AC 2009-738: NEW HEIGHTS HIGH ATTITUDE RESEARCH PROGRAM ASSESSMENT

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New Heights High Attitude Research Program Assessment

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Abstract

An investigation was conducted during the 2007-2008 school year assessing students (n = 141) enrolled in classes in which high altitude research based ballooning was integrated into the science curriculum. It was hypothesized that the unique hands on experience of the balloon research launch process would improve the students' scientific learning, motivation, and thinking skills. A pre-test post-test within group design was used to measure the changes in the students' intrinsic motivation, valuing of science, application knowledge, cognitive skills, metacognitive skills, and content knowledge. A 119 question High Altitude Research Platform (HARP) Assessment tool was used to collect quantitative data. Interviews were conducted to collect qualitative data and observational data was collected using the HARP Launch Observation instrument. Instruments used for evaluation were successfully checked for reliability and validity. It was found that the students experienced significant improvement in cognitive skills, content knowledge, and certain aspects of metacognitive skills, application knowledge, and intrinsic motivation. Triangulation of survey, observational, and interview data was performed to provide a validation and rich description of the program. The results from this study are being used to improve the instruction of the ballooning program at this university along with 20 other participating institutions that are adopting similar research based ballooning programs into their science curriculum as part of a three year longitudinal investigation.

Introduction

Introduction of Problem

The problem addressed in this research investigation was the creation of a program that engaged students in science, the development of instruments to assess the program gains of students, to assess the quality of this program, and support other institutions in applying this program to have a more significant impact on the education of students. This article describes the first three objectives of the answer to this problem forming the foundation for the later objective of generalizing the program and assessing the gains of institution over time.

Relevance of Program

The U.S. falling behind in the area of science and technology compared to other countries is a legitimate concern. Motivating undergraduates to enter Science, Technology, Engineering and Math (STEM) degree programs is one way to help to address this problem. The High Altitude Research Platform (HARP) system does this by teaching the scientific method through applying experiments in the near space field. These experiments are developed by students using microelectronics (GPS, wireless, videos, miniature sensors, etc.). The program desires to train students to practically apply theory to real-life problems making them better prepared for graduate school or employment in industry. Students learn to solve problems and overcome obstacles by performing original experiments in real world settings.

Background of Program

For four years, Taylor University's HARP program has been providing students with the opportunity apply their technical science and math instruction to interesting and relevant problems. The unique experience of a high-altitude balloon launch, including team-based problem solving, prototyping, construction and testing of experimentation, and the "hard" deadline of a launch, gives students a taste of real-world project experience, and has helped Taylor students be competitive as they pursue education and career goals beyond the undergraduate level. A student participant in the HARP curriculum component of a 2006 Introduction to Electronics class said, "Working on the balloon project was an excellent opportunity to put theory into practice; not only the electronics portion, but working as a team and planning ahead."

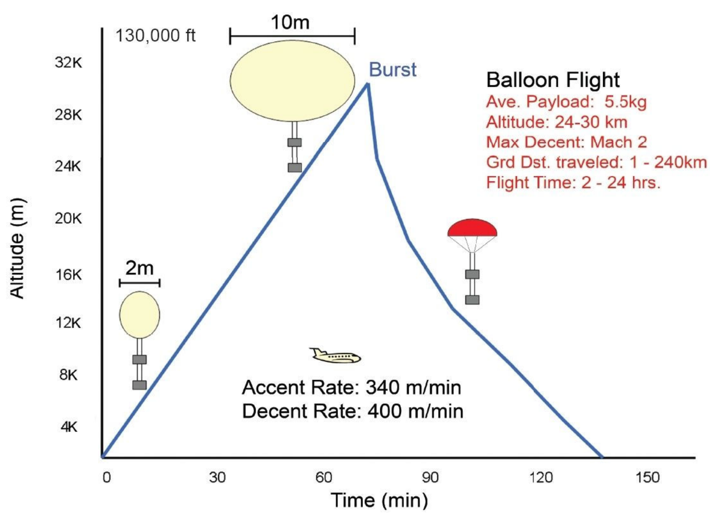
The HARP program was started in 2003 through an Indiana Space Grant Consortium grant, and has been the recipient of four consecutive grants for the continuation of the program, as well as matching funds from the Lilly Corporation, Taylor University's Center for Research and Innovation, and other INSGC grants focusing on research of individual components of the system. The program was recognized as having the potential to become a powerful new tool in Taylor University's STEM curriculum from the very beginning: in the 2003 grant, the observation was made that the program would be an asset to Taylor University students because of the requirements listed previously, but also, because "they get to apply their knowledge to an interesting project, launch a satellite to the upper reaches of the atmosphere and recover it. This is how the HARP program revolutionizes education: by providing classroom knowledge, and simultaneously integrating it with real experience. This kind of experience is not as costly as might first be expected: after an initial expense of $9,000 for a complete system, each mission costs less than $300 total in consumables (balloon, helium, recovery vehicle operation, etc).

In Taylor University implementation of the HARP program into its curriculum, students are enabled to experience every part of a truly professional research project. Once a specific problem is identified, the students are first required to study the theory needed to perform their desired research. This process starts in the classroom, but the students quickly begin to explore the finer points of how best to perform their research as a sense of ownership builds. The motivation that comes from this ownership of a project motivates students to take ownership of their education, moving from a "teach me" attitude to one of "I want to learn." The result is that the theory presented in the classroom is retained and proceduralized into a skill[12].

The students are then required to do background research into the specifics of their chosen investigation, which enables them to ideate, prototype, build and test their own instruments. The model at Taylor University has included such experiments as the adaptation of Geiger counters for high-altitude energetic particle sensing, and the modification of an electrocardiogram to sense e-fields in the atmosphere. In these kinds of projects, students begin to see the links between the theory presented in the classroom and the components that they are working with; their education also becomes suddenly practical, as they troubleshoot, refine, and calibrate real instrumentation. For example, troubleshooting can be a frustrating skill to build, but it is made easier by the ownership that each student takes of his own project. A student participant whose team developed a digital camera system to observe infrared light, wrote that he learned that "there will always be some sort of problem that I had not planned on. But in the end when I finally got to see the balloon go up, I felt good about all the hard work that I put into the project."

It is at this point that students begin to experience some of the most unique aspects of an education involving high-altitude balloon experiments: there are real procedures which must be followed to ensure a successful launch, profitable data collection, and safe recovery of their payload. Students experience the excitement of a launch, and the requirement for effective post-launch operations. Working in a "mission control" environment, students can keep track of their data, command and control their experiments, and keep track of the progress being made by the recovery team. The experience of how to handle operations in a stressful environment is valuable to students; the student director of the HARP program for two years, indicates that "success in my professional experiences as a short-order failure analysis engineer for a major government contractor is due in no small part to the experiences I had while directing the balloon team."

Fig: A typical high-altitude flight profile



On each flight, payloads are constructed modularly, and connected to the primary telemetry pod via a wireless network (using the 50 kbaud Zigbee wireless protocol). Once all of the experiment payloads have been verified, and a communications link has been established between the telemetry pod and both the recovery team and the mission control center, the payload is released and ascends to altitudes ranging from 15 to 20 miles, beyond 98% of the earth's atmosphere (see fig). Throughout the flight, experiment and position telemetry are reported over a 110 kbit link via 900 MHz spread-spectrum radios, and backup position data is broadcast via Amateur Radio APRS technology. During ascent, the balloon expands due to the reduced pressure. Eventually the balloon bursts and the payload returns on parachute with a vertical velocity at touchdown of approx. 1000 feet per minute – gentle enough to be safely caught.

Taylor University has two options for mission control: a fixed base station located in the basement of the science building, and HARP's Mobile Command Station, a 12' cargo trailer, modified to be a fully-functional command platform. The capabilities and equipment of these two stations is discussed more fully in the Facilities section of this proposal.

