fields, the experience could potentially be beneficial for undergraduates who have an interest in pursuing a non-teaching STEM field career, as well. It is believed that the proposed model will also have a strong effect on the middle school students. Current evidence suggests that by providing these students with enhanced understanding of the STEM fields and demonstrating how exciting and enjoyable they can be, student interest will be enhanced. At a minimum, students gain additional information that can be used to form an informed decision about the career choices they will make.

Past Use of HABs in Middle Schools

Recent work by Verhage (2012) has shown that HAB incorporation in K-12 curriculum has a positive impact on student interest in STEM disciplines. He utilized the Test of Science-Related Attitudes (Fraser, 1981), also known as the TOSRA, to measure students' attitude before and after the HAB experience.

Ongoing NSF-funded work at Taylor University and Ball University focuses on the development of curriculum for 6th, 7th and 8th grade students (Takehara et al., 2012). This work, performed by pre-service teachers as part of their coursework, exposed the soon-to-be-teachers to HAB concepts while also teaching curriculum development skills. At Taylor University, two iterations of this course have been conducted. The first identified several problems that needed to be addressed to facilitate success, including re-familiarization of the education students with the relevant science material. The second iteration produced a 6th grade curriculum that is planned for testing in early 2013.

Work at Ball University (Takehara et al., 2012) focused on developing curricula for the 7th and 8th grades. This work, spread over two semesters, again involved education students designing lessons for middle school students. These lessons were tested in a laboratory classroom at Ball University. Difficulties were identified in integrating with the math curriculum, as minimal correlation between the grade-applicable levels of math and HAB experimentation was identified. Instead, math questions about other payloads were developed. Various physical and technical limitations were overcome and lessons related to preparation were learned. While the work at Taylor and Ball universities demonstrates that there is curriculum correlation with and student interest in HAB activities at the middle school level; the work performed to-date has focused primarily on the educators with a positive flow-down effect on students.

Similar anecdotal evidence was provided by the North Dakota Space Grant Consortium's state-wide HAB payload competition (Jackson, Fevig, & Seelan, 2012). This exercise generated significant interest from several participating teams and students expressed an interest in pursuing STEM careers due to their involvement. HAB programs targeting middle and high school students exist in at least 13 states and involve at least 30 pre-college schools (Flaten, 2012).

Others have incorporated HAB activities into high school science classes (Beck-Winchatz, 2012) and high school science electives (Takehara, Dailey et al., 2012). Spaceport Indiana has launched the Space Corps program (Tanner, 2012) which utilizes college students to mentor K-12 students in space related programs – some related to high altitude ballooning. Numerous universities, including the University of North Dakota (Nordlie & Fevig, 2011), have incorporated HAB activities into the undergraduate curriculum. Previous work has shown the utility of using HABs to teach spacecraft engineering principles at the graduate and undergraduate level. Others (Takehara et al., 2012) have integrated HAB activities into various areas of the undergraduate curriculum. Taylor University has also developed HAB-integrated science methods courses for 6th, 7th and 8th grade classrooms (Takehara et al., 2012).

High Altitude Ballooning

A key consideration in the proposed work is whether schools can replicate the educational techniques proposed, outside of a university-managed program. High altitude ballooning can be accomplished in several ways. In addition to the helium-filled latex balloons which have been used predominantly, another lower-cost technique is available. This technique relies on the sun to heat air trapped within an easily constructible plastic balloon (Boehme, 2009). If no tracking is performed (i.e., if the payload is marked with instructions for its return), this type of balloon could be launched for approximately $50. A tracking system can cost $500 or more; however, partnering with local amateur radio operators for tracking may significantly reduce (or perhaps eliminate) this cost. An amateur radio license is also required to operate the transmitter, so having the local amateur radio operators involvement will also eliminate this additional cost / requirement (it is important to review the FCC regulations related to what qualifies as amateur operations and make sure that these are followed). Figure 1 shows the basic elements of a HAB train (the train is the collection of balloon, payloads and line). This basic concept can be used irrespective of the type of balloon selected. A mission may have a single or multiple payloads, depending on launcher needs (and compliance with FAA mass limitations).

