High Altitude Ballooning into Undergraduate STEM Curriculum: Preparing for Widespread Implementation

Donald Takehara,[1] Pamela Medows,[2] Susan Gavin,[3] Jeffrey Dailey,[4] Steven Snyder,[5] Bethany Smith,[6] and Rachel Tomasik[7]
Taylor University, Upland, Indiana, 46989

Melissa Mitchell[8], Jill Coleman[9], and Kay Roebuck[10]
Ball State University, Muncie, Indiana, 47306

Jason Krueger[11]
StratoStar Systems, Fishers, Indiana, 46037

The National Science Foundation (NSF) Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) program is funding a grant to determine how to best implement high altitude ballooning into undergraduate curriculum at higher education institutions. Based on a previous NSF TUES grant where 52 universities were trained and statistically and practically significant student learning outcomes were obtained as a result of implementing ballooning into undergraduate classes, the following are the key efforts for the current grant: 1) building a core group of universities actively using ballooning in their undergraduate classes, 2) determining best practices for engaging and training new universities, and 3) determining the potential for implementing ballooning into undergraduate education classes. Key accomplishment include:

- **the formation of a core group of 10 universities that share information and collaborate as a result of the annual Academic High Altitude Conference and videoconferences,**
- **the implementation of a website with the capability of tracking balloon flights in real time, sharing data from balloon launches, obtaining training videos, manuals for key equipment and processes, key papers, and curriculum,**
- **the Taylor University pilot for implementing high altitude ballooning into undergraduate education classes showing statistically significant undergraduate learning outcomes and the similar Ball State pilot completing a full iteration of developing curricula and field testing the curricula in an 8th grade class.**

Nomenclature

p	=	statistical probability that the pre-test and post-test results are the same
eta^2	=	ratio of variance from an analysis of variance (ANOVA)

I. Introduction

The National Science Foundation (NSF) is funding a second TUES (Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics) grant to implement Taylor University's high altitude balloon

[1] Academic Director - Center for Research & Innovation, Associate Professor, 236 West Reade Avenue, Upland, IN 46989
[2] Professor of Education, Taylor University, 236 West Reade Avenue, Upland, IN 46989
[3] Administrative Manager – Center for Research & Innovation, 236 West Reade Avenue, Upland, IN 46989
[4] Research Engineer – Physics & Engineering, 236 West Reade Avenue, Upland, IN 46989
[5] Professor of Psychology, Taylor University, 236 West Reade Avenue, Upland, IN 46989 Avenue
[6, 7] Graduated student, Psychology Department, Taylor University, 236 West Reade Avenue, Upland, IN 46989
[8] Professor of Biology, Ball State University, 2000 W. University Ave. Muncie, IN 47306
[9] Associate Professor of Geography, Ball State University, 2000 W. University Ave. Muncie, IN 47306
[10] Professor of Mathematical Sciences, Ball State University, 2000 W. University Ave. Muncie, IN 47306
[11] CEO, StratoStar Systems, Fishers, IN 46037

program (High Altitude Research Platform or HARP) into undergraduate curricula. HARP's suite of sensors (altitude, temperature, pressure, humidity, UV, visible light intensity, accelerometer, Geiger counter, IR, CO_2, etc.) streaming real-time data back to earth is an unique platform for performing experiments in a variety of science and engineering applications. The first grant enabled 52 universities to be trained to implement HARP into undergrad classes. This resulted in more than 20 universities using HARP in their classes and10 or more universities implementing HARP continuously at their university.

A longitudinal study on student learning using validated and reliable instruments (pretest and posttest given to students) was initiated with the first NSF TUES grant and is ongoing [1]. The areas of assessment include:

- **Intrinsic Motivation** - contextualization, curiosity, challenge, control, and cooperation.
- **Valuing Science** - valuing problem solving, calibration, the scientific method, reproducibility, data analysis, metacognitive planning, monitoring and assessing, teamwork, and meeting deadlines.
- **Application Knowledge** - how to use problem solving, prototyping, evaluating, calibrating, and documenting.
- **Metacognitive Processes** - planning, monitoring, and assessing ones thought processes.
- **Cognitive Skills** - application of the following (Application Knowledge) to a complex problem at the appropriate time: problem solving, prototyping, evaluation & calibration, the scientific method, reproducibility, and data analysis.
- **Content Knowledge** - knowledge of the scientific method, the technical balloon launch process, and the requirements for a balloon launch.

Table 1 shows the results with 20 universities and 526 students after the first TUES grant. The results were put into the following categories.

- **Event Group** – Schools that did a 1st launch as an event and did not integrate it into their class.
- **Novice Group** – Schools that did a 1st launch. (Integrating HARP into a particular class once)
- **Experienced Group** – Schools that did a 2nd or 3rd launch. (Integrating HARP into a particular class for a 2nd or 3rd time)
- **Expert Group** – Schools that have done more than 3 launches. (Integrating HARP into a particular class more than 3 times.)