Assessing Learning and Evaluating Innovations

<u>Theory Base</u>

A Problem Based Instructional model[12] was implemented in the STEM educational experience. This educational model assumes that learning and doing are inseparable to the learning process. The intellectual goal of this model is to develop undergraduate student's cognitive skills and strategies through sustained participation within a community of learning[6, 9,25]. In this model of learning, students are able to see how experts tackle problems, and learn to solve problems through a mentoring process[9].

Central Assessment Question

The assessment of the advanced High-Altitude Balloon Platform (HARP) program will endeavor to determine if a problem based instructional model can effectively increase student and faculty's intrinsic motivation, knowledge at an application level, cognitive skills, and the valuing of STEM educational experiences and applications. The moderating variable of length of time using the HARP program will also be evaluated

Research Design

A pre-test post-test within group design was used to measure the changes in the students' intrinsic motivation, valuing of science, application knowledge, cognitive skills, metacognitive skills, and content knowledge. Triangulation of survey, observational, and interview data was performed to provide a validation and rich description of the program.

Definition of dependent variables

Intrinsic Motivation

Student's intrinsic motivation were measured using Lepper's[20,21] modified model for intrinsic motivation. The model includes contextualization, curiosity, challenge, control, and cooperation. Contextualization or application means to overtly or covertly personalize knowledge to current or future life situations in order to change and grow. Curiosity is generated when new information creates inconsistencies or discrepancies in people's prior knowledge or their present expectations. Curiosity generates a feeling of wanting to investigate, become involved, or expand oneself to incorporate new information and have new experiences with the person or object that created the interest[11]. Challenge means calling a person to a demanding task that requires special effort and dedication in a supportive group. Control is the perception that one is an origin of the activities she attempts rather than a pawn. The student will believe she has self determined the activity undertaken or the product created. Cooperation means to pursue win-win situations where you and the other individual grow, accomplish tasks, and enjoy the process together. In this learning structure, knowledge is gained by support, participation and nurturing with others[17,18]. These areas of motivation were assessed because of their strong connection to achievement, spending time on complex activities, learning and growth goals, the use of deeper and more reflective strategies for learning, more risk taking and the focus on the learning process[21].

Valuing Science

It is a goal of the HARP program for students to learn to value science education, discovery and future careers in science. This goal will be assessed specifically by measuring the increase in students valuing the problem solving process, the calibration process, the scientific method in application to real life problems, documenting for repeatability, data analysis, metacognitive planning, monitoring and assessing, cooperation for scientific advancement, and time management for meeting deadlines.

Application Knowledge

Application knowledge is procedural content that allows a student to be able to access information successfully during a cognitive operation[1,2,14,39]. Faculty and student's knowledge of how to apply problem solving, the process of prototyping, the processes of evaluation and calibration, and the ability to perform precise documentation were evaluated.

Metacognitive Processes

The metacognitive processes of control (planning and assessing) and monitoring of one's cognitive processes were assessed to see if they increase through the student's participation in the HARP program [4,10,23]. Metacognitive planning involves stating a goal, selecting an operation, identifying potential obstacles or errors, identifying ways to recover from the obstacles, and predicting results desired and or anticipated. Metacognitive assessing involves evaluating goal achievement, judging accuracy and adequacy of the results, evaluating appropriateness of procedures used, assessing how well one handled the appropriateness of procedures used, assessing handling of obstacles, and judging the efficiency of the plan and its execution. Metacognitive monitoring involves keeping the goal in mind, keeping one's place in a sequence, knowing when a sub goal has been achieved, deciding when to go on to the next operation, spotting errors or obstacles, and knowing how to recover from errors or obstacles. Metacognition has been selected to be assessed because of its key role in transferring knowledge and skills[3,5], effective problem solving [7,13], thinking and learning [8,23,30], and memory [16,22].

Cognitive Skills

A cognitive skill is a mental operation that requires the integration of knowledge into a system of procedural steps to perform a complex activity at the appropriate time. The increased ability to use the cognitive skills of problem solving (trouble shooting), prototyping, evaluation and calibration, the scientific method, documenting for repeatability, and skillful data analysis were assessed [1,2].

Content Knowledge

The content students acquire was measured in the areas of Primary Technical Knowledge, Learning Cycle Knowledge, and Operations Knowledge. Primary technical knowledge relates to the vocabulary, instrumentation, and knowledge of the technical processes that pertains to the balloon launch process. Learning cycle knowledge assesses the student’s knowledge of the steps in both the learning cycle and scientific method. Operations knowledge assesses the student’s awareness of the rules and regulations regarding launching a high altitude balloon.

Hypothesis

It was hypothesized that the unique hands on experience of the balloon research launch process with trained instructors would improve students' valuing of science, application, intrinsic motivation, cognitive skills, metacognitive skills, and content knowledge.

Methods

As a part of the CCLI NSF grant, the following procedures and methodologies were followed in an effort to obtain our goals of creating instruments to measure student growth and conducting pilot studies in order to examine the effects of the High Altitude Research Platform (HARP) on undergraduate students. During the 2007-2008 school year, three different classes at Taylor University implemented HARP into their curriculum. Individual pilot studies were conducted on each of the three classes. An Introduction to Astronomy Class was the first class assessed during the fall semester of 2007 (N = 39). The second was also on Introduction to Astronomy Class. This class was assessed during the month long inter-term in January 2008 (N = 91). The final class assessed during the spring semester of 2008 was entitled Principles of Engineering (N = 11). The Introduction to Astronomy classes were primarily comprised of non-science majors who were taking the astronomy course to fulfill a general education requirement. The Principles of Engineering class was comprised of engineering majors. A within-groups pre-test post-test design was used to quantitatively assess all three classes using the HARP Assessment Instrument. An interview protocol produced during the fall of 2007 was used to conduct 9 interviews from the January study and 5 interviews from the spring study. Data collected from these interviews will be used to enrich the quantitative data collected from the surveys. A Balloon Launch Observation Instrument was created and used to assess the classes on the day of the balloon launch. This instrument measured student enthusiasm, student participation, student knowledge, professor competency, and organization. The balloon launches during January and the spring were assessed using this instrument. This report was developed to evaluate changes in the students learning and thinking due to the intervention HARP. Specifically evaluated was the effect of situational learning on the process of scientific education.

Reliability

Reliability addresses whether an instrument will produce the same results each time it is administered to the same person in the same setting. Extensive reliability tests were conducted individually on each of the three studies. The overall pre-test Cronbach's alpha ($\alpha = .976$) and the post-test Cronbach's alpha ($\alpha = .965$) are both excellent. These results are indicative of that the HARP Assessment Instrument is reliable.

Validity

Validity is the extent to which a test measures what it claims to measure. Professors experienced in testing methods, professors who were instrumental in creating the HARP program, and staff familiar with HARP worked together to develop questions that would accurately assess student growth as the result from the participation in HARP. Professors and staff directly involved in the HARP Program at Taylor performed a content evaluation to ensure construct validity. They evaluated every question analyzing whether or not it captures the type of growth a student would ideally experience from participation in the HARP program.

The known group difference method was applied in two different ways to indicate construct validity of the HARP Assessment Instrument. First, the significant growth from pre-test to post-test indicates our instrument is capturing the changes that are occurring within the students. Second, we can expect the engineering majors to score higher on the HARP Pretest Assessment Instrument than students in a general education astronomy class. This assumption is reasonable because the engineering students already have a greater scientific knowledge base than the other classes. They would be expected to score higher in areas assessing content knowledge, valuing science, and intrinsic motivation because they have chosen to be involved in scientific study and they have had more experience in STEM fields. If they did not score higher, then something is wrong with the instrument. Indeed, both the pre-test and post-test scores for the Principles of Engineering Courses were much higher ($p < .05$) than those of the Introduction to Astronomy class on 3 of the 6 categories on the pre-test and 5 of the 6 categories in the post test. This difference also indicates the construct validity of our instrument. These differences are discussed in depth later in the report.

