

## **AC 2007-2744: PROGRAM AND CURRICULUM ASSESSMENT FOR THE INSTITUTE FOR P-12 ENGINEERING RESEARCH AND LEARNING (INSPIRE) SUMMER ACADEMIES FOR P-6 TEACHERS**

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# **Program and Curriculum Assessment for the Institute for P-12 Engineering Research and Learning (INSPIRE) Summer Academies for P-6 Teachers**

## **Abstract**

There is a need for research and discovery-based educational programs to introduce elementary educators and students to engineering. For this reason, a mid-western Research I university recently established the Institute for P-12 Engineering Research and Learning (INSPIRE). In Summer 2006, INSPIRE developed two week-long Summer Academies for P-6 teachers to introduce P-6 educators to engineering. The first academy was for teachers in the local area and the second was for teachers from across the nation. The INSPIRE program focused on the nature and practice of engineering; differences and similarities between engineering and science thinking; what engineers do and how engineers solve problems; and problem-solving processes for engaging P-6 grade students in open-ended problem solving. INSPIRE instructors used three types of curriculum units in the program: Model Eliciting Activities, *Milton is Missing*, and *Mission to Mars*. Each of these units focused on developing engineering thinking and problem-solving skills.

The purposes of this paper is to describe INSPIRE, overview assessment strategies that are leading to research on P-12 teachers, and present curriculum and program and assessment results for P-6 teachers participating in the inaugural offering of the INSPIRE Summer Academies. Quantitative and qualitative assessments were used to ascertain local and national Academy participants' views on how well the INSPIRE Summer Academy program objectives were met as well as the quality and applicability of the curricular lessons for their own students. The aim is to understand the impact of the INSPIRE Academies upon teachers' views of engineering and opportunities and challenges for implementing engineering activities in their classrooms.

## **I. Introduction**

“More S&P [Standard & Poor's] 500 CEOs obtained their undergraduate degrees in engineering than in any other field.”<sup>1</sup> This would lead one to believe that students would be clamoring to gain entrance into our nation's engineering programs; however, this is not the case. The fact is that the number of engineers graduating in the United States has remained unchanged over the past three years, while countries like China and India have far surpassed us. In an age where technology is ever evolving, the US needs to keep up with competing countries or our place in the technological world will be threatened<sup>1</sup>.

So, why is the U.S. producing so few engineers? Why aren't university students choosing engineering as a career? It is becoming increasingly clear that the answer begins in elementary school. Unfortunately, engineering is not traditionally part of the K-12 curriculum and many teachers are apprehensive about attempting to teach these topics<sup>2</sup>. Teachers are likely uncomfortable teaching engineering concepts to their students because they, themselves, hold many misconceptions about engineering. Research shows that a large number of teachers erroneously believe that engineers construct buildings<sup>2</sup>. They also tend to believe that engineers

complete job tasks such as installing wiring, repairing cars, and driving machines. There also seems to be an unclear definition of engineering, as the term has more recently been used to describe any type of specialist<sup>2</sup>.

When teachers believe that engineers tend to be construction workers or technicians<sup>2</sup>, it is not surprising that these same misconceptions are manifesting in today's K-12 students. Research indicates that, when students are asked to draw a picture of an engineer, their images depict engineers doing construction work such as building houses or bridges, or fixing cars (auto mechanic work)<sup>3</sup>. Additionally, the students' drawings tend to portray a limited number of fields, generally focusing on only civil or mechanical engineering<sup>3,4</sup>. These facts demonstrate both a lack of understanding of the depth and the breadth of the field of engineering. If students form unfavorable perceptions of engineering in elementary school, it shapes their beliefs about the field, and can have detrimental effects on their attitudes and beliefs about engineering, thus impacting their future career choices in this domain. It is for this reason, that teacher education is imperative<sup>5</sup>.

It has been shown that students working with engineering experts (i.e. engineering graduate students, engineering professors) gain a deeper understanding of engineering. When elementary teachers were paired with engineering graduate students, children's gains in understanding engineering were substantial<sup>5,6</sup>. The students had a deeper understanding of the engineering fields and the diversity within the discipline. When compared with students who were not exposed to any sort of engineering expert, the students who were taught about engineering also began to recognize the mental processes related to engineering, and focused much less on the physical processes, such as construction work and auto mechanics<sup>5</sup>. Additionally, these students were less likely to draw a picture of a train conductor to represent an engineer.

Since most teachers have not been exposed to any sort of engineering curriculum, there needs to be a venue for them to receive such training. Previous studies have shown that there is a wide gap between the knowledge of students and the knowledge of experts at the beginning of a training session in engineering<sup>7</sup>. However, after hands-on training consisting of activities relevant to the participants' lives, the gap was significantly reduced<sup>7</sup>. Therefore, if teachers can participate in engineering workshops where they are actively involved in the learning process, and the material they are learning is relevant and meaningful, they will likely gain a deeper understanding of engineering principles, processes, and fields. Once they have this richer understanding, they will be better prepared to function as experts in their own classrooms, thus exposing their students to a truer picture of engineering. As the learning grows, the misconceptions will begin to diminish and, with time and perseverance, more students will have an accurate portrayal of the world of engineering, a portrayal that will enable them to make wise, informed career choices as they enter the university setting.

The purposes of this paper is to describe the Institute for P-12 Engineering Research and Learning (INSPIRE), overview assessment strategies that are leading to research on P-12 teachers, and present curriculum and program and assessment results for P-6 teachers participating in the inaugural offering of the INSPIRE Summer Academies. Qualitative and quantitative assessments were used to ascertain local and national Academy participants' views on how well the INSPIRE Summer Academy program objectives were met as well as the quality

and applicability of the curricular lessons for their own students. The aim is to understand the impact of the INSPIRE Academies upon teachers' views of engineering and opportunities and challenges for implementing engineering activities in their classrooms.

## **II. INSPIRE**

The Institute for P-12 Engineering Research and Learning (INSPIRE) was developed to increase the presence of engineering in the P-12 classroom. There is a desire to help educators investigate how students learn and to instill a desire in students to study engineering from elementary through high school. It is the purpose of INSPIRE to serve this function through increasing classrooms activities that build science, technology, engineering, and mathematics (STEM) skills. INSPIRE hopes to achieve this by three methods: research/discovery, education/learning, and engagement/outreach. The first, research/discovery, focuses on developing a community at the university level around the issues and opportunities for engineering education with young learners, examples include supplemental grants and programs (Young Engineers Studies grants and the P-12 Research Seminar Series), graduate research assistants, undergraduate research assistants, and faculty scholars.