A One-Way ANOVA Repeated Measures was used to assess the changes from pretest to posttest for each group. Table 1 shows the results with the areas printed in capitals showing a statistically significant change. These results show that student learning increases after multiple implementations and that implementation of HARP in the classroom results in increases in student learning especially after multiple implementations. In addition to statistically significant changes, practically significant (eta^2) changes were also obtained after multiple implementations.

Table 1: Assessment of Student Learning at Universities Implementing High Altitude Ballooning

Event Group	Novice Group	Experienced Group	Expert Group
Intrinsic Motivation	INTRINSIC MOTIVATION ($p<0.05$)	Intrinsic Motivation	INTRINSIC MOTIVATION ($p<0.05$)
Valuing Science	Valuing Science	Valuing Science	Valuing Science
Application Knowledge	Application Knowledge	APPLICATION KNOWLEDGE ($p<0.01$)	APPLICATION KNOWLEDGE ($p<0.001$)
Metacognitive Processes	Metacognitive Processes	METACOGNITIVE PROCESSES ($p<0.01$)	METACOGNITIVE PROCESSES ($p<0.001$)
Cognitive Skills	Cognitive Skills	COGNITIVE SKILLS ($p<0.05$)	COGNITIVE SKILLS ($p<0.05$)
Content Knowledge	CONTENT KNOWLEDGE ($p<0.001$)	CONTENT KNOWLEDGE ($p<0.001$)	CONTENT KNOWLEDGE ($p<0.001$)

Notes: 1. Capitalized areas show statistically significant positive change from pretest to posttest
2. p = probability pre and posttests are the same. (smaller number is more statistically significant)

The second NSF TUES grant is focusing on preparing for a widespread implementation of HARP into higher education institutions across the U.S. Three items were identified as crucial in order to prepare for this widespread implementation. They are a part of this second grant and are as follows:

1. Building a core group of universities actively using HARP in undergraduate classes

2. Determining best practices for engaging and training new higher education institutions
3. Determining the potential for implementing HARP into undergraduate education curricula for pre-service teachers

The following is a brief update on areas 1 and 2 with a more extensive update on area 3.

II. Core Group of Universities

In order to be successful in the widespread implementation of HARP, it is recognized that a core group of experienced users of high altitude ballooning in the classroom is needed. This core group is important to help mentor new higher education institutions as well as develop curricula and identify improvements in the HARP system. The following are accomplishments to date.

1. Core Group of Universities
   A core group of around 10 universities who are actively implementing high altitude ballooning at their university was established. This group is not meant to be a closed group but a group that has committed members with others participating as they desire. This group is currently examining the following activities:
   - Collaborative Project - Collaborating on a project where the final product is an instrument, curriculum, or capability that can be shared by the universities. This could be a key "rallying point" for strengthening relationships and developing partnerships.
   - Balloon Competition – The current balloon competition has struggled with low participation. Participation by a majority of the core group would bring a big boost to the competition and establish a foundation for growth.
   - Regular Teleconferences – In order to be able to follow through on the momentum obtained from the annual Academic High Altitude Conference, regular teleconferences have been initiated to create an avenue for sharing ideas and building partnerships.
   - Mentoring – There is a desire for several of the core universities to mentor other universities. This is a future area for development.
2. Curriculum Development
   A major need for universities implementing HARP into the classroom is the availability of successful and effective curricula. Funds are available to develop curriculum to be tested and shared with others. Funds for stipends and equipment/supplies are available.
3. Academic High Altitude Conference
   This conference has been well established with the 3rd year hosted at Trevecca University, the 2nd year hosted by Iowa State University, and the 1st year hosted by Taylor University. The conference has been the key way for universities to share successes/challenges as well as form collaborations.

III. Best Practices for Engaging and Training New Institutions

In order to be successful for the widespread implementation of HARP to institutions of higher education across the U.S., it is imperative to determine the best ways to engage and train these new institutions. The following summarizes the activities under this area of the grant.

1. Website (http://cse.taylor.edu/~harp/)
   A website was created that contains the following capabilities:
   - Live tracking of balloon flights
   - Sharing of data from balloon flights
   - Videos on how to perform a balloon launch
   - Curriculum with details for users to implement into courses
   - Papers and references
   - Documentation on using particular equipment and capabilities of HARP
   - Potential capability for informal networking (similar to social networking)

   The Live Tracking and Sharing of Data are up and running. The other capabilities are in the process of being created and loaded on the website. This website has the goal of containing information for someone to be trained to do balloon launches via on-line resources with the assistance of some mentoring by a core university or by StratoStar. This website is also a much needed resource for the core universities for collaboration as well as building their own programs.
2. Workshops

During the first NSF TUES grant, four 2-day workshops were very successful at training 52 universities. Variations of these workshops continue to be offered that are tailored for the particular needs of the attendees. Over 70 universities have now been trained via workshops. Due to the economic downturn, less funds are available for university professors and staff to attend workshops. Therefore, workshops are more focused and targeted to be done in conjunction with specific conferences. On August 11 and 12, 2012, a workshop specializing on the use of high altitude ballooning to develop small satellites will take place right before the annual Small Satellite conference at Utah State University.