Instruments

HARP Assessment Instrument

The HARP Assessment Instrument is a 119 item survey using a Likert Scale ranging from 1 to 6, 6 being the highest. This instrument measures student development in the areas of intrinsic motivation, valuing science, application knowledge, metacognitive processes, cognitive skills, and content knowledge. Each area is broken down into several sub-scales (See Table 3).

Interview Protocol

An interview protocol has been made whose purpose is to provide qualitative data to enhance the quantitative data collected from the survey. The interview questions parallel the structure of the survey so that all areas of student development will be discussed throughout the interview. The interviews lasted no more than a half hour. Five participants from the spring 2008 Principles of Engineering class were interviewed.

HARP Launch Observation Instrument

The HARP Launch Observation Instrument is a 25 item questionnaire to be used by observers to assess the quality of a balloon launch. During the spring semester, one launch took place and two observers were present to make observations. This tool is continuing to be used in order to make assessments of programs at the various universities the psychology team visited in the fall 2008. A set of guidelines was created to clarify the criteria for each item on the questionnaire. These guidelines are an attempt to improve inter-rater reliability.

Results

Results show that students perceive themselves growing from their experience with HARP in the areas of intrinsic motivation ($p<.01$), cognitive skills ($p<.05$), application knowledge ($p<.001$) and content knowledge ($p<.001$). They also perceived themselves growing in the areas of metacognitive monitoring ($p<.05$) and metacognitive assessing (.001). There was, however, a significant decrease which occurred in metacognitive planning ($p<.05$). There were no significant gains in the areas of valuing science ($p>.05$), challenge motivation ($p>.05$), and the documentation process of their experiments ($p>.05$) (See Table 1 and Figure 1).

Table 1. Significant differences from pre-test to post-test for the classes assessed using the New Heights Altitude Research Platform program at Taylor University (2007-2008).

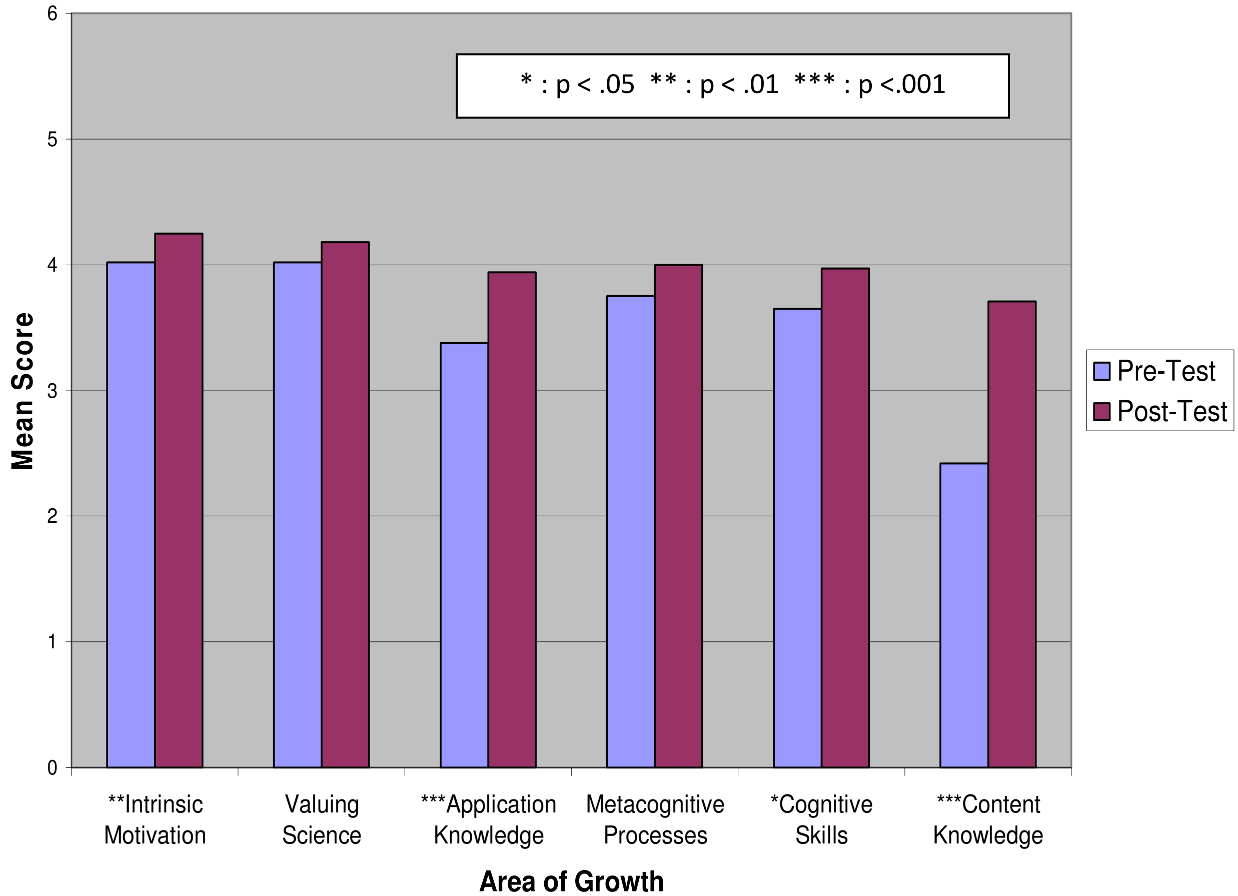
Area of Growth
Intrinsic Motivation**
Contextualization
Curiosity***
Challenge
Control
Cooperation
Valuing Science
Application Knowledge***
Apply Problem Solving
Process of Prototyping ***
Process of Evaluation ***
Documentation and Reports
Metacognitive Processes
Metacognitive Planning**
Metacognitive Assessing***
Metacognitive Monitoring **
Cognitive Skills**
Content Knowledge***
Primary Technical Knowledge***
Learning Cycle Knowledge***
Operations Knowledge***

**Metacognitive planning experienced a significant decrease.

Table 1. The bolded categories are the primary areas of growth. The subsequent not-bolded indented areas are the sub-areas which are combined to comprise the above primary area. All areas in color indicate a significant change. All areas in black indicate an area that did not experience significant change.

Table 4. Significance Levels
*Red: $p < .05$
**Green: $p < .01$
***Blue: $p < .001$
Black: $p > .05$

Figure 1 General Growth (2007-2008)



Net Growth

There was some level of net growth in the areas of content knowledge, application knowledge, cognitive skills, intrinsic motivation, metacognitive processes, and valuing science. The greatest growth occurred in the areas of content knowledge and application knowledge. The lowest amounts of perceived growth were in valuing science, and metacognitive processes. There is a significant difference between these areas of growth ($p<.001$) that is practically significant ($Eta^2 = .315$). Students showed significantly higher scores on content knowledge when compared to all the other variables of growth ($p<.05$). Application knowledge was significantly higher than cognitive skills, intrinsic motivation, metacognitive processes and valuing science ($p<.05$). There were no significant differences between cognitive skills, intrinsic motivation, metacognitive processes, and valuing science ($p>.05$).

Table 2: **Net Growth** in descending order.