The second, education/learning, includes the two week-long INSPIRE Summer Academies hosted at the university (one for local teachers, one for national teachers), academic year teacher professional development opportunities, and the Bechtel Fellows Program. The Bechtel Fellows Program allows highly qualified teachers to work with the INSPIRE team during the summer. These teachers arrive prior to the summer academies and helped with the planning, curriculum development and refinement, and implementation of the summer academies.

The final method by which INSPIRE hopes to achieve their goals is by engagement/outreach. This is done by soliciting the input of an external advisory board comprised of a wide array of talented and knowledgeable individuals, co-sponsoring the International Community of Teachers of Mathematical Modeling and Applications (ICTMA) Conference<sup>8</sup>, being a part of the university science, mathematics, and engineering learning community, and co-sponsoring the EPICS high school program coordinator. INSPIRE hopes to continue to host successful summer programs as well as focus on collaboration with successful national programs, engaging key national leaders, build stronger ties with P-12 systems, create a more visible national presence, develop an undergraduate degree program in engineering education, and develop outreach into the state and federal landscapes. In everything, INSPIRE is striving to prepare and place teachers with confidence in their engineering knowledge and abilities into P-12 classrooms and ultimately strengthen and diversify the pipeline of students pursuing engineering careers.

## **III. Method**

### **A. Setting**

Two INSPIRE Summer Academies were conducted during the summer of 2006. The first was held on June 26th – 30th for teachers local to the university's campus. The second was held on July 10th – 14th with teachers from across the nation. The educators worked side by side with engineering education researchers who are excited about building partnerships between

universities and schools. The main goals of the academies were to enable teachers to (1) convey a broad perspective of the nature and practice of engineering; (2) articulate the differences and similarities between engineering and science thinking; (3) develop a level of comfort in discussing what engineers do and how engineers solve problems with P – 6th grade students; and (4) use problem-solving processes (i.e. science inquiry, model development, and design processes) to engage P – 6th grade students in complex open-ended problem solving. Educators learned how to present complex problems to their students and guide solution development through an engineering design process.

Teachers within both summer academies completed curricula based upon their grade levels. During the local academy, preschool-4<sup>th</sup> grade teachers completed *Milton is Missing*, a curriculum that is targeted for grades 3 and 4. Each activity is described in Appendix A. Students are introduced to the way engineers solve problems through a series of activities that enable the students to identify the individual(s) that have captured a summer camp mascot. Activities encompass problem-solving in general with math and science based tools, mathematical modeling, and engineering design.

Fifth and 6<sup>th</sup> grade teachers completed *Mission to Mars*<sup>9</sup>, a curriculum that allows students to conduct several activities geared towards investigating and designing systems in order to sustain human life on mars. See Appendix B for a description of the activities. During the national academy, 3<sup>rd</sup>-6<sup>th</sup> grade teachers completed only one curriculum - *Mission to Mars*. Each lesson addresses an average of 5 to 7 National Science and Math standards<sup>10, 11</sup>.

All educators were introduced to Model-Eliciting Activities (MEAs), which are open-ended, real-world problems requiring the creation of a mathematical model for a given situation. These problems are based on the models and modeling perspective<sup>12, 13</sup>. These activities have origins in mathematics education and have migrated to undergraduate engineering education<sup>14</sup> and back to K-12 education with the integration of engineering thinking and contexts. Several MEAs were completed with the INSPIRE teachers (Appendix C). During the local academy, all teachers completed the *Soccer Ball* MEA and the *Reading Certificate* MEA; 3<sup>rd</sup> -4<sup>th</sup> grade teachers completed *Footprint* MEA as part of the *Milton is Missing* curriculum and 5<sup>th</sup>-6<sup>th</sup> grade teachers completed the *NASA* MEA. The national teachers completed the only the *Soccer Ball* MEA and the *Paper Airplane Challenge* MEA.

The week of each academy ended with the educators teaching a lesson to students at a local day camp – the lesson was drawn from materials and learning the teachers had experienced during the week and modified for their assigned target age students at the day camp. Pairs of teachers worked with a group of five to six children. The faculty and staff affiliated with the INSPIRE Summer Academies observed these sessions to identify the range of methods teachers used in the lessons and as a formative assessment of the teachers' use of the instructional materials. These observations are helping to formulate future research questions, methods we will use in teaching future academies, and writing proposals for additional funding.

## B. Participants

INSPIRE Summer Academy I was held during the week of June 26th – 30th and was exclusively for the local school district teachers. The district has a total student population of 7,027 with the following ethnic diversity: 69% Caucasian, 17% Hispanic, 9% Black, 4% Multiracial, and 1% Asian. In addition, the district has 41% of its students on free lunch and 10% on reduced lunch compared to the state average of 37%. There were a total of 33 teachers from the local district who attended the workshop. The total number of students reached by the participating teachers is roughly 1112 in science classes and 837 in math classes. Additional demographic information about Summer Academy I participants is listed in Table 1.

INSPIRE Summer Academy II was held during the week of July 10th – 14th and it was open to PreK-6 educators nationwide. The Academy was publicized at an engineering education presentation at National Association of Science Teachers (NSTA) national convention in Anaheim, CA in April 2006. An application process was used to select participants. Applicants demonstrating some prior knowledge about engineering and an expressed interest in using engineering content in their classrooms were selected for participation in Summer Academy II. From a total of 53 applicants, 30 teachers attended the workshop. The participants represented 12 states including 5 midwestern states, as well as NY, CA, TX, CO, CT, MA and AZ. Approximately 13% of the teachers had attended a previous workshop relating to engineering. The total number of students reached by this group is roughly 1,787 in science classes and 1,362 in math classes. Additional demographic information about Summer Academy II participants is listed in Table 1.