3. Webinars

   The marketing study that was completed over a year ago revealed that there was a lack of understanding among university faculty and staff of what high altitude ballooning was and the capabilities of the HARP system. Therefore, one hour webinars to introduce people to HARP and its capabilities were implemented by StratoStar Systems and Taylor University. This has proven to be effective in introducing people to HARP.

IV. Implementing HARP into Undergraduate Education Curricula

Only one education professor attended the workshops from the first NSF TUES grant. Therefore, the potential impact of HARP in education curricula was not adequately addressed during the first grant. As a result, the current grant is piloting the implementation of HARP into education curricula at Taylor University and Ball State University. In particular the pilots include HARP implementation into the science methods courses at these universities with the students developing 6th, 7th, and 8th grade science curricula and field testing the curricula in actual classes at local schools.

The impact of implementing HARP in undergraduate education curricula has the potential for very significant impact from the standpoint of number of undergraduates in education majors across the U.S. In addition, President Obama's recent introduction of a National STEM Education Initiative called "Educate to Innovate," identified improving the quality of math and science teaching to American students as one of the three priorities for STEM education. According to the National Science Education Standards (National Research Council 1996), “inquiry into authentic questions generated from student experiences is the central strategy for teaching science” [2]. And yet, many teachers have never had the opportunity to inquire into their own authentic science questions. While many university laboratory experiences include at least some aspects of authentic science inquiry, all too often they have pre-determined outcomes and are based on questions which reflect not the interests of students, but the limitations of time, space, and budget. If we are to prepare and train new K-12 science teachers confident and capable of leading their own students in scientific inquiry, they must have comparable experiences of their own. These pilots put that opportunity into science methods classes rather than traditional science labs so that pre-service teachers understand the importance of modeling for their students not only the skills of scientific inquiry, but also the attitudes toward science that inquiry demands.

The 6th, 7th, and 8th grades seem an opportune time to engage students in real-world inquiry that will lead to greater appreciation for and more in-depth understanding of the STEM fields. Blessed with an overabundance of energy and enthusiasm, these students are at an age where classroom experiences can positively influence future career choices. The 6th, 7th and 8th grade High Altitude Balloon Curricula written and field-tested by pre-service teachers in this program includes not only discipline-specific science and mathematics content connections, but will also make connection related to the development of skills and processes that are essential elements in all STEM fields. The curricula provide ample opportunities for students to engage in science as inquiry and to extend their abilities of technological design---asking questions, solving problems, interpreting data, and formulating explanations based on evidence.

The intention of this project is to inspire a new generation of students through exciting practical learning experiences that require them to investigate and apply their knowledge to a real-world laboratory. Those students range from the Geography Majors taking an upper division atmospheric science course to Elementary and Secondary Science and Mathematics Teaching Majors taking an upper division content methods course to 6th-8th grade students taking an elementary or middle school general science course. In each case, students put the scientific method into practice with research question development, experiment construction, problem solving, data analysis and interpretation and final project synthesis. These outcomes are the result of each group having the opportunity to experience the High Altitude Research Platform (HARP) system in a setting which is appropriate for their needs and backgrounds. Through the work of the teaching majors, they will come to understand that science and mathematics concepts and skills are learned by doing. The curriculum that they write and the lessons that they teach will have translated their own learning experiences into an age and grade appropriate experience for their students. We believe that it is this kind of teaching that will have a dramatic impact on the learning that takes place in the 6th-8th grade classrooms.

Taylor University Pilot

At Taylor University, the HARP system was introduced to 60 undergrads in elementary science methods classes via a one-semester model that produced 6^{th} grade science lessons that will be field tested in 6^{th} grade classes. This model reflects that at most universities, elementary education majors take only a one semester science methods course. In this model one set of students would develop curricula using HARP during one semester of the Science Methods course and another set of students would field test these curricula the next semester that the Science Methods course is offered.

In the first semester of implementation (Spring 2011), 14 students participated in the project. This number was lower than expected due to changes in scheduling. The HARP system was introduced and students worked in groups of three or four to create experiments for a balloon launch. The students experienced the launch and reviewed the resulting data. Again working in groups, students created lessons appropriate for sixth grade students that encompassed the following topics: layers of the atmosphere, temperature, air pressure, and humidity.

The inaugural semester was definitely a learning experience for both the professor and pre-service students. Several challenges emerged resulting in changes for the next round of implementation. It was noted that the lack of science content knowledge of students preparing to teach in the elementary classroom significantly affected their ability to develop and implement experiments for launch. It was clear that students needed to review basic concepts relating to air pressure, temperature, humidity and characteristics of the layers of the atmosphere. While this seemed to be a negative aspect, it was also a positive in that it reinforced the idea that sixth grade students would also need to have the background knowledge to create their own experiments. A decision was made to delay the field testing of the curricula with sixth grade students until adjustments were made and the development of curricula could be repeated in the science methods course.

