High Altitude Ballooning in High School Science Classes

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Taylor University has partnered with Marion High School in Marion, Indiana to implement high altitude ballooning into their AP Chemistry classes (40 students), Chemistry II classes (60 students), and Integrated Chemistry and Physics classes (275 students) covering a broad range of student ability and motivation in science classes. The curricula ranged from engaging students with the scientific method and discovery process to the specific topic of the chemistry of nuclear reactions. In all cases, real world, hands-on project based learning was employed with experiments reaching near space. Outstanding gains with high practical significance in student learning for the first AP Chemistry class were obtained in all six areas of intrinsic motivation, valuing science, application knowledge, metacognitive processes, cognitive skills, and the scientific method. Some statistically significant gains were also obtained for the other two courses. This is very encouraging considering that these were first time implementations. This suggests that HARP appears to be a promising tool to significantly engage and teach high school students in STEM. In general, these implementations into high school classes show that ballooning can be transitioned from the undergraduate classroom to the high school with strong potential for significant change in student learning.

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

It is well known that the U.S. is falling behind in science and engineering and therefore falling behind in competing on a global scale. A primary cause for this situation is that only 4% of the nation's workforce is in the sciences and engineering [1]. In order to make a long term impact, the U.S. needs to draw children into the science, technology, engineering, and mathematics (STEM) fields.

Taylor University's high altitude balloon program (High Altitude Research Platform or HARP) significantly increases undergraduate students' learning in the following areas [2]:

- **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.

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- **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.

It is believed that younger children would respond even more to HARP in the classroom due to the fact that most are still in the early stages of formulating ideas about their future careers. In addition, we have seen the excitement in the eyes of children as they witness the launching of a balloon into near space 20 miles above the earth where one sees the blackness of space, the thin layer of earth's atmosphere, the slight curvature of the earth, and the features of land and clouds below.

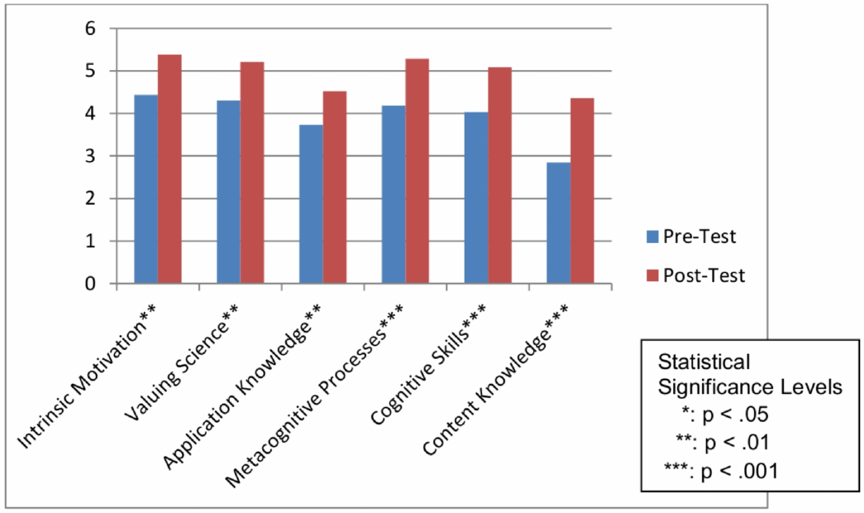
Therefore, it is desirable to extend the implementation of HARP from undergraduate curricula into high school, middle school, and even elementary school curricula. Due to the close proximity of Marion High School (Marion, IN) to Taylor University as well as the eagerness of the science teachers to implement HARP into their classes, an effort was initiated to implement HARP into the Advanced Placement (AP) Chemistry, Chemistry II, and the Integrated Chemistry and Physics classes at Marion High School. The following reports on the effectiveness of the implementation into these classes from May 2011 to May 2012.

II. AP Chemistry Implementation

The AP Chemistry classes during two different school years (2010-2011 and 2011-2012) implemented HARP in the classroom. In early May, the AP Chemistry students take the AP Exam. For the rest of the school year it is difficult keeping the students engaged in learning. As a result, the teachers realized that implementing HARP in the classroom could keep them engaged and learning.