**Table 1. Description of Teachers in Each INSPIRE Summer Academy**

Local Teachers (n=33)		National (n=30)	
<b>Gender</b>		<b>Gender</b>	
<b>Males</b>	9%	<b>Males</b>	30%
<b>Females</b>	91%	<b>Females</b>	70%
<b>Grade Level Taught</b>		<b>Grade Level Taught</b>	
<b>P-2<sup>nd</sup></b>	27%	<b>P-2<sup>nd</sup></b>	n/a
<b>3<sup>rd</sup></b>	12%	<b>3<sup>rd</sup></b>	10%
<b>4<sup>th</sup></b>	15%	<b>4<sup>th</sup></b>	3%
<b>5<sup>th</sup></b>	6%	<b>5<sup>th</sup> + **</b>	47%
<b>6<sup>th</sup> *</b>	30%	<b>6<sup>th</sup> + **</b>	27%
<b>All grades</b>	9%	<b>1<sup>st</sup> or 3<sup>rd</sup> - 5<sup>th</sup></b>	7%
		<b>Administrator</b>	7%

\* One 6<sup>th</sup> and 8<sup>th</sup> grade teacher

\*\* That grade only, or that grade and higher grades

### **C. Data Collection**

Quantitative and qualitative assessments were used to ascertain local and national Academy participants' views about the discipline of engineering and what engineers do; their ratings of the importance of design, engineering, and technology within elementary grades; their understandings of differences between science and engineering thinking; and their overall ratings of the INSPIRE Summer Academy.

Table 2 describes all of the assessments teachers completed during INSPIRE. All but the Curricular/Program Assessments were given in the form of pre- and post-tests during each week of the Academy in an effort to understand the impact of the Academy upon teachers' views of engineering within their P-6 classrooms. Table 2 also lists the research topics of interest associated with each assessment instrument.

This paper focuses on select results of the Curricular/Program Assessments. Curricular assessments were conducted with the teachers at the end of each activity. Program assessments were conducted at the end of each day with a more extended program assessment being completed on the last day at the conclusion of the academy.

## **IV. Results & Discussion**

The following selected results focus on 2006 Academy participants' views of the Model-Eliciting Activities (Figures 1-3), the *Mission to Mars* (Figures 4 and 5) curriculum, the *Milton is Missing* curriculum (Figure 6), and the program overall (Figures 7-9).

### **A. Curricular Assessment**

Figures 1-6 present teachers' level of agreement (on a 5-point Likert scale of strongly agree to strongly disagree) with the following three statements:

- I am interested in implementing this activity during the 2006-2007 academic year.
- I am comfortable applying the math/science content of this unit within my classroom.
- I believe I can implement this activity in my classroom.

These figures provide the percentage of teachers who agreed or strongly agreed with these statements.

Model-Eliciting Activities: The local preschool-4<sup>th</sup> grade teachers responded more favorably to the *Soccer Ball* MEA than to the *Reading Certificate* MEA (Figure 1). A majority of the teachers were both comfortable with the material and were interested in utilizing the *Soccer Ball* MEA during the 2006 – 2007 academic year. The *Soccer Ball* MEA was also received favorably by the majority of the local 5<sup>th</sup> and 6<sup>th</sup> grade teachers for each of the three questions (Figure 2). The local 5<sup>th</sup> and 6<sup>th</sup> grade teachers were more comfortable with the content and their ability to implement the *Reading Certificate* MEA than the local preschool-4<sup>th</sup> grade teachers (Figure 11 and 2). The local 5<sup>th</sup> and 6<sup>th</sup> grade teachers completed an additional *NASA* MEA. Over half of the teachers answered positively for each of the three questions (Figure 2).



**Table 2. Description of the five INSPIRE Assessment Categories**

ASSESSMENT/ PURPOSE	DATA COLLECTION TYPE /METHOD	RESEARCH TOPICS OF INTEREST
<p><b>ENGINEERING PHOTO JOURNAL</b> Notes changes in P-6 teachers and Fellows' views of engineering via their photographic and written documentation of scenes related to engineering before and during the Academy</p>	<ul style="list-style-type: none"> <li>▪ 10 photos with written descriptions</li> </ul>	<ul style="list-style-type: none"> <li>▪ P-6 teachers' perceptions of engineering</li> <li>▪ Similarities and differences in P-6 teachers' perceptions of engineering <i>before</i> and <i>after</i> Summer Academy</li> </ul>
<p><b>DESIGN, ENGINEERING, AND TECHNOLOGY (DET) SURVEY<sup>15</sup></b> Notes P-6 teachers' views of the importance of DET; familiarity with DET; stereotypes of DET; and knowledge of engineering characteristics on the first and last days of the Academy</p>	<ul style="list-style-type: none"> <li>▪ 41 quantitative Likert-scale questions</li> <li>▪ 15 additional closed-ended questions</li> </ul>	<ul style="list-style-type: none"> <li>▪ Comparisons of P-6 teachers' views of DET parsed by gender, teaching, experience, grade levels, and location</li> <li>▪ Impact of Academy upon P-6 teachers' views of DET</li> </ul>
<p><b>SCIENTIFIC/ENGINEERING PROCESSES ASSESSMENT</b> Compares teachers' descriptions of the goals of scientists with the goals of engineers and teachers' descriptions of the scientific process and the design process on the first and last days of the Academy</p>	<ul style="list-style-type: none"> <li>▪ 4 open-ended questions</li> </ul>	<ul style="list-style-type: none"> <li>▪ P-6 teachers' understandings about similarities and differences between science and engineering and between the steps in the scientific process and the engineering design process</li> <li>▪</li> </ul>
<p><b>ENGINEERING SURVEY</b> Records teachers' perceptions of the engineering discipline; what engineers do; and the applicability of engineering to P-6 education</p>	<ul style="list-style-type: none"> <li>▪ 6 open-ended questions</li> </ul>	<ul style="list-style-type: none"> <li>▪ Teachers' definitions of engineering, descriptions of what engineers do, and beliefs about engineering within P-6 grades</li> <li>▪ Changes in teachers views about the role of engineering within P-6 grades</li> </ul>
<p><b>CURRICULAR/ PROGRAM ASSESSMENTS</b> Records teachers views of INSPIRE curriculum and Academy logistics and Fellows and teachers satisfaction with the Summer program</p>	<p>Curricular Daily</p> <ul style="list-style-type: none"> <li>▪ 9 Likert-scale questions</li> <li>▪ 1 additional open-ended question</li> </ul> <p>Program Daily</p> <ul style="list-style-type: none"> <li>▪ 1 Likert-scale question per activity (4 additional questions on Day 1)</li> <li>▪ 5 additional open-ended questions</li> </ul> <p>Program Last Day</p> <ul style="list-style-type: none"> <li>▪ 30 Likert-scale questions</li> <li>▪ 5 additional open-ended questions</li> </ul>	<ul style="list-style-type: none"> <li>▪ Assessments will primarily be used for program evaluation purposes</li> </ul>

