UASPP: Three Years of Helping Middle School Teachers Devise Their Own Hands-on Engineering and Science Activities

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Abstract

The University of Arkansas Science Partnership Program (UASPP) was developed in 2006 to focus on the professional growth of 6th, 7th and 8th grade science teachers through summer institutes and follow-up activities. Teachers were teamed with engineering faculty to improve teaching skills and to increase the use, understanding and application of hands-on exercises in the classroom. The program has been operational for three years, and has recently received funding from the Arkansas Department of Education to continue for an additional three years.

As UASPP has matured, a number of changes have been made which have had a positive impact on the use of the program activities by the teachers in the classroom. Examples of these changes include movement away from providing experiments to the teachers and toward teacher-developed experiments, the development and use of design-based experiments, and increased use of engineering professors in summer institutes and follow-up activities. This paper highlights program developments and their impacts throughout the three year history of UASPP, and presents the format for new activities as the program moves into its next three years.

Introduction

The National Science Foundation has recognized the need to introduce engineering and science to students at an early age in order to increase the number of students entering engineering disciplines. However, most students in the middle level grades (6th, 7th and 8th) are unaware of opportunities in engineering and do not recognize engineering as a rewarding career option. Furthermore, research tells us that women and minority students are drastically underrepresented in the engineering fields.[1] To more effectively prepare students for engineering and science degrees, K-12 students should be engaged in activities which develop the critical thinking skills necessary for solving problems in the real world. It is universally accepted that all student benefit from hands-on learning activities in the classroom. Studies show that hands-on activities are especially important for English language learners (ELLs), and are therefore an important way to tap this increasingly large and diverse pool of future engineering students.[2, 3, 4]

In 2005, the College of Engineering and the College of Education and Health Professions at the University of Arkansas formed a partnership to assist the Northwest Arkansas Education Renewal Zone (NWA-ERZ) in engaging students in hands-on, standards-based science activities. This University of Arkansas Science Partnership Program (UASPP), funded by the Arkansas

Department of Higher Education, focused on the professional growth of 6^{th}, 7^{th} and 8^{th} grade science teachers from 23 partner schools in the NWA-ERZ. The program was organized as a series of summer institutes and follow-up activities which teamed teachers with engineering faculty to improve teaching skills and to increase the teachers' use, understanding and application of hands-on laboratory exercises. It included classroom/laboratory development, follow-up activities at the schools and evaluation, both during and after each institute. The purpose of this paper is to summarize developments in the UASPP program and their impacts throughout the three year history of UASPP, and to present the format for new activities as the program moves into the next three years.

Getting Started

The first step in putting together the partnership program was to obtain commitments from each of the schools to agree to participate in the program. Commitments were received from the principals of each of the 23 participating schools, and letters of commitment were obtained from the school districts, agreeing to participate in the program for three years.

A needs assessment was devised to assess teacher quality and to identify professional development needs in the teaching and learning of science. The assessment showed that 100% of the respondents taught in the academic subject and grade level for which they were trained and licensed, and therefore met the State's definition of a highly-qualified teacher. All respondents marked lab activities as one of their top three priority needs. The top four areas of greatest need in developing hands-on experiments were Arkansas land forms, Newton's three laws of motion, predicting weather conditions and determining solubility rates.

The Year 1 (2006) Institute

Table 1 shows the school and teacher involvement in the summer institutes. In 2006, the first year of the institute, 13 of the 23 partner schools sent participants to the two week institute. Of the 27 science teachers participating in the institute, 8 were sixth grade teachers, 11 taught seventh grade and 8 taught eighth grade.

Table 1. Teacher Involvement in Summer Institutes

Year	Number of Schools Involved	Number of Teachers Involved*			
		6^{th}	7^{th}	8^{th}	Total
2006	13	8	11	8	27
2007	11	8	9	10	27
2008	12	11 (3)	6 (0)	14 (2)	36
2009**	17	21	21	0	42

*The 2008 Institute included Science and Math teachers. The numbers in parentheses for 2008 are math teachers, and the numbers outside the parentheses are science teachers
**Based on commitments prior to institute

A summary of the Year 1 laboratory experiments and other institute activities (including teacher testing, evaluation, curriculum mapping, horizontal and vertical alignment among participants) is shown in Table 2. Each of the teachers was given all of the supplies required to carry out the laboratory activities, a notebook containing background material and options in performing each experiment, a detailed equipment list for each experiment, and a list of experimental procedures and safety issues that should be addressed when implementing an experiment. Even though the workshop experiments were designed to be safe and the teachers ultimately used the experiments in a classroom setting, a safety mindset is of paramount importance in participating in any hands-on activity. Teachers were divided into groups of four to five members from different schools and grade levels and asked to perform the experiments with the assistance of UA faculty. Further details of the Year 1 institute and follow-up activities were presented by Davis *et al.*[5, 6]