During the first semester, pre-service teachers created a variety of experiments but again, their lack of content knowledge may have limited their creativeness or knowledgeable selection. Most of the experiments centered around what would happen to common objects as they were exposed to lower air pressure, lower temperatures or differences in humidity. One group sent up an egg that was cushioned to withstand turbulence. It did not survive! Other groups wanted to see the effect of lower air pressure on a can of soda and a can of Pringles. Another experiment tested the freezing point of regular soda versus diet soda. Another group sent up some dough and upon its return, baked it along with a control portion to see if there was difference. Unfortunately, the launched dough was not recovered immediately and sat around for some time before it was baked which made comparison difficult. In considering how sixth graders would handle this part of the project, most pre-service teachers thought that a list of possible experiments might work better for this age level.

The student learning assessment described in the Introduction was administered for the first semester. Results are are shown in Fig. 1. The first bar for a particular assessment area is the pretest results. The second bar for a particular assessment area is the posttest results. Significant growth in curriculum development knowledge was obtained which was a major focus of this project. The area in greatest need of improvement was application knowledge which could be directly tied to pre-service students' lack of content knowledge. It will be interesting to see if there is any change in these results with the second group of elementary education majors after the modifications concerning content knowledge were made. Four other areas, intrinsic motivation, valuing science, and metacognitive processes, all showed statistically significant changes. This is particulars impressive since this was achieved after only the first implementation of HARP in the course.

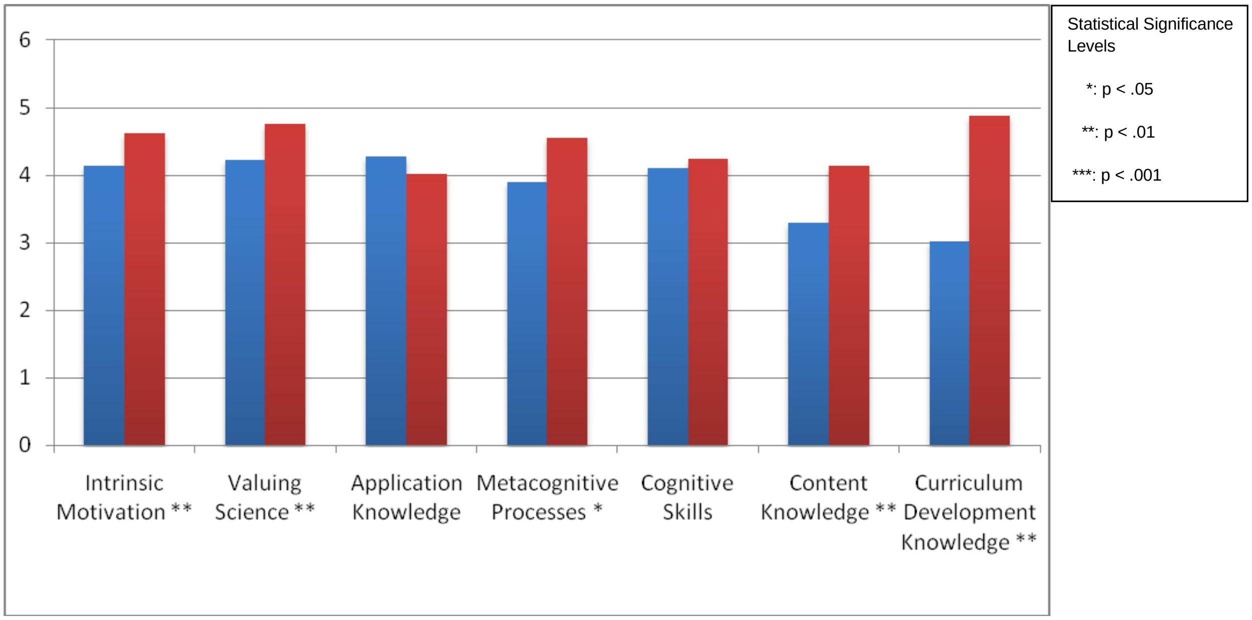

Fig. 1. Results from Assessment (Pretest and Posttest) – First Implementation of HARP in Taylor University Science Methods Course

During the second semester (Spring 2012), 46 pre-service elementary education majors participated in the HARP project. In response to the inaugural semester challenges, students were again introduced to the HARP system but this time were presented background information on air pressure, humidity, temperature and layers of the atmosphere. Building on this content knowledge, students worked in groups of three or four to design experiments for launch. All students participated in the launch and were able to view the real-time data and path of the balloon as it travelled east. A few days later, data were received for review. Unfortunately, several pods/experiments were lost and not recovered. Students then worked in groups of three or four to create curriculum for sixth grade students that incorporated the HARP system. These lessons will be field tested with sixth grade students in the spring of 2013 so that some of these same pre-service teachers can participate in this work.

The second semester's schedule seemed to work better as far as informing the pre-service students on content information, experiment requirements, review of data, and writing curriculum. It is important to note that developing curriculum using the HARP system does demand a time commitment for elementary education students. It would also be helpful to build in a class period or two to allow students to share their experiments and lesson plans with the rest of the class. The schedule for the second semester looked like this:

HARP system explanation Background information – air pressure, temperature, humidity, layers of the atmosphere	2 class periods (1 class period is 50 minutes)	Whole class
Pod Information – construction of pods, sensors Group Work – groups met to choose experiment	2 class periods	Whole class Group work
Launch Day	1 class period	Whole class
Review of results/launch discussion	1 class period	Group work
Curriculum Development – discussion and assignment of topic(s)	2 class periods	Whole class Group work
Lesson Plans	On own time – 2 weeks	Group work

With one year remaining in the NSF TUES grant project, the following preliminary conclusions can be made concerning using the HARP system to excite students in the STEM fields both at the university and elementary/junior high levels.