One of the challenges with using MEAs with P-6 teachers as a means of introducing model development is that MEAs have rarely been used below the 6<sup>th</sup> grade level. All of the MEAs used in the academies were adapted from existing MEAs intended for older students. A concerted effort was made to add components to the *Soccer Ball* MEA for younger children (e.g. use of simple shapes) while offering opportunities to see how the MEA could be used with older children. Results indicate that these adaptations were successful.

The *Reading Certificate* MEA was unexpectedly very difficult to implement. The local teachers were perhaps too familiar with the context of the problem. Issues arose with the data set that prevented the teachers from engaging in the mathematics of the problem. The teachers made recommendation to improve the book list for each child and the level of difficulty associated with each book on the list. They also recommended the addition of a reading level for each child. Certainly, the assessment results reflect teachers dislike of this problem. This MEA was not carried over into INSPIRE Academy II.

The NASA MEA was originally targeted for first-year engineering students. Attempts to adjust the MEA to a 5<sup>th</sup>-6<sup>th</sup> grade level were met with mixed results.

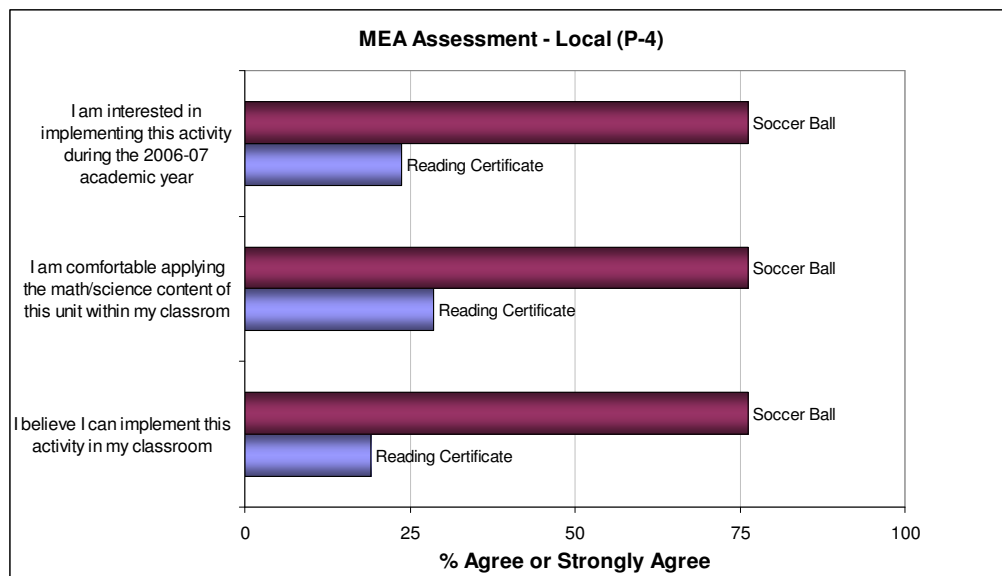
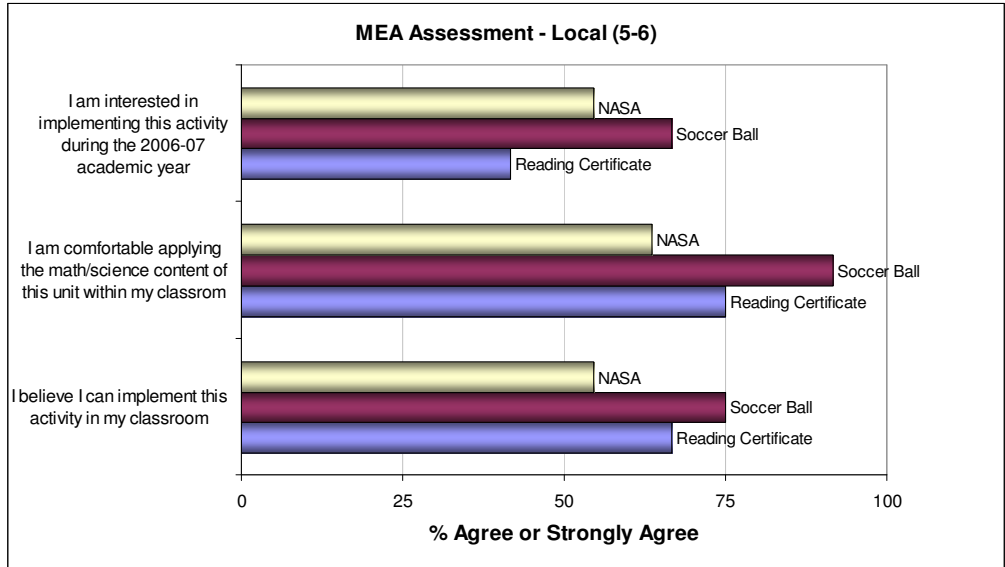
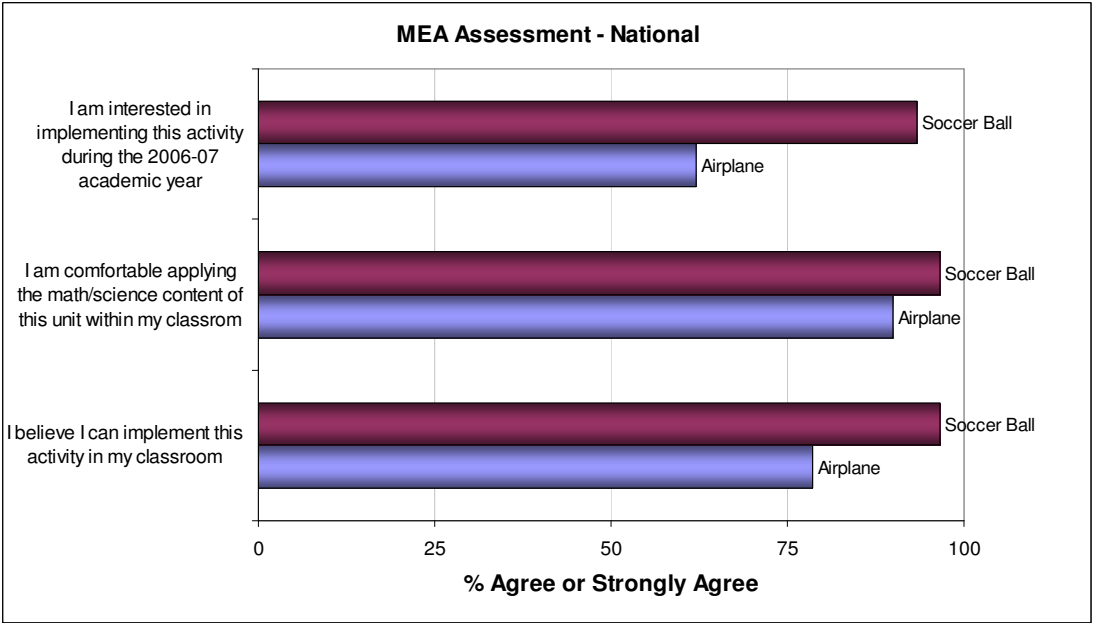