Category	**N**	**Std. Deviation**	**Mean Net Growth**
Content Knowledge	136	1.13	1.29
Application Knowledge	136	1.02	.506
Cognitive Skills	138	1.21	.239
Intrinsic Motivation	141	.897	.196
Metacognitive Processes	139	1.05	.103
Valuing Science	139	.988	.100

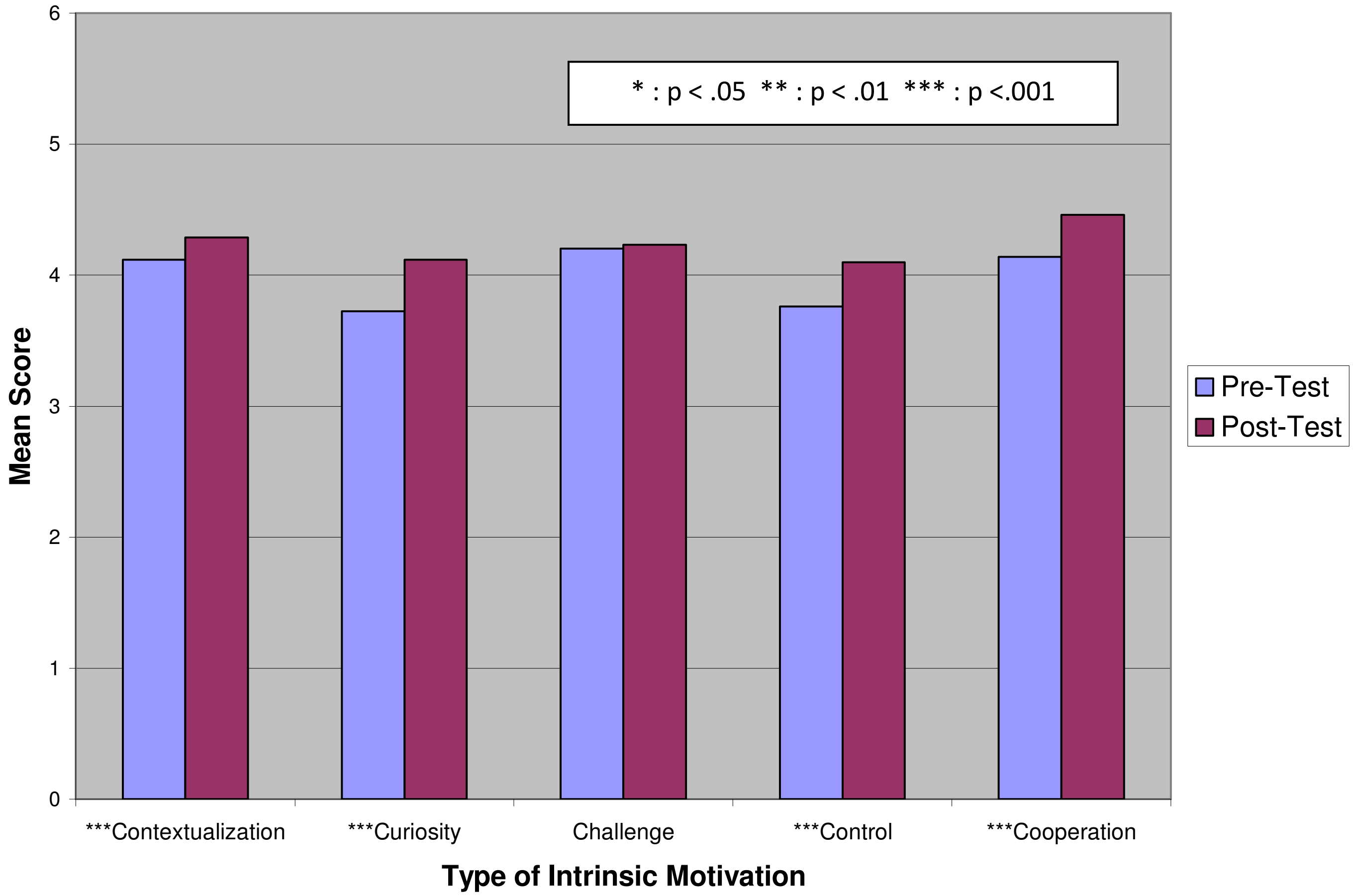
Results by Category

Intrinsic Motivation

The students' intrinsic motivation showed a significant improvement in three of the five categories. These categories were curiosity ($p<.001$), control ($p<.01$), and cooperation ($p<.01$) (See Figure 2). The curiosity generated by the HARP Program indicates the students possessed a desire to investigate, become involved, or expand themselves to incorporate new information and have new experiences with ballooning technology (Fredrickson, 1998). The students expressed a sense of control which is the perception that they are the origin of the activities rather than a pawn. The students believed they self determined the activity undertaken and the product created. Growth in cooperation means the students pursued win-win situations where individuals working in a team grew, accomplished tasks, and enjoyed the process together. We encourage the professors to continue to give the students a sense of freedom and control over deciding the design and function of their pods both individually and as a group.

There was no significant change in contextualization ($p > .05$) and challenge ($p > .05$). The lack of improvement in contextualization indicates that the students are not consciously or subconsciously personalizing knowledge to activities involved in ballooning. We suggest instructors to make an intentional effort to relate content learned in the classroom to specific ballooning activities. The content of the course may make this very easy or very difficult. In our study, most of the students ($n = 130$) were enrolled in an astronomy class. Relating constellations and planetary movements would be more difficult to relate to the ballooning process than it would be in a Principles of Engineering course. The lack of improvement in challenge indicates that the HARP program did not call the students to a demanding task that requires special effort and dedication in a supportive group. The lack of challenge may parallel the lack of difficulties experienced in the launch. We recommend allowing the students to fail within the confines of an adequate support system. A balance must be found between letting the students arrive at solutions independently and ensuring a successful launch. This balance may increase the degree of challenge in their learning. It should be noted that the mean for challenge motivation was the highest of all the intrinsic motivational constructs before the HARP experience was undertaken, even though it did not improve during the experience.

Figure 2. Intrinsic Motivation (2007-2008)



Valuing Science

Valuing Science experienced the least amount of improvement ($p > .05$) of all of the educational variables measured. This may be in part because valuing science had the highest incoming pre-test scores making improvement difficult. Although the incoming pre-test scores were high, it is critical that students make the connection between the ballooning done in class and 'real-world' science. The students must realize that scientists outside of the classroom are performing very similar experiments with comparable technology. They should understand that their projects in class have real-world applications and the potential for new and exciting discovery. It seems students already valued science in this way, but we continue to encourage the professors to make explicit references to the students regarding the value of science that a certain part of the project possesses. Students will not necessarily pick up on or even think about these values unless the professor initiates these thought patterns by making explicit statements.