In May 2011, the AP Chemistry teacher, Dave Tippey, decided to use HARP to give the students hands on experience with the scientific method. The approximately 20 students were very enthusiastic about the project as they brainstormed potential hypotheses that they could test using HARP. This occurred after the students received an introduction to changes in temperature, pressure, humidity, visible light intensity, radiation, UV that occur as a function of altitude as well as the sensors that the HARP system has to measure these changes. Since the objective was to engage the students with the scientific method, the students could do experiments in all areas of science (not just chemistry). Some of the projects included testing the mobility of cockroaches after experiencing a balloon flight and the electrical resistivity changes during flight. The students ran control experiments in the lab before the launch. Many of the students participated in the launch and several of them participated in tracking and retrieving the balloon. After analyzing the data, all the students gave PowerPoint presentations to the class. All the students were required to critique the presentations and the students made modifications to their presentations as a result of this input.

The students participated in the HARP assessment of the 6 areas described in the introduction. This included an instrument (pretest and posttest taken by the students) that was tested for reliability and validity. A One-Way ANOVA Repeated Measures was used to assess the changes from pretest to posttest. The results 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.



Note: p = probability pre and posttests are the same. (smaller number is more statistically significant)

Fig. 1. Results from Assessment (Pretest and Posttest) – AP Chemistry, May 2011

These results are quite remarkable. There are statistically significant gains in all 6 areas. In addition, practical significance as determined by eta^2 was present for all six areas as follows:

Intrinsic Motivation ($eta^2 = 0.67$)
Valuing Science ($eta^2 = 0.65$)
Application Knowledge ($eta^2 = 0.64$)
Metacognitive Processes ($eta^2 = 0.82$)
Cognitive Skills ($eta^2 = 0.78$)
Content Knowledge ($eta^2 = 0.90$)

In May 2012, HARP was again implemented in the AP Chemistry (about 20 students) course in the same manner as before but with a different teacher, David Mui. Though there was insufficient data to do the statistical analysis, the students were engaged and gave feedback that this project was one of the more interesting ones that they have done during high school. In addition, David Mui, thought that the project went well and would like to do it again next year in his AP Chemistry class.

III. Chemistry II Implementation

The Chemistry II classes (with about 20 students in 3 classes for a total of about 60 students) took a different approach in implementing HARP into the curriculum. In this case, HARP was used to specifically teach about nuclear chemistry. The topic of shielding of radioactive particles and waves was used. Geiger Counters that are typically used on the HARP system were brought into class and the shielding of low level radioactive sources of alpha, beta, and gamma radiation was demonstrated with various types of shielding. The impact of charge and particle size on the type of material needed for effective shielding was explained and demonstrated to the class. In particular, larger particle size and increased charge needs less dense and less thick materials to shield the radioactivity. Therefore, alpha radiation can be shielded with paper but beta needs denser and thicker materials and gamma needs even more dense and thick materials. The students then brought in various materials to be tested with the same radioactive sources. For the balloon experiment, the students were required to do research on the type of radiation that is present in the atmosphere that the balloon will encounter and hypothesize what materials would shield the radiation. A contest between the 3 classes was held where each class had to pick a material that would adequately shield 80% of the counts from the Geiger counter on the high altitude balloon. The class that was successful in shielding and also had the lowest mass per unit area would be the winner. All 3 classes were not successful in shielding 80% of the counts. There are very high energetic particles in the atmosphere that increases with altitude that needs very dense and very thick shielding material.

Fig. 2. shows the results from the HARP assessment. Though there are increases in all 6 areas, none of them are statistically significant with $p < 0.05$. The following subgroups did have statistically significant changes, though.

Curiosity (subgroup of Intrinsic Motivation) $p < 0.05$
Monitoring (subgroup of Metacognitive Processes) $p < 0.05$
Use of Prototyping (subgroup of Cognitive Skills) $p < 0.01$