Figure 1. Percent agree or strongly agree for MEA assessment for local P-4 teachers (N=21)



**Figure 2. Percent agree or strongly agree for MEA assessment for local 5-6 teachers (N=12)**

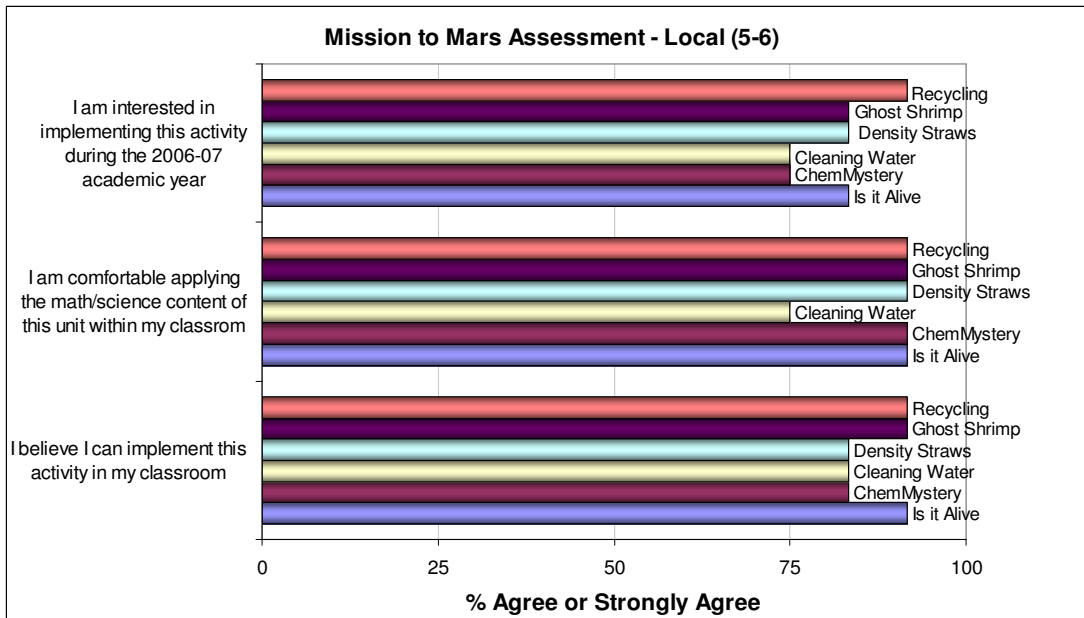
Nearly all of the national teachers agreed or strongly agreed to the three questions pertaining to the *Soccer Ball* MEA (Figure 3). Over 75 % were comfortable with the content of the *Paper Airplane Competition* MEA and believed in their ability to implement the activity in their classrooms (Figure 3).



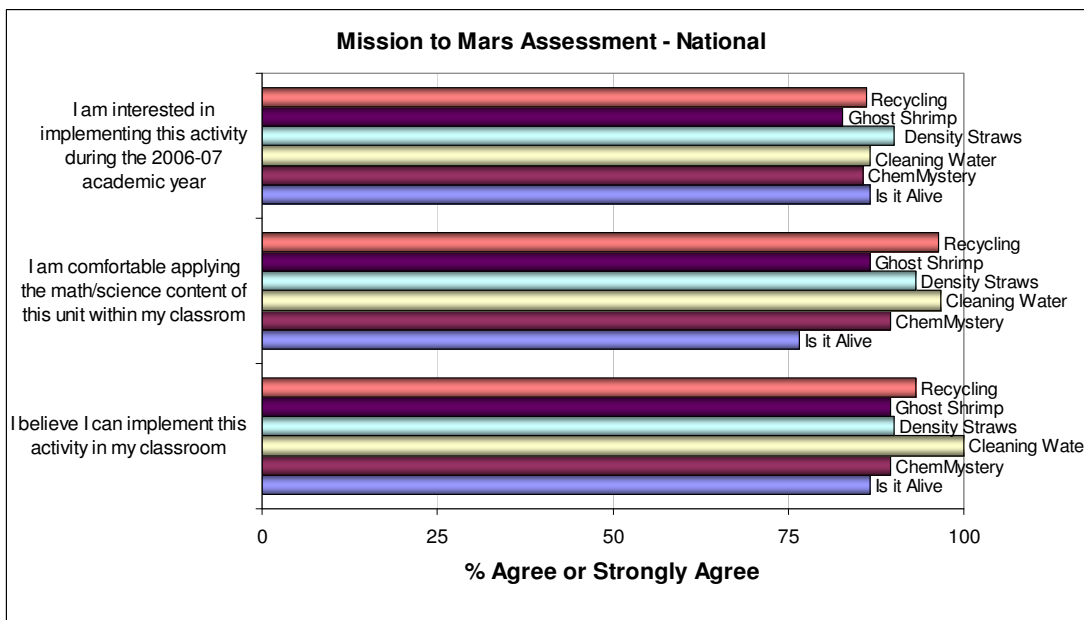
**Figure 3. Percent agree or strongly agree for MEA assessment for national teachers (N=30)**

*Mission to Mars*: Overall, the *Mission to Mars* curriculum was well received by the local 5<sup>th</sup> and 6<sup>th</sup> grade teachers as well as the national teachers. At least 75 % of the teachers agreed or strongly agreed with the questions asked for each *Mission to Mars* activity (Figure 4s 4 and 5). Teachers seemed to feel that each activity was grade appropriate and would be feasible to use in their classrooms.