1. Using the HARP system seems to be an excellent way for students to use their content knowledge and the opportunity to "do" science to create interest and enthusiasm for STEM fields.
2. Background knowledge is crucial if students are to be able to use this knowledge to make applications in real world settings.
3. Developing curriculum using the HARP system in an elementary science methods course takes a considerable time commitment especially if content development is employed.
4. Limitations need to be considered when constructing experiments that will be launched using the HARP system. These include limited space in the pods, the ability to immediately view or control the environment of the specimen upon recovery, or ability to view the experiment via camera during the launch.
5. It might be more advantageous with a greater likelihood of success if elementary/junior high students choose from a list of possible experiments rather than creating one of their own.

Ball State University Pilot

In contrast to Taylor University, Ball State University is using a two-semester model where secondary science and mathematics education students typically take a two semester sequence of science methods courses. During the first semester (spring), students would develop curricula using HARP for 7th and 8th graders. During the second semester (fall), typically the same students who developed the curricula during the first semester would field test the curricula in 7th and/or 8th grade classes.

One and a half iterations of the two-semester model have been completed at Ball State. During Semester I (Spring 2011), 39 students were introduced to the history of high altitude ballooning, were given basic information about Earth's atmosphere, and were placed into 10 interdisciplinary groups (math, life science, earth/space science, and physical science) to brainstorm potential experimental questions. Each group wrote two papers: a) a Background Report that included basic information about the technical aspects of balloon launch and retrieval and an overview of the data that have previously been collected about the atmosphere and near space and b) an Experimental Design Plan that described the methods and materials they would use to test their own hypotheses. Following the launch and retrieval of all 10 experiments, students analyzed their respective data and made formal oral presentations of their results. Before the end of the semester, students were asked to write an inquiry-based lesson plan suitable for use with middle school students to teach some aspect of high altitude ballooning. The lesson plans were written not by the original interdisciplinary groups, but by groups of math teaching majors for a middle school math class and by groups of science teaching majors for a middle school science class. Twelve science lesson plans and 8 math lesson plans were completed.

Because of scheduling conflicts, during Semester II (Fall 2011), no math teaching majors participated in the pilot, and of the original 23 science teaching majors, only 14 registered for the second half of the science methods class. Those 14 were divided into 4 groups who then interacted with 24 middle school students assigned to the 8th grade science classroom of Mrs. Bianca McRae at Burris Laboratory School at Ball State University. After a review and revision process, the 12 science lesson plans that had been written in Semester I were eventually combined and condensed into 4 lessons. The 4 lessons covered the topics of The Scientific Method, Atmosphere & Weather, Temperature & Pressure, and Osmosis & Equilibrium. The lessons were taught to Mrs. McRae's class approximately once a week by the teaching majors and were supplemented with additional lectures and activities by Mrs. McRae so that an entire unit of instruction on the atmosphere was presented. (Sample lesson plans are found in the Appendix.) In addition, Dr. Roebuck visited the Burris classroom to teach a math lesson on using GPS coordinates to locate objects and Dr. Coleman visited twice—once to provide an introduction to high altitude ballooning and once to coordinate pod construction. Teaching majors returned to the classroom to provide assistance as students designed experiments and then again as they analyzed data from their own balloon launch. Near the end of the semester, 8th graders made formal oral presentations of their research to younger students in grades 3, 4, and 5. This was the end of Iteration One.

During Semester III (Spring 2012), two new groups of math and science teaching majors were introduced to the pilot. Because scheduling conflicts prevented the two sets of teaching majors from interacting with each other, each set worked independently to design and launch experiments, to report their results, and to write lesson plans for use with a second group of middle school students. The 11 science teaching majors were joined by 9 Elementary

Education majors who had chosen science as their content minors (i.e., these students had taken 15 additional science content hours beyond the 9 hours required for their major). While these two sets of students never collaborated on assignments, their combined numbers allowed for more HARP experiments to be designed and flown and for more middle school lesson plans to be written over the course of the semester. Interestingly, it was observed that the quality of both the experiments and the lesson plans from the Elementary Education majors were of a higher quality than the ones designed/written by the science teaching majors. It may be that the El Ed majors (who are trained as science generalists) were better prepared than the science teaching majors (who are prepared as specialists in a single science discipline) to combine the various sciences (earth/space, life, and physical) into single, cross-disciplinary lessons. While the Elementary Education majors reported their final research results in the form of PowerPoint presentations, the science teaching majors wrote reports reminiscent of articles published in scientific journals.