Table 2. Year 1 Summer Institute Activities

Day	Activity
1	Introduction, safety training, earthquakes
2	Teacher testing
3	Acids and bases, measuring the pH of household items
4	Ball sorting exercise
5	Preparing a mold terrarium
6	Ethanol by fermentation of sugars
7	Measuring the densities of solids
8	Vegetable/fruit batteries
9	Chemical reactions and reaction rates
10	Teacher testing, evaluation

The daily experiments were organized as follows:

- A presentation/discussion of the topic background
- Execution of the experiment
- A discussion of the experiment, possible alterations and the problems/limitations for use in the individual classrooms
- A discussion of how the experiment fits into the state mandated science frameworks
- A daily evaluation

As an example, consider the production of ethanol by fermentation, the experiment of Day 6. The background focused on ethanol as an alternative fuel source (from sugars, corn, lignocellulosics), the yeast as a living organism and its ability to grow both aerobically and anaerobically, and the planned execution of the experiment. The experiment then followed, where the teachers compared anaerobic growth and production of ethanol vs. aerobic growth (and no ethanol), and CO_2 production during ethanol production both with and without agitation. The faculty member and teachers then discussed what happened and why, possible questions that the teachers might pose to students (such as why the same yeast can be used in making bread, making beer and wine, and producing energy), and experimental alternatives (fermentation of molasses or starch, the addition of nutrients, temperature effects). The integration of this particular experiment that lasts several hours into the classroom setting was also discussed, as well as how the length of the experiment would affect its ultimate use in their classrooms. Finally, the teachers evaluated the presentation and the experimental investigation.

Table 3 summarizes the features and shortcomings of the Year 1 institute. The teachers enjoyed the hands-on experimentation, rated the workshop as a great learning experience and invited several of the professors from the U of A for follow-up visits to their classrooms. While the summer institute gave the teachers eight hands-on experiments for use in their classrooms (not bad for last minute work due to late funding of the project), the teachers did not actually use many of the experiments in their classrooms because they did not feel comfortable with their understanding of the experiments and they felt that the experiments did not match well with State-mandated science frameworks. The major exception was the ball sorting exercise (Day 4), which challenged the students to develop an apparatus to separate three different size balls (BBs, marbles and ping pong balls), and assigned costs to raw materials and value to the separated balls. This design-oriented experiment was well received, and was used in most of the classrooms during the subsequent school year.

Table 3. Features and Shortcomings of the Year 1 Institute

Features	Shortcomings
• Teachers enjoyed hands-on experimentation and rated the workshop as a great learning experience • Teachers were given eight hands-on experiments for use in the classroom. This worked well, considering the "last minute" time constraint. • Of the Year 1 experiments, the simple design-oriented experiment (ball sorting) was used most in the classroom	• Teachers only marginally used the experiments from the summer institute. Are teachers are more likely to use "teacher-developed" experiments? • Some experiments did not match well with the State-mandated 6-8th grade science frameworks • Workshop organizers needed to better understand role of science frameworks in curriculum development

The Year 2 (2007) Institute

In 2007, 11 of the partner schools sent participants to the two week institute. Of the 27 science teachers participating in the institute, 8 were sixth grade teachers, 9 taught seventh grade and 10 taught eighth grade (see Table 1). With an extra year to plan the institute activities and the experience from Year 1, the Year 2 institute took on a new look, the use of the design loop method. Brad Dearing, a consultant with experience in the teaching and use of the design loop method, was hired to moderate the two-week institute. Engineering faculty from the U of A assisted Mr. Dearing during the workshop, and also observed and participated in follow-up activities during the academic year.

An overview of the daily institute activities (excluding daily feedback) is shown in Table 4. Each participant received the textbook *Understanding by Design*, 2nd edition, by Wiggins and McTighe,[7] and was provided a "toolkit" consisting of a typical worker's toolbox (approximately 1ft x 2ft x 1ft) and a large Rubbermaid® box (approximately 2ft x 3ft x 2ft) containing tools and miscellaneous supplies that can be used in a variety of hands-on activities. Further details of the Year 2 institute and follow-up activities were presented by Davis *et al.*[8, 9]

Table 4. Year 2 Institute Activities

Day	Activities
1	Introduction, needs assessment, engineering design problem solving, design briefs
2	Teacher testing, creating design briefs, design examples
3	Working through a design problem—buoyancy, presentation of design solutions
4	Analysis of designs, working through a second design problem—spinning wheels, ties to Arkansas science frameworks
5	Constructing a design brief activity
6	Finishing design briefs, preparing experiments
7	Swapping and performing another design brief
8	Finalizing and testing designs, presentation of results
9	Teacher testing, finish presenting results
10	How will you use design problem solving in your classroom?, resource exchange