All of these activities were originally written to accompany 5<sup>th</sup>-6<sup>th</sup> grade science curriculums and they had gone through extensive piloting and revision. To some degree, engineering thinking or an engineering design element was incorporated into these activities. *Cleaning Water* is a good example of an activity where engineering design was easily integrated into the original science activity. However, teachers were less interested in and comfortable with this more engineering problem.



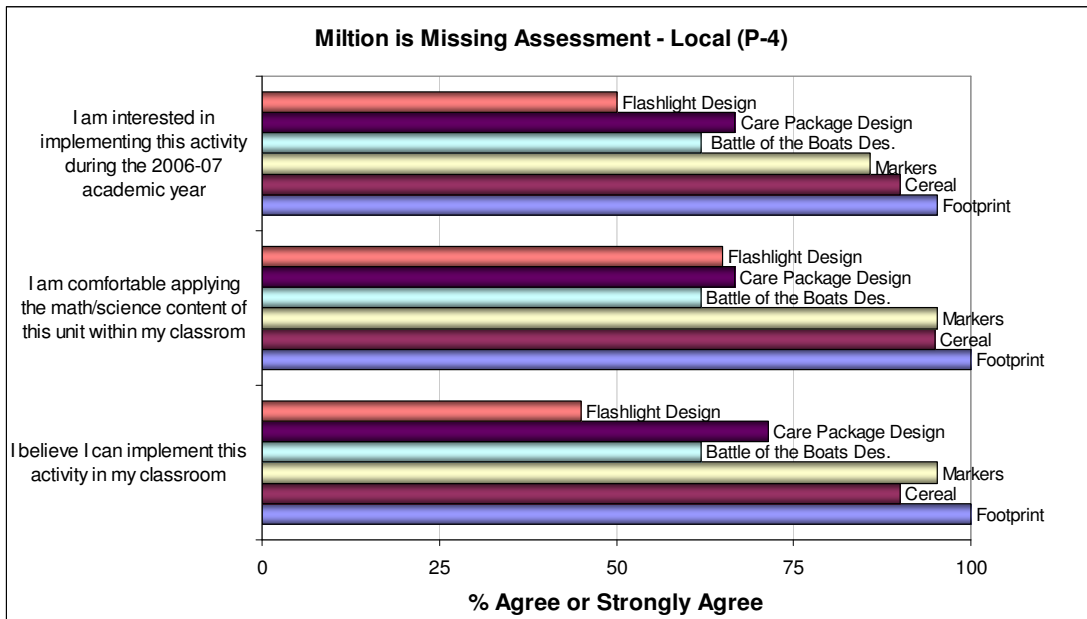
**Figure 4. Percent agree or strongly agree for *Mission to Mars* assessment for local 5-6 teachers (N=12)**



**Figure 5. Percent agree or strongly agree for *Mission to Mars* assessment for national teachers (N=30)**

*Milton is Missing*: For *Milton is Missing*, over 85 % of the local preschool-4<sup>th</sup> grade teachers agreed or strongly agreed with each of the statements for the Markers, Cereal, and Footprint activities (Figure 6). These activities seemed similar to science activities with which the teachers were already familiar. Fewer teachers were interested in implementing, comfortable in applying, or believed they could implement the other three *Milton is Missing* activities. The teachers had difficulty with these three engineering design activities, often citing that the target age was really higher than anticipated. Perhaps because these activities dealt more with design and redesign concepts, the teachers need more practice to become comfortable with these processes.

*Milton is Missing* is comprised of a series of existing activities that were modified for grade level and incorporated into a story line. All activities had undergone varying degrees of piloting and revision prior to the academies.



**Figure 6. Percent agree or strongly agree for *Milton is Missing* assessment for local P-4 teachers (N=21)**

## B. Program Assessment

At the end of INSPIRE Summer Academies, the teachers rated the extent to which the following four academy objectives were met on a 5-point Likert scale of None (N), Little (L), Some (S), Very (V), Extremely (E):

- (1) Convey a broad perspective of the nature and practice of engineering.
- (2) Articulate the differences and similarities between engineering and science thinking.
- (3) Develop a level of comfort in discussing what engineers do and how engineers solve problems with P – 6th grade students.

(4) Use problem-solving processes (i.e. science inquiry, model development, and design processes) to engage P – 6th grade students in complex open-ended problem solving.

More of the local preschool-4<sup>th</sup> grade teachers than the local 5<sup>th</sup> and 6<sup>th</sup> grade teachers reported that all four of the objectives were extremely well achieved (Figure 7 and 8). Overall, for both academies, at least 70 % of the teachers responded that the objectives were very well or extremely well achieved, with the exception of Objective 2 for the local 5<sup>th</sup> and 6<sup>th</sup> grade teachers (Figure 7-9).