The original intention of the Ball State Pilot was to have science and mathematics teaching majors write cross-disciplinary lesson plans. What we discovered was that, for the most part, the math required for the experiments designed in Semester I was either too low level or too high level to lend itself to the middle school math curriculum. Differences between control and experimental variables were often determined by counts (e.g., the number of seeds that germinated) or results were simply the presence or absence of an observable trait. As a consequence, during Semester III, the 21 math teaching majors did not design experiments for flight. Instead, working in groups of 3-4, they wrote questions that could be answered mathematically from data that would be gathered by the command pod instrumentation (altitude, temperature, pressure, wind speed, humidity, etc.). Questions included “What is the relationship between altitude and atmospheric pressure?”, “What is the relationship between distance traveled and altitude?”, and “What is the relationship between altitude and temperature?” While the general relationships between these variables were already known from the students’ background research, the learning goal was to describe the relationships using rules and equations. Each of the six groups then wrote a sequence of lessons surrounding their question. The sequence included some lessons that would be taught prior to balloon launch and recovery and some lessons that would be taught following balloon launch and recovery. Lessons plans for early in the sequence included such things as distinguishing independent and dependent variables and identifying linear and non-linear relationships. Lesson plans for later in the sequence used such things as Excel to create scatter plots and to determine equations of best fit. Other plans were centered around concepts related to graphing in the coordinate plane. The development of such concepts and skills is more in line with the Grade 8 Common Core Standards for Mathematics. Like the science lesson plans developed in Semester III, the math lessons will be revised and then taught to Burris School students during Semester IV (Fall, 2012).

Successfully implementing the HARP student experiments has been challenging in several respects. The Ball State pre-service teachers are a heterogeneous group, specializing in a variety of science disciplines (e.g., physics, biology, chemistry, earth science) with equally as diverse ideas for experimentation and lesson plan development. While most of these students have conducted experiments in a controlled laboratory environment with direct instructor supervision, they have not conducted experiments of their own with the substantial limitations on equipment and time that HARP launches impose. Consequently, the pre-service teacher experimental designs are often too complex, require components that are inappropriate for HARP specifications, and/or may be unsuitable for a near-space environment. For example, one student experiment was designed to determine the atmospheric pressure at which different types of alcohols would begin to boil. This experiment was well constructed for a controlled laboratory environment, but for a balloon launch it posed several problems that could not be successfully solved such as: 1) large plastic vials that were too large for the experimental pod (and which were eventually replaced with smaller, glass (and therefore, breakable) jars; 2) reliance on an internal camera to film the boiling point without consideration of adequate viewing angle or light source within the experimental pod; and 3) the need to maintain an internal pod temperature during sub-zero launch conditions (a chemical hand-warmer proved insufficient). In contrast, the biology-related experiments frequently offer easier construction, but often require greater manipulation during launch set-up and recovery. Several experiments involving biological materials (e.g., bacteria, fruit, chicken skin & muscle) could not be prepared in advance and needed immediate refrigeration upon recovery. Consequently, with these types of experiments on board, the balloon launch was delayed while making last minute preparations and immediate post-launch equipment recovery becomes more critical.

Different challenges have occurred with middle school experiments that tend to focus on the physical changes easily observed in organic and inorganic objects (e.g., insects, plants, and food stuffs) after flight. While these experiments typically required only simple or no instrumentation, they often had pre-determined outcomes, since freezing of the specimens was inevitable. The main problem experienced in Semester II with middle school projects could be attributed to middle school behavior: namely, students "forgetting" to bring the experimental materials their designs were based on and, instead, locating last-minute (and often inappropriate) substitutions that were simply found on the school grounds or at the launch site. This, of course, required last minute adjustments to pre-constructed pods and took time away from other, more essential pre-launch activities. In both cases, the lesson learned was that experimental designs must be completed earlier in the semester so that Dr. Coleman can "trouble-shoot" potential problems, and Mrs. McRae needs to collect middle school specimens in advance of launch day to ensure their availability when needed.

V. Conclusions

Significant progress has been made on the NSF TUES grant entitled "High Altitude Ballooning into Undergraduate STEM Curriculum: Preparing for Widespread Implementation." In particular the pilots implementing HARP into education curricula at Taylor University and Ball State University, have made significant progress with statistically significant learning outcomes with undergraduates at Taylor University and a complete iteration of curriculum development and field testing of the curricula in an 8^{th} grade class at Ball State University. Several key learnings have been uncovered in both pilots. In addition, a core group of 10 universities actively using HARP at their universities has been formed with active sharing of information and partnerships forming as a result of the annual Academic High Altitude Conference and teleconferences. Also, a website is up and running with the capability of tracking balloon flights in real time, sharing data from balloon launches, obtaining training videos, manuals for key equipment and processes, key papers, and curriculum.

Appendix - Ball State Pilot – Sample Lesson Plans

What Can Helium Balloons Tell You About the Scientific Method?

Indiana Academic Science Standards

8.8.1: Recognize and describe how scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.

8.1.3: Recognize and describe that if more than one variable changes at the same time in an experiment, the outcome of the experiment may not be attributed to any of the variables.