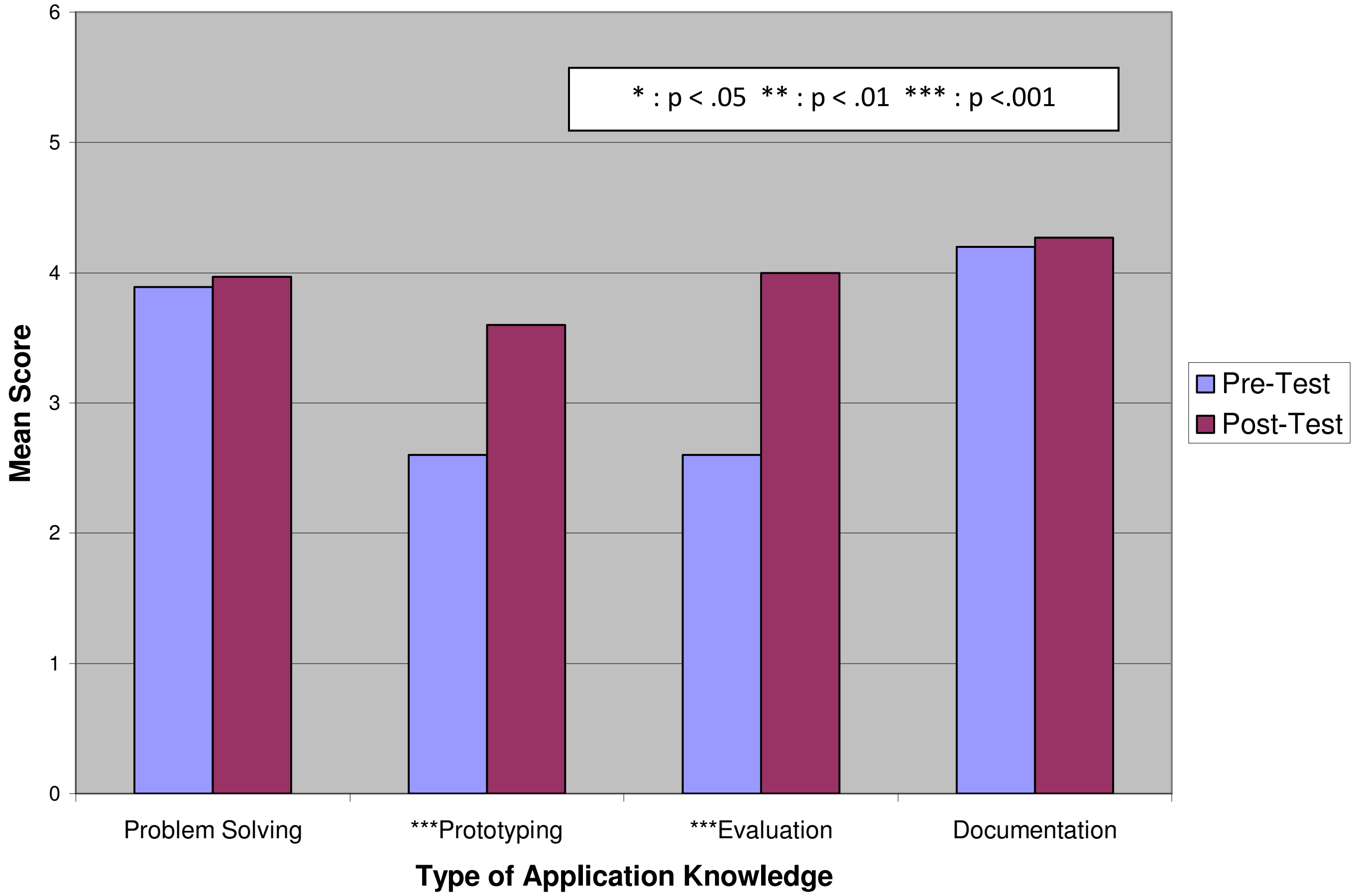
Application Knowledge

There were significant gains in both the process of prototyping ($p < .001$) and the process evaluation and calibration ($p < .001$). The increase in scores for prototyping suggests that students learned how to construct circuits and perform baseline tests on those circuits. The increase in scores for evaluation and calibration suggests that students learned if circuits were working properly and how to gather and correlate raw data.

There was not a significant change in the categories of applying problem solving strategies ($p > .05$) and performing precise documentation and reports ($p > .05$). The lack of change in the application of problem solving strategies indicates the students are not utilizing strategic methods typical of good problem solving. To promote this type of thinking, we encourage the professors to get involved in and steer group discussions towards appropriate problem solving strategies. The professor should encourage students to think about sub-goals, timelines, predictions, etc. Class structure could also promote problem solving. Professors could require students to turn in a detailed plan of execution including timelines and sub-goals.

The lack of change in performing precise documentation and reports indicates the students are not getting adequate instruction and experience in data analysis, making graphs and charts to interpret their results, and presenting their results. We would encourage the instructors in this program to require that student teams document in written form the steps and processes they used in the project. The students should create a written plan of the steps they will use to use before they build their pod. They should also record the process of what actually happened and note how the steps performed in reality were different from what they had planned to do. This type of documentation not only helps the process run more smoothly, but it increases the students' awareness of the steps they go through instead of haphazardly moving from step to step responding to the needs of the moment.

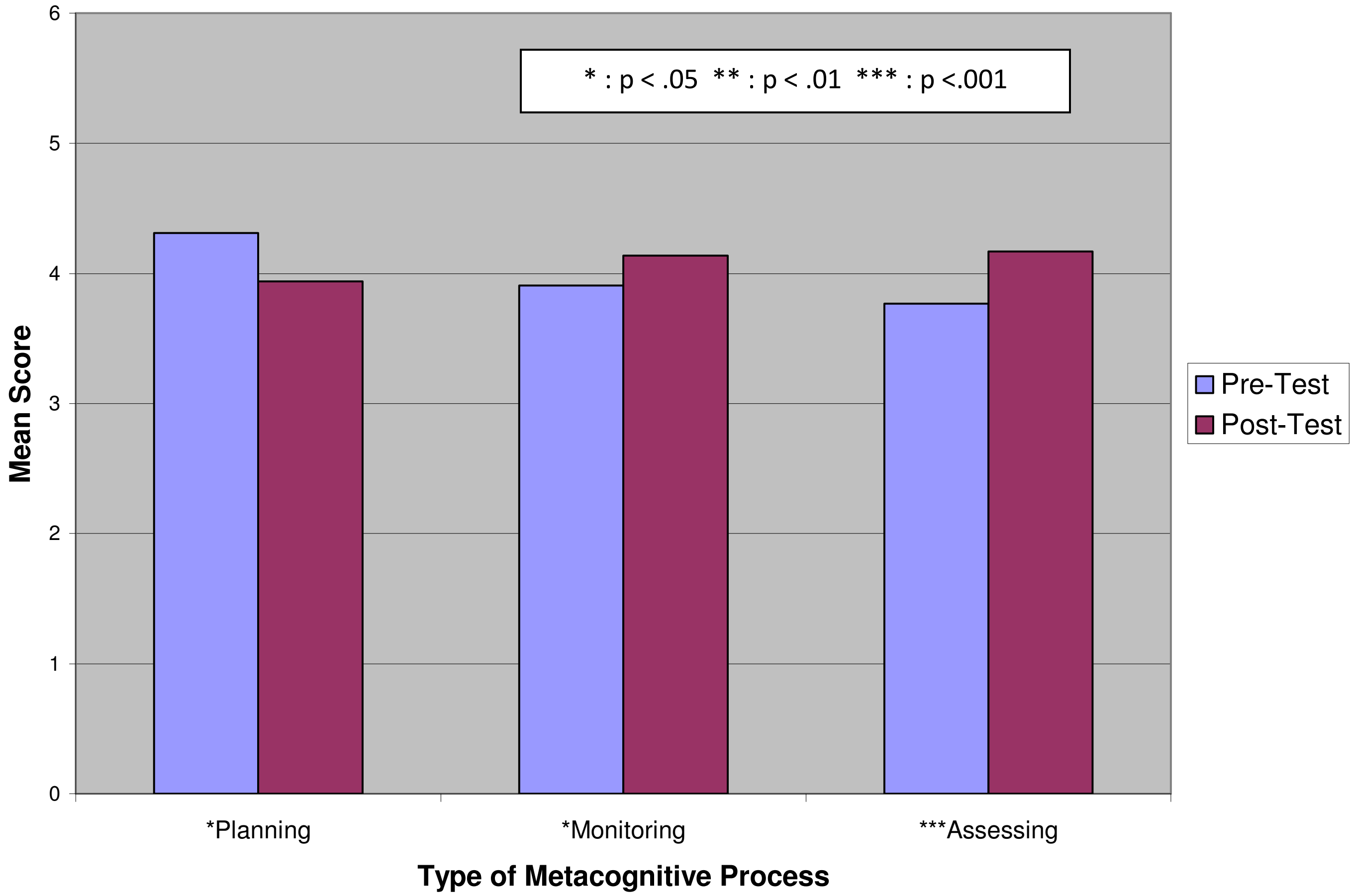
Figure 3. Application Knowledge (2007-2008)



<u>Metacognitive Processes</u>

The students perceived a significant growth in their metacognitive monitoring ($p < .01$) and assessing ($p < .001$). However, the students experienced a significant decrease in metacognitive planning (See figure 4). A metacognitive process is when one is aware of their thought processes and is able to control them. Being aware of and able to control one's thought process is critical not only to performing good science but also to being productive and successful in other realms of life. It should be a goal of educators in all academic fields to promote this type of thinking. The date indicates the students are aware of and have control of their thought processes during a pod construction and launch and looking back on their performance, but struggle in organizing their thoughts to formulate a plan before the execution of ballooning activities. We would recommend requiring the students to write out a plan of execution before they begin building their pods and to do an individual assessment of their steps used to reach their goal. We realize there is an urgency to begin the balloon launch process, but it is important to take the time to allow the students to plan and map out their strategies to complete the mission objective.