Safety for all stakeholders (launchers and other uses of the air space) is critical. A set of regulations for safe operations of high altitude balloons has been proposed (Straub, Nordlie, & Anderson, 2013). This discusses both the requirements for regulatory compliance (e.g., mass limits, payload line strength) as well as best practices for a responsible educational HAB operator. A school performing this type of project for the first time would likely find it helpful to work with an experienced operator. Assistance may be available from a local/regional university with experience in this area or from a commercial provider. Some commercial providers will perform complete launch services, including supplying all required equipment and launching, tracking and recovering the payload. In his work, Verhage (2012) had schools send back their completed payload to his location and he launched them in groups and sent them back to the school. While perhaps not as exciting, remote viewing (via internet video) may be a lower-cost way to derive many of the benefits described.

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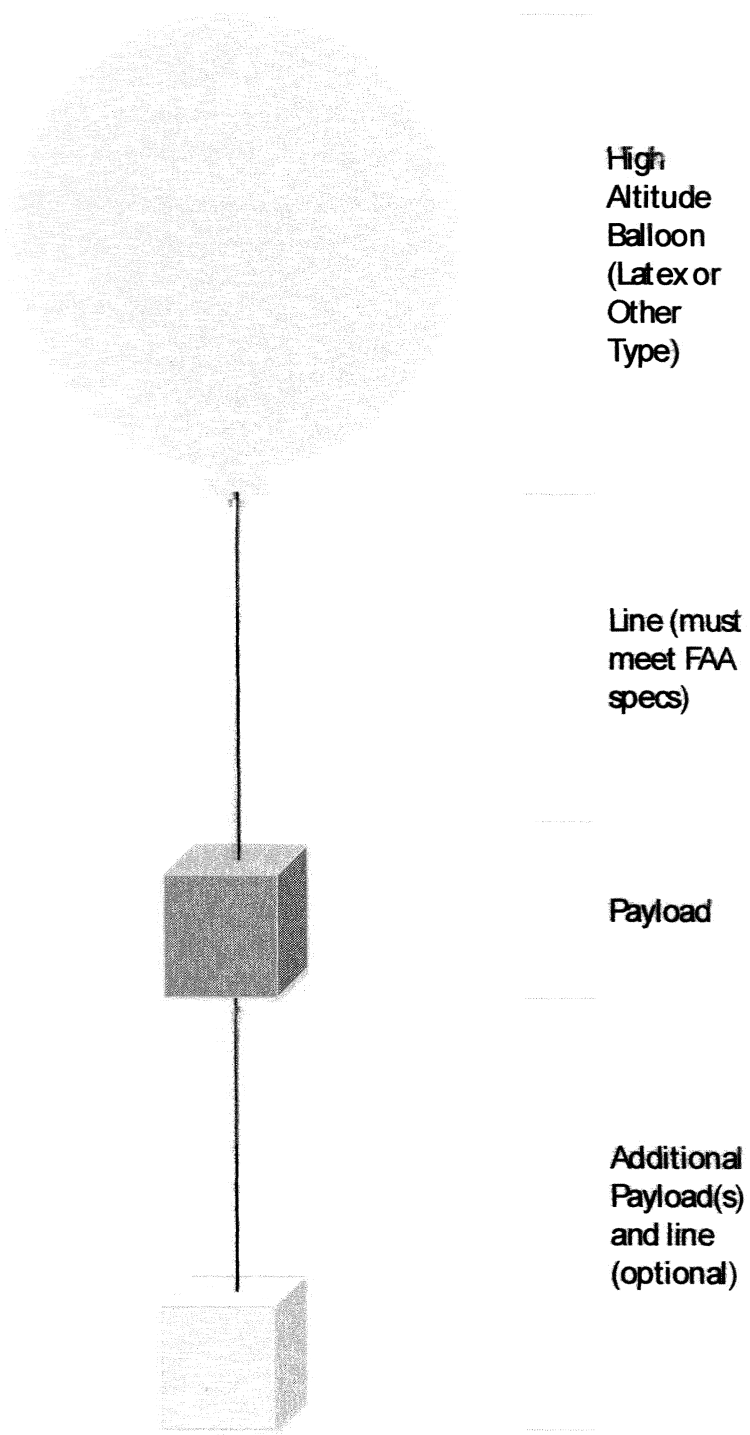

Figure 1. High Altitude Balloon Payload Train.