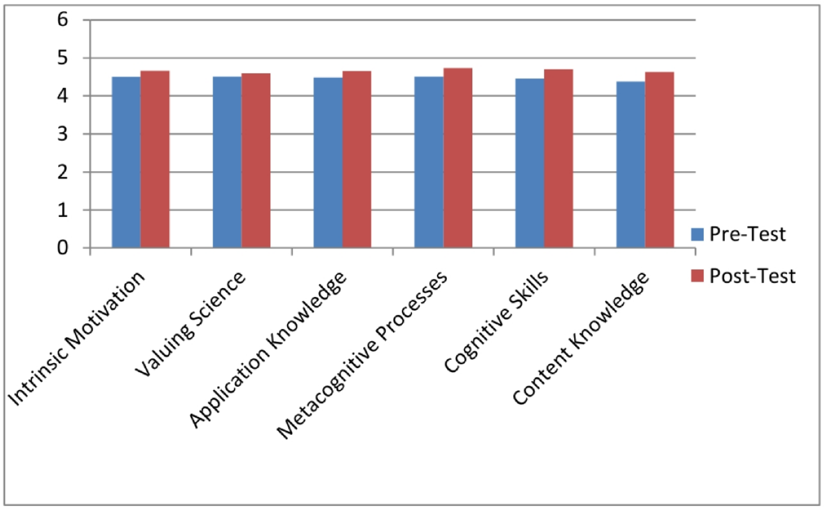


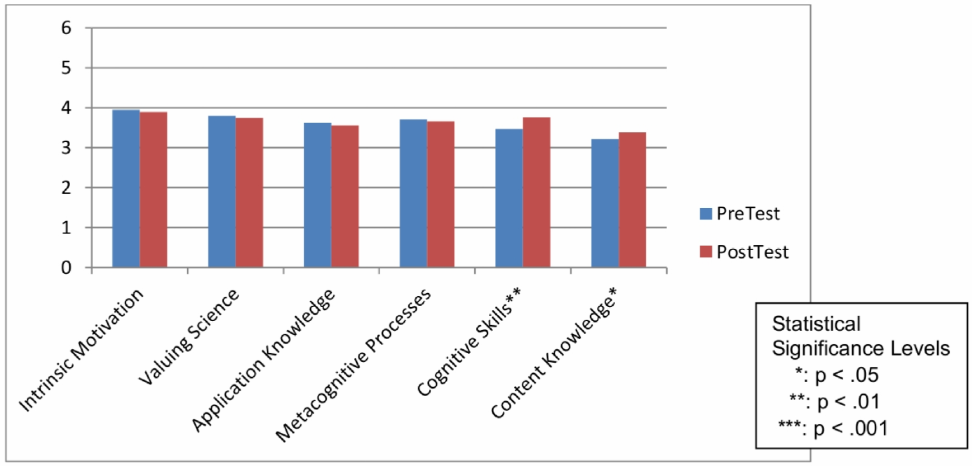
Fig. 2. Results from Assessment (Pretest and Posttest) – Chemistry II, April 2012

Therefore, it appears that there were some changes in student learning that did occur but not to a large extent. Results from implementation into undergraduate curricula showed that multiple implementations of HARP of 3 or more times were often needed to see statistically significant gains. In addition, the students did seem to be engaged in the curricula and excited about the competition. The teacher, Kari Terhune, would like to do HARP in her Chemistry II classes again next year.

IV. Integrated Chemistry and Physics (ICP) Class Implementation

During the first few weeks of school (Fall 2011), HARP was implemented into the Integrated Chemistry and Physics (ICP) classes which had around 275 students. The ICP students are typically not as motivated as the Chemistry II and AP Chemistry students. The teachers thought that engaging these students early in the year with HARP could help their engagement for the rest of the year.

For these classes, the students were given an introduction on what changes the balloon encounters as it goes up in elevation. The students were then given the phrase "What would happen if …" to give them an inquiry based framework. They were then asked to test their thoughts on the high altitude balloon. Fig. 3 shows the results from the HARP assessment. Statistically significant gains in Cognitive Skills and Content Knowledge were obtained. This is very promising based on the fact that these students are typically much less motivated than students in the other two classes. In addition, from our work with undergraduate curricula, it is expected that more gains will be seen with multiple implementations.



Note: p = probability pre and posttests are the same. (smaller number is more statistically significant)

Fig. 3. Results from Assessment (Pretest and Posttest) – Integrated Chemistry and Physics, September 2011

V. Conclusions

Overall, the results from implementation into the AP Chemistry, Chemistry II, and Integrated Chemistry and Physics classes are very promising. Outstanding gains with high practical significance in student learning for the first AP Chemistry class were obtained. Some statistically significant gains were also obtained for the other two classes. This is very encouraging considering that these were first time HARP implementations. Our work with undergraduate curricula suggests that the gains will increase with additional implementations in the classes. This suggests that HARP appears to be a promising tool to significantly engage and teach high school students in STEM.

Acknowledgments

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

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