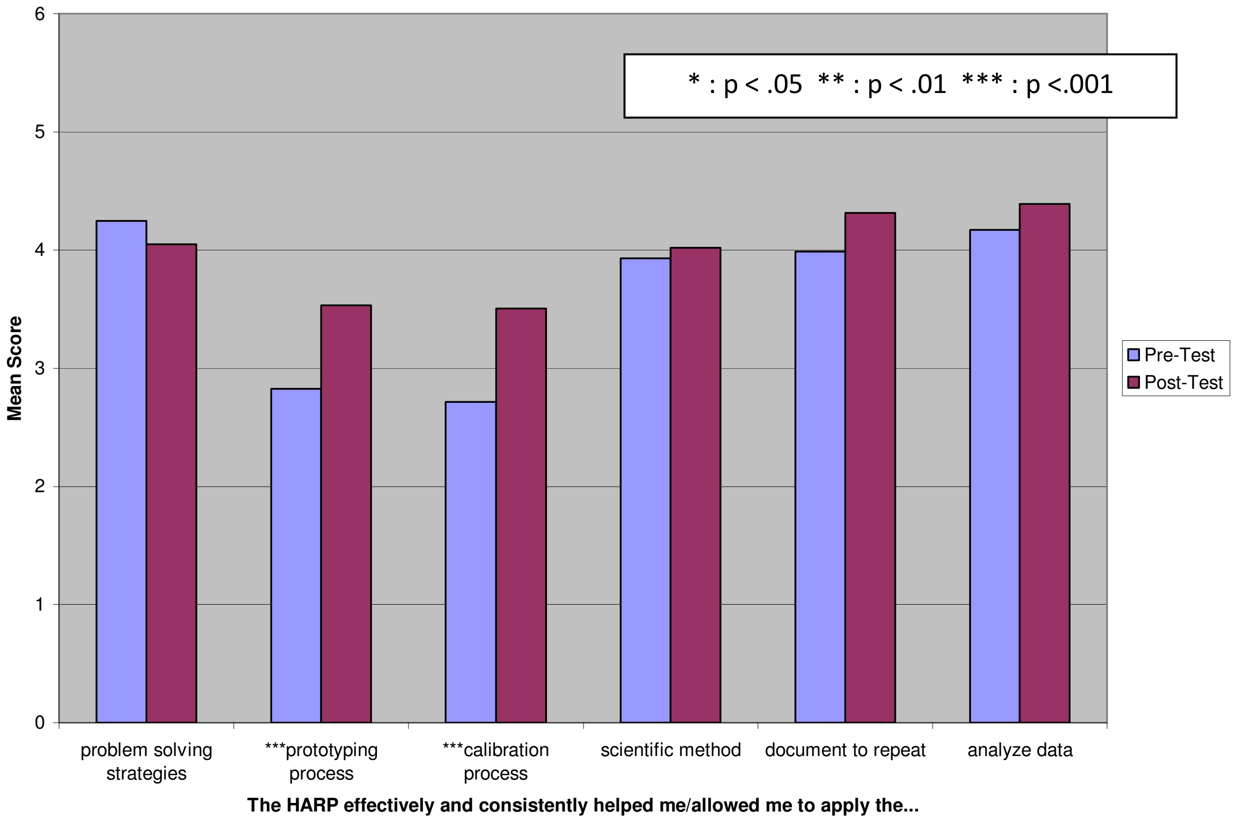
Figure 4. Metacognitive Processes (2007-2008)



<u>Cognitive Skills</u>

The cognitive skills category evaluates how the ballooning experience aided the students in applying problem solving strategies, utilizing the prototype process, applying the calibration process, using the scientific method, and documenting the process for the purpose of repetition, and how to analyze data. The two lowest pre HARP experiences, prototyping and calibration had significant perceived changes by the students due to the HARP experience ($p<.05$). The only area to decrease, although not significantly, was problem solving. Cognitive skills evaluates if the students consistently applied key concepts evaluated in other categories. We recommend the professors work to embed explicit and specific problem solving skills within the process of learning in this experience.

Figure 5. Cognitive Skills (2007-2008)



<u>Content Knowledge</u>

There was a significant improvement (p < .001) in all of the areas of content knowledge. Primary technical knowledge, learning cycle knowledge, and operations knowledge all experienced significant growth.

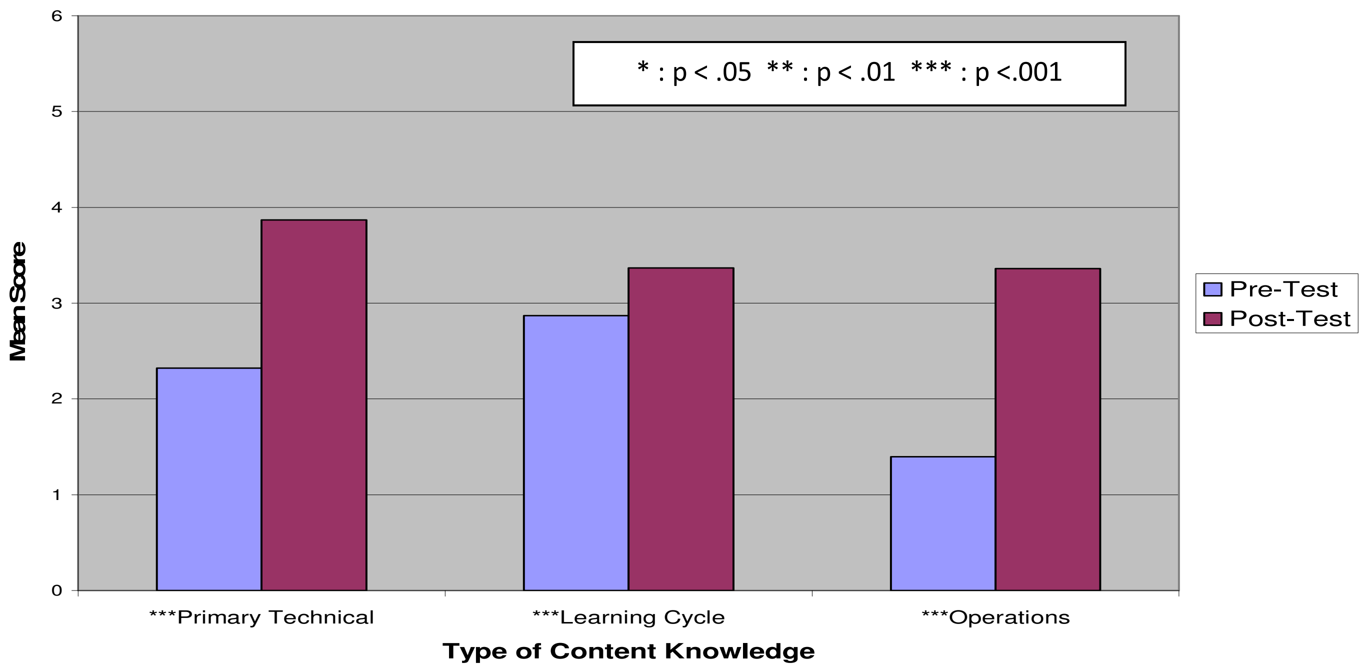
The improvements in technical knowledge may be due to having technical knowledge embedded in a hands-on project. The students are able to grasp technical knowledge very easily when they see the concept applied directly to something they are working on.