The Program

The proposed program seeks to demonstrate and evaluate the efficacy of utilizing HABs to inspire and instruct students in 6th, 7th and 8th grades (with an initial focus on grade 8). There are, thus, inherently two parts to this work. First, there are the research activities which seek to measure the desired learning outcomes of the proposed curriculum. Second, is the curriculum and its delivery. This section presents an overview of the program from a research prospective. Section 4 presents an overview of the educational content of the program.

Objectives & Significance

The proposed program will begin as a small empirical study to test the theses, currently supported by only anecdotal evidence, that (1) high altitude ballooning is a way to inspire student interest and improve performance in STEM disciplines and (2) utilizing higher grade-level students to teach lower grade-level students provides a substantive learning benefit to both students. This will be done by conducting studies in a single school district. This study will utilize four experimental groups. One will not change its educational approach, one will incorporate only the high altitude ballooning component experimental condition, one will incorporate only the student-teaching-student experimental condition, and one will incorporate both high altitude ballooning and students-teaching-students. The results from evaluation instruments delivered in all four groups will be analyzed.

A curriculum will be developed that will bring the 8th grade science curriculum alive. The incorporation of high altitude ballooning / near-space activities integrates well with the current 8th grade science curriculum. The standards shown in Table 1 govern the science curriculum in North Dakota (similar standards exist nationwide):

Table 1
Eighth Grade Science Curriculum Standards 1 (North Dakota Department of Public Instruction, 2006).

Standard	Description
Standard 1	Students understand the unifying concepts and processes of science.
Standard 2	Students use the process of science inquiry • Scientific Investigation (making systematic observations, making accurate measurements, identifying and controlling variables)
Standard 3	Students understand the basic concepts and principles of physical science. • Properties of Matter; Force and Motion; Energy Transfer and Transformation; Vibrations and Waves
Standard 4	Students understand the basic concepts and principles of life science. • Structure and Function
Standard 5	Students understand the basic concepts and principles of earth and space science. • Weather, Seasons, and Climate; Characteristics of Earth; The Universe
Standard 6	Students understand relations between science and technology.
Standard 7	Students understand relations between science and personal, social, and environmental issues.
Standard 8	Students understand the history and nature of science.

Specifically, HAB activities will be incorporated into units of the 8th grade science curriculum responsive to three of the eight objectives. These are the units on scientific investigation, basic concepts and principles of physical science and weather and climate, and space studies (the universe, planets, solar system and evolution of earth systems).

Broad Design

A three-phase research program, which will span a three-year period is proposed. Phase one will last six months. During this phase, specific teaching material will be produced for HAB curriculum incorporation at the initial two levels: collegiate undergraduate education and middle school education. These materials will be developed in conjunction with classroom teachers that will be involved in this effort. Concurrently, training will be provided to the masters-level students that will be assisting with the undergraduate education and the upper-level undergraduates that will become the first teams to work in the middle schools. These students will have involvement with the teaching material preparation and will also lead additional ad-hoc HAB missions in conjunction with the schools that will have HAB curriculum incorporation to prepare the

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teachers.

Phase 2 will begin at the start of the subsequent academic year and be a two-year period. During phase 2, the masters-level students will facilitate the incorporation of HAB concepts into lower-level undergraduate labs and coursework (as defined during phase 1). The upper-level undergraduates will facilitate HAB incorporation in the selected middle school classrooms and mentor middle school participants.

Phase 3 will commence with the end of phase 2. During this six-month period, the results of the two-year experimental period will be analyzed and disseminated.

Experimental Methods and Procedures, Research Design and Methodology

The four experimental condition groups will facilitate determining the impact of the two treatments. Written and oral pre- and post-tests will be administered to all four experimental groups of middle-school students, to the college undergraduates that will participate in the HAB-inclusive curriculum and to a set of college undergraduates in similar courses that do not include the HAB element. These surveys will assess knowledge areas specifically related to the HAB curriculum component and problem-solving abilities. They will also ask students to qualitatively and quantitatively characterize their interest in STEM disciplines, and describe their future educational and career plans. Quantification of student STEM interest will be achieved through the administration of a mechanism such as the Test of Science Related Attitudes (Fraser, 1981). Learning achievement will be measured using a mechanism such as The Astronomy and Space Science Concept Inventory (Sadler et al., 2009), which is well aligned with national eight-grade learning standards. Final selection of the qualitative evaluation mechanisms will be performed by the project team and external evaluators during the curriculum development period. Qualitative assessment of student STEM interest will be performed through open-ended response questions and follow-up interviews. The impact on career planning will be assessed for a sub-group of students who agree to participate in an initial survey and follow-up surveys at three, five and nine year intervals to track their career choices and progress.