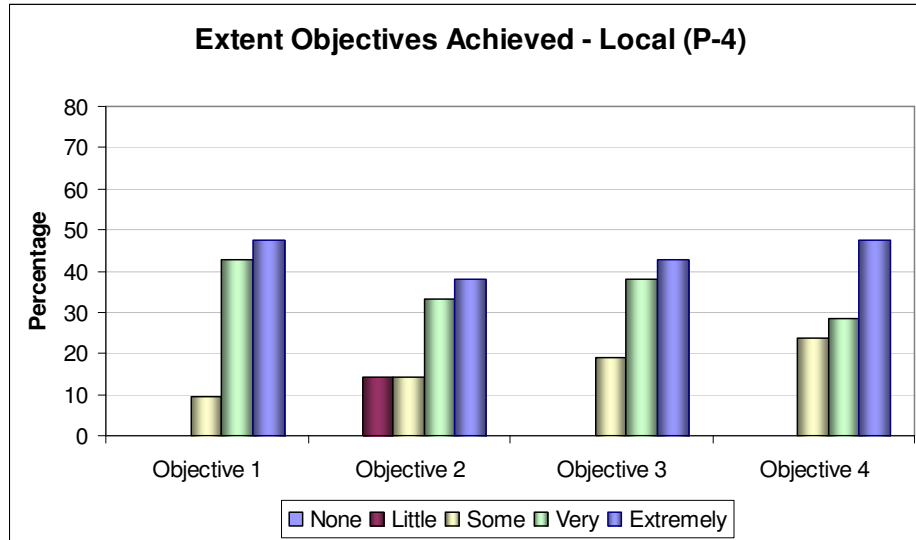


Figure 7. The extent program objectives were achieved for local P-4 teachers (N=21)

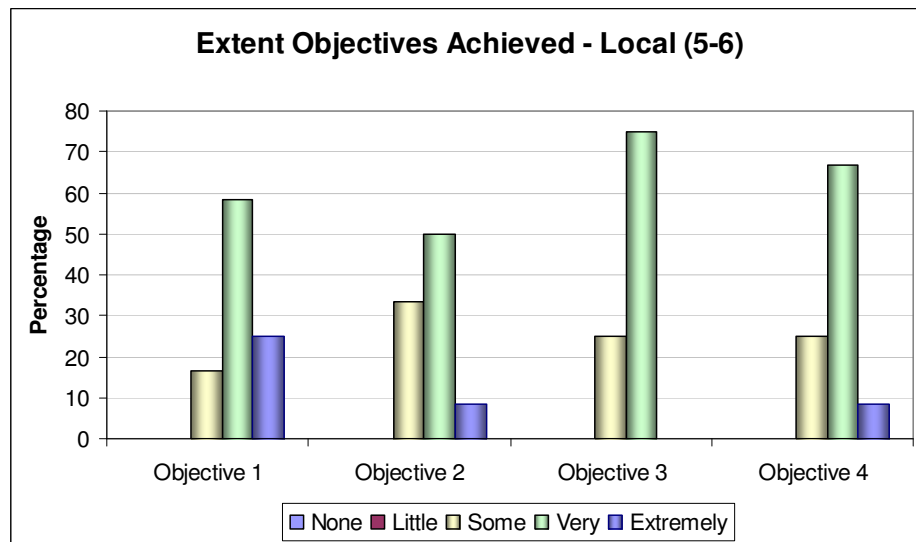
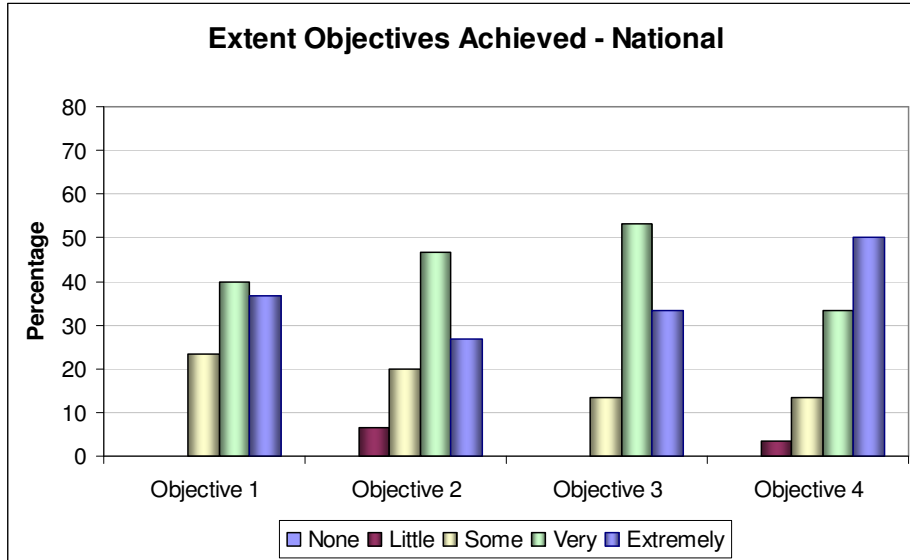


Figure 8. The extent program objectives were achieved for local 5-6 teachers (N=12).



**Figure 9. The extent program objectives were achieved for national teachers (N=30).**

Most of the teachers at both academies felt that the academies conveyed a broad perspective of the nature and practice of engineering. However, there were fewer teachers who felt that the differences and similarities between engineering and science thinking were clearly articulated. Teachers at both academies also believed they developed a reasonable level of comfort in discussing what engineers do and how engineers solve problems with preschool to 6<sup>th</sup> grade students. The majority of teachers also felt comfortable using problem solving processes to engage preschool to 6<sup>th</sup> grade students. Based on these results, INSPIRE will continue to emphasize the four objectives as well as place a greater emphasis on problem solving and the differences and similarities between engineering and science thinking.

## Conclusion

This paper has overviewed INSPIRE and the various assessment strategies leading to research on P-6 teachers. This paper also summarized some of the results of the inaugural INSPIRE Summer Academies. Initially many teachers reported that they were uncomfortable with the ambiguity and open-endedness of engineering. After the INSPIRE Summer Academies, many teachers indicated that they were more familiar with what engineers do and how engineers solve problems. The teachers generally expressed a desire to continue working with INSPIRE educators. Researchers found that certain curriculum units were feasible for use in classrooms and other curriculum units needed to be modified for classroom application. Overall, the INSPIRE assessments provide valuable information for the development of P-6 teacher engineering programs.

These results have provided information that INSPIRE researchers will use to develop future academies and that others interested in developing such programs can utilize. The teachers demonstrated a high level of interest in implementing certain activities, and INSPIRE could work with teachers in their classrooms to pilot such activities. This would assist the redevelopment of activities for the next academies. Also teachers could begin to discuss the nature and practice of

engineering and engineering problem solving with their students and receive feedback from INSPIRE researchers. As INSPIRE researchers go into the classroom environment, they can work to improve teacher comfort levels with the redesign and revision process as well as helping them to realize the differences between science inquiry and engineering design.