Questions asked in the primary technical knowledge section were based on concepts the professors thought a student should have grasped after participating in the HARP Program. The nature of a course will affect the type of knowledge a student possesses or will gain throughout the program. We recommend the professor look over the primary technical knowledge questions and evaluate how the questions correspond to what the students should have learned in this class. The data analysis can then be adapted to match the professor's objectives.

Growth in Operations Knowledge indicates the students are becoming more knowledgeable about the rules and regulations pertaining to launching a high altitude balloon.

It is important to note that only the J-term group experienced significant growth (p < .001) in learning cycle knowledge. There was no significant growth in (p > .05) both of the full semester programs in the fall and the spring. We believe it is important for the students to be aware that they are going through the learning cycle and the scientific method during the ballooning process. It seems professors are not effectively educating the students on the learning cycle and scientific method. We have found that students are often unaware of the steps in these processes and are unable to apply the steps in these processes to what they are doing in the ballooning process. We recommend professors make explicit statements regarding the scientific method and learning cycle related to activities being conducted in the program. These simple statements could organize the student's thoughts and let them see the purpose of their daily activities and the role each task plays in reaching the final goal. It may also be helpful to make a poster of the learning cycle and scientific method and place them on locations that the professor could refer to when making statements regarding the learning cycle or scientific method.

Figure 6. Content Knowledge (2007-2008)



Discussion

Conclusion for Student Growth

The majority of the measured areas of growth, 15 of the 20, experienced a significant improvement ($p < .05$). Integrating this balloon launch program into a class curriculum seems to improve the students' intrinsically by increasing their curiosity, control, and cooperation. This program allows the student's to apply the prototyping process and the process of evaluation and calibration. The students are performing metacognitive assessing and monitoring as the work through the balloon launch, data collection, and analysis processes. The students are effectively using cognitive skills and their primary technical, learning cycle, and operations knowledge are all improving. Our data indicates the HARP program is an effective educational tool to enhance the learning process in a STEM related classroom. These results would support the hypothesis that the unique hands on experience of the balloon research launch process with trained instructors would improve students' valuing of science, application, intrinsic motivation, cognitive skills, metacognitive skills, and content knowledge.

Conclusion for Instructional Improvement

The areas that did not significantly improve from pre-test to post-test were contextualization, challenge, valuing science, applying problem solving strategies, applying the process of documentation and reports, and metacognitive planning. Instructional suggestions were offered to improve each of those categories and the following is a summary of such suggestions.

To improve the students' contextualization, we suggest instructors to make an intentional effort to relate content learned in the classroom to specific ballooning activities.

To increase the students' challenge, we recommend allowing the students to fail within the confines of an adequate support system. A balance must be found between letting the students arrive at solutions independently and ensuring a successful launch.

Valuing science was consistently an area that experienced no significant growth. We recommend professors to make explicit references to the students regarding the value of science that a certain part of the project possesses. Students will not necessarily pick up on or even think about these values unless the professor initiates these thought patterns by making explicit statements.

To encourage the students to engage in proper problem solving strategies, we encourage the professors to get involved in and steer group discussions towards appropriate problem solving strategies. The professor should encourage students to think about sub-goals, timelines, predictions, etc. Class structure could also promote problem solving. Professors could require students to turn in a detailed plan of execution including timelines and sub-goals.

To engage the students in documenting the process of their experiment and reporting their findings, we would encourage the instructors in this program to require that student teams document in written form the steps and processes they used in the project. The students should create a written plan of the steps they will use to use before they build their pod. They should also record the process of what actually happened and note how the steps performed in reality were different from what they had planned to do. This type of documentation not only helps the process run more smoothly, but it increases the students' awareness of the steps they go through instead of haphazardly moving from step to step responding to the needs of the moment.

Metacognitive planning was the only area of growth that experienced a significant decrease ($p < .05$). This indicates that the students are not engaging in the We would recommend requiring the students to write out a plan of execution before they begin building their pods and to do an individual assessment of their steps used to reach their goal. We realize that the urgency to begin the balloon launch process, but it is important to take the time to allow the students to plan and map out their strategies to complete the mission objective.

We believe taking the time and effort to utilize these suggestions while implementing HARP into a curriculum would increase the educational benefits the students would receive from participating in the program.

Goal Conclusion

As part of the CCLI NSF grant, there were several goals that were set and reached during the 2007-2008 school year. The first goal was to create reliable and valid instruments to measure student growth and conduct pilot studies examining the effects of the High Altitude Research Platform (HARP) on undergraduate students was successful. The second goal of seeing if a problem based instructional method could have a positive influence on key instructional variables in science education was supported as an instructional model. The results above supported our hypothesis that the HARP learning experience allowed students to improve their ability to learn scientific concepts when embedded in an applicable context.

Theory Conclusions

Problem based instruction seems to be very effective teaching strategy for helping students to make gains in their intrinsic motivation of curiosity, control, and cooperation, their ability to apply knowledge, metacognitive monitoring, cognitive skills, and content knowledge in STEM curriculum. The problem solving instructional methodology seems to be limited in its ability to create gains in the students' perception of the value of science, general metacognitive planning, and the application knowledge areas of problem solving and documentation.

Limitations and Developments

The first limitation of this investigation is that it measures students perceived changes not observed differences. The area in which this is most questionable is content knowledge. To add to the quality of the investigation, students need to be directly observed through lab and balloon launches that the students participate in, interviewed and their logs for the class need to be assessed. All of these enhancements to the design of the study are currently being done but have not been integrated into the results.

The second limitation is the design of the study involved a pretest posttest design rather than a true experimental design so causation of the findings needs to be questioned. The investigation did assess the gains of students you took classes over two semesters to reduce this error. The investigation will continue over a three year period to further reduce invalidity of the conclusions of the investigation.

Table 1. Bolded scales indicate super-ordinate scales. Non-bolded scales are sub-scales of the preceding super-ordinate scale.