Comparing of the performance of the four middle school experimental group results and two college undergraduate group results will facilitate an evaluation of the impact of the two treatments. Additionally, comparing the two cases where only one treatment was received to the case where no treatment was received will be informative with regards to the existence of any Hawthorne-style effects (Cook, 1967). The assignment of undergraduate mentors to each middle school class will be assigned through a randomized method to try to mitigate the presenter-effect as much as possible. There may still be some element of this present, which cannot be compensated for, due to the actions or predisposition of the classroom teacher.

Educational Content of Program

This section provides a brief overview of the educational content of the proposed program. This content is aligned with three standards of the eight grade curriculum: 1) the process of scientific inquiry, 2) the principles of physical science, and 3) Earth and space science. For each unit, a brief description of the goals of the unit is provided, followed by an experimental description and the expected outcomes and learning benefits to students. A summary of these units is presented in Table 2.

Table 2

Overview of Proposed Learning Units and Their Topics.

Unit	Topic
Process of Scientific Inquiry	HAB design creates a learning environment that provides students with the time, space, and resources needed for learning science through inquiry.
Principles of Physical Science	Allows students to experience the nature and properties of physical science, concepts such as gravity, energy, mass, and motion begin to make sense.
Earth & Space Science	Students actually experience near-space exploration.

Process of Scientific Inquiry

The *National Science Education Standards* (National Research Council, 1996) defines scientific inquiry as "the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world." Early adolescents learn best when they interact with their environment, ask questions and then, are encouraged by their teachers to seek ways to answer those questions. By designing lessons that are anchored to inquiry experiences, student understanding of science concepts and ideas are significantly enhanced.

The unit on the process of scientific inquiry is responsive to these needs. The HAB project will implement approaches to teaching science that allow students to question and explore and to use those experiences to raise and answer questions about the world they live in. Teachers will guide and facilitate learning using inquiry by selecting teaching strategies that nurture and assess student's developing understandings and abilities. The HAB design will create a learning environment that provides students with the time, space, and resources needed for learning science through inquiry.

Students will learn the process of scientific inquiry: 1) state the problem, 2) gather information, 3) form hypothesis, 4) test hypothesis, 5) analyze data, 6) draw a conclusion. Even more importantly, students will discover that scientific inquiry is a powerful way of understanding science content. Students will learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students will learn, through high altitude ballooning (HAB), to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions.

The obvious benefits are that students will learn the process of scientific inquiry that will assist them in developing their critical thinking and quantitative reasoning skills. But, the benefits of actively participating in HAB will go far beyond those essential skills. This project will allow students to think creatively and learn important life skills such as using their imagination, paying attention to details, looking for patterns, following hunches, and learning to interpret ideas.

Principles of Physical Science

Physical science concepts allow students to study and predict how nonliving matter influences their lives. By placing students in settings that allow them to experience the nature and properties of physical science, concepts such as gravity, energy, mass, and motion begin to make sense. To just have students read about mass and a westerly wind doesn't have the lasting effect that occurs when the students have to track their payload using calculations, measurements, and data analysis based upon those concepts.

The unit on the principles of physical science in the HAB project is conceptualized upon a "hands-on, minds-on" model. The middle school students will utilize the law of motion, calculate how force, weight and mass will affect their design, contemplate how heat transference could benefit or hinder their payload, and determine how the change of temperature will alter their payload as it travels to and from near-space. Using global positioning systems (GPS) technology, students will learn to track, monitor, measure, and record data that will assist them in determining how physics and chemistry influence the physical world they live in.

Students will design their payloads utilizing their knowledge about the law of motion and the concepts of force, weight, mass, and momentum. They will consider the effects of gravity and the transfer of energy on the object they intend to put into near-space. During the construction phase, students will have to apply the knowledge that they have gained regarding atmospheric temperatures and the various elements of heat transfer (conduction, convection, and radiation) to best ensure that their payload successfully reaches near-space but also allow the student to conclude whether their hypothesis was correct.