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## **Appendix A: *Mission to Mars*<sup>1</sup>**

### ***Introduction Presentation***

The Mission to Mars is introduced with a presentation that explains the research in the NASA Center for Research and Training in Advanced Life Support (ALS/NSCORT). This presentation outlines the factors involved in creating a habitat on Mars.

### ***Recycling in Space***

This activity, created by Marybeth Eden, should be used after the Big Question to set the stage for the entire module. Students gain knowledge about why recycling is important for survival in space, and why we cannot bring all our food, water and oxygen with us when we travel in space for long-duration missions.

### ***Ghost Shrimp Ecosystem***

We will be creating a model of an ecosystem in the design of the Mars habitat...Students investigate the survival needs of a ghost shrimp, design an ecosystem that will ensure the survival of the ghost shrimp and apply that knowledge to the survival needs of humans in the Mars habitat.

### ***CheMystery***

This module introduces students to inquiry learning/research. Students are engaged in a “research” project, directed by questions generated from an Alka-Seltzer experiment. ....Students will learn about the use and testing of variables, use of a control, and experimental design. Students design a procedure to determine the quantity of ingredients needed to produce a desired amount of gas.

### ***Cleaning Water on Mars***

This activity is a representation of the ALS/NSCORT research on water treatment in the Mars habitat...Students can be introduced to Cleaning Water on Mars as a representation of the biofilm, to show students how it works. The bundles in the activity represent the biofilm coated bio-discs. Students will design and construct a column that will allow the bundles (the biofilm) to most efficiently clean gray water, the water used in hygiene and dish washing....

### ***Is IT Alive?***

Yeast will be a staple in the Mars habitat...Astronauts crave fresh food, and yeast will allow them to make their own food with very little materials that occupy very little space. Student discussions should include whether or not yeast is “alive.” This will give the activity a dual objective: students will gain an understanding of yeast and food along with an understanding of the survival needs of organisms. Data analysis will provide information to students about the “survival” needs. Control experiments will provide insight into the importance of using a control in research.

### ***Density Straws***

This activity is used as a precursor for “Cleaning Water on Mars.” This lesson introduces students to the concept of density. It also relates the important role density plays in the Mars habitat. Students determine the density of different solutions in relationship to each other and design a method for figuring out the relationship of the density of a new solution to given solutions.

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## Appendix B. *Milton is Missing*

### A. A fresh footprint is found in the mud next to Milton's cage.

#### *Model-Eliciting Activity: Footprint*

Through this activity, students will develop a mathematical model that predicts the height of animals, dinosaurs, and humans from the length of their respective footprint. Development of a working model requires understanding of the system to be modeled. Once a working model is established, it must be tested to determine whether it adequately models the system. Through this testing, values predicted using the model are compared to actual system values. The difference between the predicted and actual values is evaluated to determine whether the model must be revised.

#### **Cereal crumbs are found around Milton's cage.**

#### *Problem Solving Activity: There's Something In My Cereal!*

Students will perform a scientific investigation to detect the presence of elemental iron. To do this investigation, students first need to learn about magnets.

### B. A wet note is found in Milton's cage. Part of the ink is smeared, but the part that can be read says:

"If you ever want to see Milton again, send us the design of your boat along with a care package of Milton's favorite food. "

#### *Problem Solving Activity: What Marker or Pen Wrote This Note?*

This activity is designed to help students see how a scientific experiment can be used as a tool, in that case to investigate a clue. Students first consider how they can mix colors to get a new color. This purpose of the second activity is to introduce a means of learning what colors were used to create a color. Chromatography is introduced as a method to separate colors into their component parts. The students will then use chromatography to investigate who among the suspects could have written the ransom note for Milton.

#### *Design Activity: Care Package for Milton*

In this activity, students will design a packaging system to protect a fragile item that must be sent through the mail. To complete this activity, students will work through the design process. Students will learn about design under constraints and with competing variables. They will have a fixed budget for designing and shipping their package. They must strike a balance between maximizing the food delivered and minimizing the damage to the package.

#### *Design Activity: Battle of the Boats*

In this activity, students will design a boat that can travel unassisted in a channel. Students are challenged to design a boat that will travel a specified distance in the shortest amount of time. To complete this activity, students will work through the design process. The design of the boat is constrained by the materials available in the junk box. Students will experience an iterative process of design and redesign to produce the best boat possible. (Adapted by Macon Beck from *Junk Box Wars: Battle of the Boats* with permission provided by author Stacy Baker. See *Junk Box Wars* at <http://school.discovery.com/networks/junkyardwars/pdf/junkboxboats.pdf>)

### C. Campers want to look for clues at night.

#### *Design Activity: Flashlight Design*

In this activity, students will design a flashlight. This is a design project that can be used to teach students the design process, getting them used to establishing criteria for success, drawing their ideas for the design, keeping records of their design, and evaluating their design.

## Appendix C: Model-Eliciting Activities

### ***Soccer Ball***

This MEA focuses on math skills such as shape recognition, tessellation, dimensions, and area. Students are tasked with creating a procedure to maximize the number of identical shapes that can be cut from a specified size sheet of material. They work with squares, circles, hexagons, and pentagons in the given problem; however, the procedure they create should be applicable to any shape.

### ***Reading Certificate***<sup>1</sup>

Students are asked to develop a method for awarding certificates to students within a classroom. Data provided includes the number of books each child read, the number of pages each child read, and the number of “difficult” books each child read. Students need to develop a procedure that considers the available data to fairly award reading certificates to the top readers in the class.

### ***NASA***

Students represent a team working for NASA Advanced Life Support and are given several different air life support systems ranked from best to worst by a NASA expert. Various factors (weight, volume, etc.) are shown for each air life support system. The student teams use this data develop and test a reusable procedure to rank other air life support systems based on the factors provided.

### ***Paper Airplane Challenge***<sup>2</sup>

This is more appropriate for upper elementary age students. The students are asked to develop a process for judging a paper airplane contest and they must consider multiple data sets in order to determine a winner in each of three categories: most accurate, best floater, best boomerang, and best overall. Their procedure must work for the given data as well as for future data that will be generated in upcoming paper airplane contests. Students can work at their own academic level as they draw upon various mathematics skills ranging from comparing mean scores and standard deviations to using weighted averages to calculate winners.

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