Lesson Objectives

By the end of the lesson, students will be able to:

List the components of the scientific method and suggest practical applications for its use.
Explain the difference between dependent and independent variables.
Participate in careful and accurate data collection and interpretation.
Describe the relationship between the size of a balloon and the amount of weight it can carry.
Demonstrate cooperation in all group work.

Materials List

Latex balloons (3 round balloons of a single color per group of students)
Meter stick (1 per group)
Ball of string (1 per group)
Scissors (1 per group)
Metal washers (10 per group)
Tank of helium (rented from a party store)
Goggles (for everyone!)

Safety Precautions

Each student should be wearing goggles during the entire lesson.
Only the teacher should fill the balloons with helium.
Students should be cautioned against inhaling helium!

Engagement

Begin the class with a demonstration. Have two balloons already filled—one with air; the other with helium. Allow the students to examine the balloons, but be careful that they are not accidentally released. Ask students to predict what will happen when you let go of the balloons. Release the balloons. The helium balloon should rise and the air filled balloon should fall to the floor. Ask students to explain what they just observed. What is it about the two balloons that might have resulted in their different behaviors?

Now lead the students in an open discussion of the factors that affect a balloon's capacity to float and to carry a load. This discussion should include the weight of the load, the size of the balloon, the material the balloon is made of, and the type of gas that is used to inflate it. Have a Periodic Table of the Elements handy to examine the location (and associated atomic structure) of various gases that might be used for this purpose. How does oxygen differ from helium or nitrogen? What about hydrogen? Do any of these differences account for what students just observed?

Exploration

Students should now be challenged to design an experiment that tests the relationship between the inflated size of a balloon filled with helium gas and the height at which the balloon will lift a known weight above the floor. Provide each group with 3 balloons, several dozen metal washers, a ball of string, a pair of scissors, and a meter stick. Tell them they must use all three balloons and that they must measure and record the circumference of each balloon after it is filled, but that all other details pertaining to how the experiment should be run is completely up to them. Students should have a written plan of their experiment for you to safety check prior to beginning.

You, of course, will be in charge of the helium tank. Before class begins, fill one balloon until it actually pops. This will give you a feel for when to stop inflating. Each group should receive one "small," one "medium" and one "large" balloon, although actual sizes will likely vary from one group to another. Once each balloon has had washers attached and is released, it can be left floating while the next one is readied for flight because each group has it's own identifying color. Once a group has all 3 of its balloons in the air, they should be able to literally "see" a pattern in their color-coded data. Ask them to summarize in one sentence the relationship between balloon size and the height above the floor at which it floats. At this time, students should also complete the attached Group Data Sheet.

Explanation

As each group reports its individual data, you should ask questions about their selection of variables and controls. This will give you an opportunity to introduce specific terms related to variables and to relate each term to the balloon experiment. (*What variable did your group test? This is called the manipulated or independent variable. What variable did you measure? This is called the responding or dependent variable. What aspects of the experiment did you keep the same? These are called the constants or controls. What would have been the result if you hadn't kept these things the same?*) Go over answers to the Group Data Sheet. Have each group place their individual data on a class chart that you have prepared on the board or overhead. Point out discrepancies among the group data and ask why students think those discrepancies occurred. Have each group graph the class data. Do these results differ significantly from their own group graph? Why or why not?

Now, direct the discussion to the Scientific Method. What have students learned about the "method" by doing their experiment? How did their experiment begin? (With an observation of the two-balloon demonstration.) What did that observation lead to? (A question was asked and tested,) Why was it important to identify and control variables in the experiment? (So that the experiment could be repeated. So that results could be attributed to a single cause. So that a pattern or relationship could be uncovered.) Did every group perform the experiment in exactly the same way? (No.) Can a single question be answered in a variety of ways? (Yes.) Is it possible that there is more than one Scientific Method? (Yes.)

Teacher Note: Balloon lift is directly proportional to volume of helium. Volume is directly proportional to the diameter/circumference of the balloon. Therefore, the fastest way to increase lift (or increase the height to which a weight will be lifted) is to increase diameter/circumference.

Elaboration

Individual students may choose to do <u>one</u> of the following:

Exercise:

Using the methods (and the materials) you just practiced, find out what circumference a balloon must have in order to lift 15 metal washers 3 feet off the floor. Once you have that answer, extrapolate to determine what the circumference of the balloon must be in order to lift 50 washers the same height.

Report:

In preparation for your work later in the unit, you will do background research into the types of balloons used by the U.S. Weather Service. What do latex party balloons have in common with high altitude balloons launched into near space? What kinds of materials are these scientific balloons made of? How heavy are their payloads? What gases are they filled with? What is their average diameter/circumference at the time of launch? What is their average diameter/circumference at the time of burst? How do scientists know how much gas to use? What variables encountered by the balloons during flight might play a part in making this decision?

Evaluation

There are several points within the lesson where evaluation can occur. During Exploration, the Group Data Sheet can be collected and graded. During Explanation, student contribution to the general discussion or answers to specific questions can be noted/recorded. Students can also be asked to summarize the parts of the Scientific Method or asked to explain which part of their experiment best illustrated a particular component. During the Elaboration, students can be asked to present their findings from either the exercise or the report to the rest of the class.