Often times, students are able to participate in laboratory experiments that look at separate, isolated concepts of physical science. Even though laboratory work is recognized as active learning because students are "doing the experiment", it really cannot compare to putting the student that the "heart of the learning experience" as will this comprehensive project. The HAB project will require students to take the various concepts of physical science (in combination with similar earth/space theories) and construct an object (payload) that will withstand the forces of our earth's natural system.

Earth & Space Science

Earth is a complex, dynamic system we do not yet fully understand so we must entice student to want to know more about the Earth's atmosphere and space. Middle school students tend to be concrete learners so being able to understand elements outside their immediate world is challenging. The purpose of the high altitude ballooning project is that it allows these students to actually experience near-space exploration.

The unit on Earth and space science is designed to allow middle school students to become scientists (e.g., astronomers) as they explore the atmosphere, weather, and near-space. The HAB project will allow our eighth grade students to meet the (ND) science standards as follows; the students will explore changes in patterns, identify and control variables, determine relationships between matter and temperature, consider gravitational force, and study atmospheric pressure and winds.

The creation of a project (HAB) that allows students to experience the previously mentioned abstract aspects of

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space and atmosphere should enhance retention of the science concepts. Another outcome of this project should be an appreciation of and increased interest in STEM. As these students enter high school, it is anticipated that they will be more likely to take courses and even consider careers in STEM fields.

By bring earth science alive, students will gain a greater understanding of the scientific method, learn hands-on technology skills (e.g., design), explore engineering principles (e.g. heat transfer), consider the effects of atmospheric conditions (e.g., temperature), test physic concepts (e.g., acceleration), and learn data analysis skills (e.g., statistical findings). Ideally, students will demonstrate and communicate a deeper understanding of critically important concepts in the world of science, technology, engineering, and mathematics.

Qualitative Evaluation of Program Benefits

The evaluation of any program must include consideration of the benefits that it could produce as well as the likelihood of the program producing these benefits. The proposed program is well situated on both fronts. The following sections describe and evaluate the significant advancement to knowledge and understanding that the proposed work is poised to create.

Benefit to Society

This proposed program is poised to provide significant societal benefit. It is, of course, impossible to guarantee the outcome of a scientific experiment prior to its implementation. However, anecdotal evidence (Jackson et al., 2012) suggests that participation in a high altitude balloon experience is inspirational to the student participants. In each instance, the students explored different areas learning about topics that they had limited or no prior knowledge of. They were provided instruction by university faculty, staff and students as well as members of the community, during this process.

By conducting a longer-duration, more involved HAB experience that is specifically designed to align with grade-specific curricula and utilizing student assistants to reduce the level of teacher effort required, it is believed that even greater educational benefits will ensue. By quantifying these activities within a controlled experimental framework, the educational community benefits from scientifically valid data supporting (or refuting) the proposed approach. Irrespective of the outcome, this will facilitate further research and ultimately develop new educational methodologies for STEM education.

Advancement of Knowledge & Understanding

The United States educational system is in a state of dramatic flux. The historic teach-and-recall model is being shown to be outperformed by approaches that involve students in hands on activities. Floersheim and Johnston (2010) have shown that more focused, but interdisciplinary learning – such as is common in many Asian countries – outperforms the compartmentalized approach that is common in the United States.

It is planned to further enhance pedagogical knowledge and understanding by conducting a rigorous controlled study that will demonstrate the specific impact of two different pedagogical elements (students mentoring lower grade-level students and high altitude balloon curriculum incorporation). At the completion of the proposed work changes will be proposed to the national 8th grade curriculum and teaching styles, based on the firm scientific footing provided by the experiment.

The 8th grade is one of the most critical points in a child's life. Students, at this point, lack the drive that permeates (for many) the high school and college experience of knowing that their actions have far-reaching career and life consequences. However, students that 'turn off' during this year, may not 'turn back on' during high school and may end up dropping out or under-performing their potential. As the developing adolescent cannot be expected to understand (nor should be burdened with the understanding of) the importance of the decisions and actions that are being made and taken, respectively, it is critical to find positive ways to influence these youth towards desirable paths be found. The proposed work represents one such method. The knowledge and understanding gained through this trial will allow others nation-wide to evaluate this proposed method for incorporation in their state and local curriculum.