1- Strongly Disagree 2- Moderately Disagree 3-Mildly Disagree 4-Mildly Agree 5- Moderately Agree 6- Strongly Agree

Table 1. Significance Levels

Red: $p < .05$; Green: $p < .01$; Blue: $p < .001$; Black: $p > .05$

	Subscale	Mean	N	t	Sig. (2-tailed)
Pair 1	**Intrinsic Motivation Pre Test**	4.06	140	-2.60	.010
	Intrinsic Motivation Post Test	4.26			
Pair 2	Contextualization Pre Test	4.16	140	-1.35	.171

	Contextualization Post Test	4.30			
Pair 3	Curiosity Pre Test	3.77	140	-3.38	.001
	Curiosity Post Test	4.15			
Pair 4	Challenge Pre Test	4.22	140	.016	.987
	Challenge Post Test	4.21			
Pair 5	Control Pre Test	3.78	140	-2.64	.009
	Control Post Test	4.09			
Pair 6	Cooperation Pre Test	4.19	140	-2.86	.005
	Cooperation Post Test	4.48			
Pair 7	**Valuing Science Pre Test**	4.07	138	--1.19	.236
	Valuing Science Post Test	4.16			
Pair 8	**Application Knowledge Pre Test**	3.40	135	-5.79	.000
	Application Knowledge Post Test	3.91			
Pair 9	Apply Problem Solving Pre Test	3.91	139	-.41	.685
	Apply Problem Solving Post Test	3.94			
Pair 10	Process of Prototyping Pre Test	2.03	137	-11.03	.000
	Process of Prototyping Post Test	3.61			
Pair 11	Process of Evaluation Pre Test	2.65	137	-10.10	.000
	Process of Evaluation Post Test	4.00			
Pair 12	Process of Documentation and Reports Pre Test	4.26	138	.00	1.00
	Process of Documentation and Reports Post Test	4.26			
Pair 13	**Metacognitive Processes Pre Test**	3.97	138	-1.15	.250
	Metacognitive Processes Post Test	4.07			
Pair 14	Metacognitive Planning Pre Test	4.24	140	2.55	.012
	Metacognitive Planning Post Test	3.91			

Pair 15	Metacognitive Assessing Pre Test	3.80	139	-3.77	.000
	Metacognitive Assessing Post Test	4.16			
Pair 16	Metacognitive Monitoring Pre Test	3.91	138	-2.03	.045
	Metacognitive Monitoring Post Test	4.11			
Pair 17	**Cognitive Skills Pre Test**	3.70	137	-2.32	.022
	Cognitive Skills Post Test	3.94			
Pair 18	**Content Knowledge Pre Test**	2.40	135	-13.34	.000
	Content Knowledge Post Test	3.69			
Pair 19	Primary Technical Knowledge Pre Test	2.28	137	-14.80	.000
	Primary Technical Knowledge Post Test	3.86			
Pair 20	Learning Cycle Knowledge Pre Test	2.89	138	-3.59	.000
	Learning Cycle Knowledge Post Test	3.31			
Pair 21	Operations Knowledge Pre Test	1.37	138	-15.12	.000
	Operations Knowledge Post Test	3.32			

Reference List

1. Anderson, J.R. (1996). ACT: A simple theory of complex cognition. *American Psychologist, 51*, 355-365.

2. Anderson, J.R. (1987). Skill acquisition: Compilation of weak-method problem solutions. *Psychological Review, 94,*192-210.

3. Belmont, J.M., Ferretti, R.P., & Mitchell, D.W. (1982). Memorizing: A test of untrained mildly mentally retarded children's problem-solving. *American Journal of Mental Deficiency, 87(2),* 197-210.

4. Beyer, B. (1987). Practicing strategies for the teaching of critical thinking. Boston: Allyn and Bacon.

5. Brown, A.L., Bransford, J.D., Ferrara, R.A., & Campione, J.C. (1983). Learning, remembering, and understanding. In J.H. Flavell & E.M. Markman (Eds.), *Carmichael's manual of child psychology* (Vol 1, pp.77-166). New York: Wiley.

6. Brown, J. S., Collins, A., & Duguid, (1989). Situated cognition and the culture of learning. *Educational Researcher, 18,* 32-42.

7. Carlson, E.R. (1997). *Experienced cognition*. Mahwah, NJ: Erlbaum.

8. Cohen, M.S., Freeman, J.T., & Wolf, S. (1996). Metacognition in time-stressed decision making: Recognizing, critiquing, and correcting. *Human Factors, 38(2),* 206-219.

9. Collins, A, Brown, J. S., & Newman, (1989). Cognitive apprenticeship: Teaching students the craft of reading, writing, and mathematics. In L. Resnick (Ed), *Knowing, learning, writing, and instruction: Essays in honor of Robert Glaser* (pp. 453-493). Hillsdale, NJ: Erlbaum.

10. Flavell, J.H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist, 38*, 906-911.

11. Fredrickson, B.L. (1998). What good are positive emotions? *Review of General Psychology, 2,* 3, 300-319.

12. Gijbels, D., Dochy, F., Bossche, P.V. (2005). Effects of Problem-Based Learning: A meta-analysis from the angle of assessment. *Review of Educational, 75* (1) 27-61.

13. Glaser, R., & Chi, M.T.H. (1988). Overview. In M.T.H. Chi, R. Glaser, & M. Farr (Eds.), *The nature of expertise* (pp. xv-xxxvi). Hillsdale, NJ: Erlbaum.

14. Haskell, R.E. (2001). Transfer of learning: Cognition, instruction, and reasoning. San Diego: Academic Press.

15. Hendricks, C. (2001). Teaching causal reasoning through cognitive apprenticeship: What are results from situated learning? *The Journal of Educational Research, 94,* 302-311.

16. Jarman, R. F., Vavrik, J., & Walton, P. D. (1995). Metacognition and the frontal lobe processes: At the interface of cognitive psychology and neropsychology. *Genetic, Social, and General Psychology Monographs, 121*, 153-210.

17. Johnson, D., Johnson, R., & Smith, K. (1991). Cooperative learning: Increasing college faculty instructional productivity (ASHE-ERIC Higher Education Report No. 4). Washington, DC: The George Washington University.

18. Johnson, R.T. (1976). The relationship between cooperation and inquiry in science classrooms. *Journal of Research in Science Teaching, 31(1),* 55-63.

19. Lepper, M.R. & Henderlong, J. (2000). Turning "play" into "work" and "work" into "play": 25 years of research on intrinsic versus extrinsic motivation. In C. Sansone, J.M. Harackiewicz (Eds.), *The search for optimal motivation and performance*. (pp. 257-307) San Diego, CA: Academic Press.

20. Lepper, M.R. (1988). Motivational considerations in the study of instruction. *Cognition and Instruction, 5(4),* 289-309.

21. Lepper, M.R. (1988). Motivational considerations in the study of instruction. *Cognition and Instruction*, *5* (4), 289-309.

22. Lepper, M.R. & Henderlong, J. (2000). Turning "play" into "work" and "work" into "play": 25 years of research on intrinsic verses extrinsic motivation. In C.Sonsone, J.M. Harackviewicz (Eds.) *The search for optimal motivation & performance.* (. 257-307) San Diego, CA: Academic Press.

23. Moses, L., & Barrd, J. A. (1999). Metacognition. In R. A. Wilson & F. C. Keil (Eds.), *The MIT encyclopedia of the cognitive sciences* (pp. 533-534). Cambridge, MA:MIT Press.

24. Nelson, T. O. (1996). Consciousness and metacognition. *American Psychologist, 51*, 102-116.

25. Palincsar, A. S., & Brown, A. L., (1984). Reciprocal teaching of comprehension-fostering monitoring activities. *Cognition & Instruction, 1,* 117-175.

26. Prawat, R. S. & Floden, R. E. (1994). Philosophical perspectives on constructivist views of learning. *Educational Psychology*, *29*, 37-48.

27. Saxe, G. B. (1991) *Culture and cognitive development: Studies in mathematical understanding*. Hillsdale, NJ: Erlbaum.

28. Scribner, S. (1984). Studying working intelligence. In Rogoff & J. Lave (Eds.), *Everyday Cognition* (pp. 9-40). Cambridge MA: Harvard University.

29. Segers, Dochy, F., & Cascallar, E, (2003). *Optimizing new modes of assessment: In search of qualities and standards.* Boston/Dordrecht: Kluwer Academics.

30. Sternberg, R.J. (1986). Intelligence applied: Understanding and increasing your intellectual skills. San Diego: Horcourt Brace Jouanovich.

31. Swanson, H. L. (1990). What developes in working memory? A life span perspective. *Developmental Psychology*, 35, 986-1000.

32. Young, M. (1993). Institutional design for situated learning. *Educational Technology Research and Development, 41*, 43-58.