Teacher Note: This lesson is a prelude to students designing experiments that will be launched by a high altitude balloon. Depending on their background and experience, you may need to provide this practice more than once.

Group Data Sheet

Answer the following:

1. What was your investigative question?

2. What was your independent variable?
3. What was your dependent variable?
4. What other variables in the experiment did you control?

5. Describe the steps of your experiment. Number each step in order.

6. Fill in the table with your data.

Balloon #	Circumference of Balloon (cm)	Number of Washers Attached	Height of Balloon Off the Floor (m)
1			
2			
3			

7. On the piece of graph paper attached, construct a line graph that represents your results. Be sure to label both the x and y axis and to give the graph a title.

8. Based on your graph, what is the answer to your investigative question?

How Does GPS work??

Objectives: Students will know it takes three measures to identify a position using triangulation

Students will use compass and ruler to locate a position on a map given distances from three locations

Students will create and solve triangulation problems

Prerequisite knowledge:

Students must be able to solve proportion problems and use a compass to transfer segments and draw circles.

ENGAGE:

ASK: When we launch a High Altitude Balloon, we need to be able to recover it; we need to track it as it floats. How do we do this? How does GPS work?

Allow students to discuss this question.

How do we determine an unknown position using distances from known positions?

EXPLORE:

Distribute maps, rulers and compasses.

ASK: Suppose we know someone is located 100 km from Muncie. Where might they be?

What can we determine about a location if we know only 1 "distance from" measurement?

What if we also know the person is 200 km from Lexington? Where might they be?

Is this additional information enough to locate the person? Why?

And if we know the person is 125 km from Terre Haute? Where is the person? Are we sure?

Try again: Suppose we know a location is 150 km from Lexington, 100 km from Cincinnati and 125 km from Dayton. Where is the location?

How many distances do we need to know in order to fix a position on the map?

EXPLAIN:

This is the process of *Triangulation* – from 3 known distances from three known locations, we can determine an unknown location. The first distance locates points on a circle with the given distance as the radius from the known location. A second circle with a distinct center point will intersect the first in at most two points. If a third circle intersects it will be at only one of these two points therefore specifying a single location.

How would these "known distances" be determined? Look at a precursor to GPS – Ship navigation and the use of fog horns! Distribute student pages 55-56 from "Mission Math". This scenario features a ship sailing on Lake Superior out of Duluth Minnesota. To answer Question 1, knowledge of two constants is necessary: the speed of sound is 1100 ft per second, and there are 5280 ft per mile

In question 2, only two distances from foghorn stations can be calculated. This means two positions are possible based on the data. What additional information might be known that would allow identification of position S_1?

Locate the ship at positions 4 and 5 in question 3

Locate the ship in question 4.

Where do these distances come from in GPS? In the U.S. system of NAVSTAR (**Nav**igation **S**atellite **T**iming **a**nd **R**anging) twenty-four satellites orbit Earth making at least 5 satellites visible from any point on earth at all times. These satellites send radio signals which are picked up be receiver units. These radio signals travel at a speed of about 186,000 miles per second. The GPS receiver knows the location of the satellite sending the signal. Each signal also contains a code which tells the receiver the time of the signal's transmission from the satellite.

In three dimensions, how many signals would be necessary to pinpoint a location? What would the geometric interpretation of this situation be in three dimensions? In how many places can two distinct spheres intersect? In how many places can three distinct spheres intersect?

ELABORATE:

Look back at the initial situation described in the EXPLORE section above. If a radio receiver was located 100 km from a transmitter in Muncie, how long would it take the signal to reach the receiver? How long would it take a radio signal to reach a receiver located 200 km from a transmitter in Lexington? (Here students use ratio and proportions to covert kilometers to miles, and the speed of radio signals to determine the time.)

EVALUATE:

Suppose transmitting stations are located at Indianapolis IN, Columbus OH, and Louisville KY. If a small plane went down in Cynthiana KY, what information would we be given to find it? What distances from the transmitting stations would be known. What length of time would a radio signal need to travel from the transmitting station to the receiver in the plane?

Create a location problem for you partner to solve: choose locations for transmitting stations, a location for a missing person and the times it would take signals to be received. Trade problems and solve.

References:

House, Peggy, et. al., 1997. "Mission Mathematics: Linking Aerospace and the NCTM Standards". National Council of Teachers of Mathematics. Reston, VA. ISBN #0-87353-436-0

Acknowledgments

The authors would like to thank the National Science Foundation for its generous support of this effort under Grant No. 1047557 and Grant No. 0717787 . Any opinion, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

The authors would also like to thank the Taylor University and Ball State University for the support of this effort.

References

[1] Snyder, Steven, Romines, Elise, Dodge, Rachel, Booth, Travis, Gates, Josh, Kreuger, Jason, "New Heights High Altitude Research Program Assessment," *ASEE Annual Conference Proceedings,* AC 2009-738.

[2] *National Science Education Standards,* National Academy Press, Washington D.C., 1996, pg. 31.