Transformative Nature of Work

The proposed work is poised to have a transformative impact on the United States STEM education system. If successful, it will provide an example for two paradigm-shifting educational approaches: the curriculum integration of high altitude ballooning activities and the utility of augmenting the teaching capabilities of classroom teachers with students from higher-grade levels. The latter, while not new (Barker & Muse, 1986), is a technique that has been utilized only occasionally (Simon, Abrams, McDonnough, & Warren, 2009; Stecz, 2009; Yu & Stokes, 1998) – generally with very positive results – since the separation of students by grade levels and the grouping of various grade levels into tiers of education.

If shown to be successful, the proposed activities could provide a low-cost, highly effective way to capture and retain student interest in the STEM disciplines. Various studies (Bahr, 2007) have demonstrated that a deficiency in either learning or retaining science and math skills learned exists in adults. These deficiencies must be remedied at higher levels of education; however, this is not desirable as it impairs student achievement in newly presented material (Bahr, 2007). Other studies have demonstrated that being forced to recall and reuse information over an extended period of time can aid long-term recall (Davis et al., 2010). Thus, it is believed that the utilization of higher grade-level students will not only aid the classroom teacher and lower grade-level students by providing personalized instruction assistance, it will also aid the higher grade-level students by forcing recall and reuse of this information. Additionally, to provide even greater benefit for the higher-level students (to justify the commitment of some of their educational time to this effort), curriculum-integrated goals will be created that can be achieved in concert with the lower-level students. For example, middle school students may be asked to design a payload structure; high school students could be asked to assist them in refining it, utilizing knowledge gained via a physics course and collegiate engineering students may be asked to define a formal test plan to validate its safety for flight under the FAA regulations and HAB best practices.

Evaluation

Three key program evaluations will be conducted: (1) an evaluation of the learning outcomes achieved by students, (2) an evaluation of the technical achievements by students under guidance from higher-level student and faculty mentors, and (3) the success of the experiment from a pedagogical perspective.

The learning outcomes achieved by students will be the key focus of study for this project. Ongoing evaluation will be required (in addition to the pre- and post-test evaluations) to ensure that the curriculum is being delivered effectively. To ensure the value of the study, the learning outcomes must be maximized. It is also critical to ensure that changes made during the process from interim lessons learned are documented so that they can be evaluated as part of the overall outcome evaluation.

Technical achievements made by students during this project, in addition to being their own source of merit, certainly advance the level of learning outcomes achieved. Particularly at the collegiate (and possibly the high school level), work that is meritorious from a technical perspective (outside of the pedagogical context) may be achieved. This should be evaluated and disseminated, as this could be a key component of the program's value and a key justification for expanding it on a national level.

The success of the experiment from a pedagogical research perspective is, of course, the overarching evaluative criteria for this project. Ongoing evaluation will be required to maximize the value of this experiment to its participants and the nation.

Analysis of Program Impact

The proposed work is designed to provide useful scientific data to assess whether the incorporation of high altitude ballooning activities and the proposed student teaching/mentoring learning model would be beneficial on a nationwide basis. The data that is collected should facilitate further refinement of the proposed activities as well as providing data about STEM learning and student STEM interest in general that can benefit the education community at-large. In addition to the scientific data products produced, the students involved will no doubt benefit from the additional attention that will be paid to them by undergraduate participants and researchers. Even if this is a Hawthorne-style effect (Cook, 1967), it is none-the-less a tangible benefit for the students involved and the replication of this program to provide just the Hawthorne effect may, in fact, have merit (though ideally, a program would be developed that provided benefit from content and process exposure, in addition to the additional attention paid to students therein).

Benefits of the Middle School Environment

The middle school concept provides a unique opportunity for this HAB curriculum to be integrated within several disciplines. The interdisciplinary teaming approach used in the middle school would allow the curriculum developed to be implemented in the science, mathematics, and technology classrooms simultaneously. This level of integration enhances retention, transference of knowledge, and piques interest in the topic being addressed, possibly leading to student STEM career choices.

Broadened Participation of Underrepresented Groups through Class Incorporation

It is proposed that the high altitude balloon curriculum be developed for and implemented within the 8th grade science curriculum, not as an after school program. All students will have an opportunity to participate, allowing diverse groups of students (e.g., students from different socioeconomic statuses, disadvantaged students, at-risk students, and students with disabilities) to actively participate in the study. This type of comprehensive participation should have a broad impact on numerous students and teachers. The development of curriculum should lead to continued teacher participation year after year, thus a fostering self-perpetuating interest in HAB and STEM.

When considering the goals of this program, devising innovation and discovery-based science curricula as well as promoting STEM career paths naturally fits with middle school education. The time when most students begin thinking about their future careers typically starts during their middle school years. Early adolescence is a time of great exploration and it is through this inquiry process that students begin to find their niche. Discussions about their futures and career exploration occur daily in the middle school classrooms. Teachers are constantly designing their curriculum and instruction to meet the interest and needs of their students. This approach results in lessons that promote experiential learning.

Benefits to Society at Large

The proposed work stands to provide two types of benefits to society-at-large. First, society will benefit from an increased understanding of the impact of the proposed pedagogical method and high altitude balloon curriculum

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incorporation. Existing evidence suggests that incorporating both of these elements into the middle school curriculum will enhance the student learning experience and excite students about learning – particularly in relation to STEM fields (Jackson et al., 2012). High altitude balloons travel to the edge of space and can return imagery, videos and other data that can inspire students in a way that few other activities (particularly those with this cost level) can. Students who are inspired by these activities may make more productive life choices, deciding to pursue additional education and enjoying the increased earning power and providing the increased benefit to society commensurate with their higher education level.

Second, independent from the added understanding that may facilitate the deployment of this type of program on a nation-wide basis, the student participants derive a tangible benefit from their participation in this program. The undergraduate students attain additional training and experience in educational methods and their implementation. They also gain experience in curriculum design. Participation in the proposed program should also be an auspicious resume-building experience that positions them well for future employment or admission for higher levels of education.

The middle school students will benefit from greater-than-normal levels of instructional attention and mentorship. The Hawthorne effect is well understood (Cook, 1967) and, if for no other reason than this, participation in this program should have a positive impact of the lives of these students. Existing evidence suggests that the program-specific elements should further enhance this effect. This should include encouraging students to pursue collegiate education and favorably influencing their career selection and life choices.

Conclusion

The proposed work is poised to transform the way middle school STEM curriculum is taught. It is believed that demonstrating the efficacy of utilizing higher-level students for educating/mentoring lower-level students could produce a significant and beneficial change to the student learning process in the United States. Even just the Hawthorne-style effects produced by the small-group attention (Cook, 1967) that will be provided should have significant benefit. By placing responsible and highly visible role models in the lower grade-level schools, students' aspirational self-perspectives can be modified. It is known that peer pressure is highly influential on adolescents – particularly peer pressure from slightly older students. By placing these positive super-peer role-models in direct and longer-term contact with students, their lives can be positively influenced.

The high altitude ballooning/engineering component is also designed to be highly impactful. The chance to 'touch' the edges of space will have profound impact for many students. The chance to participate in a hands-on activity will draw in students from a variety of backgrounds. Students who have difficulty self-motivating may find motivation from peer and super-peer involvement. Students who do not believe that they are interested in STEM disciplines may change this perspective after they understand the ways that the STEM fields permeate the world around them – as exemplified by the various STEM lessons taught through building a high altitude balloon payload.✈

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Ronald Fevig has significant experience in high altitude ballooning, incorporating high altitude ballooning into course curriculum and engineering education. Dr. Fevig was responsible for the engineering aspects of the 2012 North Dakota High Altitude Balloon Payload Competition, interacting with collegiate and secondary educators as part of this effort. He also teaches space mission design and spacecraft systems engineering courses at the University of North Dakota. Prior to his appointment as a tenure-track assistant professor, Dr. Fevig was a post-doctoral researcher in the Electrical Engineering Department where he was involved in student education projects. He has also mentored numerous student engineering design projects related to space and aerospace engineering.

Gail Ingwalson has been in the education field since 1980. She has served as the coordinator of the middle school program in the College of Education and Human Development since 1998 but has been associated with the program since 1995. She is considered an expert regarding middle school curriculum, adolescent development, best practice for middle level students, and

has a strong understanding of brain research (tendencies, possibilities, and limitations) for individuals between the ages of 10-14. Dr. Ingwalson currently coordinates a mentoring program for first year (middle school) teachers, is a licensed counselor, and has extensive experience in middle school education. She has advised over 60 master degree candidates in middle level education. Dr. Ingwalson has recently evaluated the utility of space exploration activities for exciting middle school students.

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