As a way of teaching the participants how to design their own hands-on experiments, a series of design problems was presented to the teachers during Days 3 and 4 of the institute. After solving each design problem, the entire group analyzed the different designs. Through led discussion, the design activities were tied to the Arkansas science frameworks for each grade level. The focus then shifted to the preparation of design briefs and activities which were of particular interest to the participants. This was the perfect time for the participants to develop an open-ended design activity on a subject that was not previously illustrated very well in their classrooms. The teams of two teachers from different schools, but the same grade level, developed 18 new design briefs.

An example of these activities is the experiment entitled “Beak Builder Blowout”. This activity was designed for 6th graders, inviting them to investigate structural adaptation in a bird species. The students represent a team of genetic engineers who must create a prototype of a bird beak that can help the bird survive on a new food source, a type of worm that lives in sand. The students must construct various beak types from a list of materials and then test their suitability in removing gummy worms from sand. After the completion of the experiment and demonstrations by each team, the students are given a summary questionnaire that evaluates their understanding of what their team did. Evaluation of the students is based on their design plan, teamwork, creativity and workability of the designs.

Table 5 summarizes the features and shortcomings of the Year 2 institute. Brad Dearing was very effective in teaching the design loop method, including the preparation of design briefs. As a result, the 27 teachers created and shared 18 hands-on design-oriented experiments which matched well with State-mandated science frameworks. The teachers made significant progress in solving open-ended problems, moving from trial-and-error problem solving techniques at the beginning of the workshop to more of an analytical solution by the end of the workshop. However, some of the teachers did not fully grasp the techniques for creating and solving the problems, and will not likely transfer the concept to their classrooms.

Table 5. Features and Shortcomings of the Year 2 Institute

Features	Shortcomings
• A consultant who was proficient in the design loop method was hired to run	• Although the teachers made significant progress in creating and solving open-

the summer institute • The teachers were taught the design loop method, including the creation of design briefs • The teachers created and shared 18 hands-on design-oriented experiments which matched well with State-mandated science frameworks	ended problems, some teachers did not fully grasp the concept and will not likely transfer the concept to their classrooms

The Year 3 (2008) Institute

In 2008, the summer institute was switched to a one-week format at the request of the teachers, and 12 of the partner schools sent participants to the institute. Of the 36 teachers participating in the institute, 14 were sixth grade teachers, 6 taught seventh grade and 16 taught eighth grade (see Table 1). The 2008 institute also included math teachers (5 of the 36 teachers taught math), who were very interested in partnering with science teachers from their school to present math-oriented hands-on activities to their students. Due to the success of the Year 2 institute, Brad Dearing was once again hired to moderate the institute. In addition, seven engineering/math/science faculty members from the U of A were hired as consultants to serve as resources and assist the teachers in developing design-oriented activities.

An overview of the daily institute activities (excluding daily feedback) is shown in Table 6. As in Year 2, each new participant received the textbook *Understanding by Design.* All teachers were provided a new "toolkit" consisting of a typical worker's toolbox (approximately 1ft x 2ft x 1ft) and a large Rubbermaid® box (approximately 2ft x 3ft x 2ft) containing tools and miscellaneous supplies that can be used in a variety of hands-on activities. It should be noted that the contents of the Year 2 and Year 3 toolkits were not the same.

Table 6. Year 3 Institute Activities

Day	Activities
1	Introduction, teacher testing, mini-review of engineering design problem solving/design briefs, math teachers in the mix, working through a design problem—catapults
2	Finishing the catapults, meeting the faculty, working through a design problem—speakers, creating new design briefs
3	Finishing the speaker project, creating new design briefs
4	Focusing on teaching design briefs to students, continuing the preparation of design briefs
5	Presentation of design briefs, teacher testing

Because of the success of the Year 2 institute and follow-up activities, major changes in the format for Year 3 were not warranted. The Year 3 institute started with a mini-review of engineering design problem solving and design briefs, which then led to a discussion of how to include math teachers in the teaching of hands-on activities. Although math teachers can and should create their own design briefs, this is not a familiar activity for the typical math classroom. Perhaps a better idea is for math and science teachers to work together to create joint activities which have both math and science content. Joint activities may create classroom coordination problems, but the problems are relatively minor when considering the benefits of the hands-on activities. The participants were presented with two hands-on activities as learning exercises, and then spent the balance of the institute developing and sharing design brief activities that were created by the teachers. The teams of math and science teachers developed 16 new design briefs.

An example of a design brief which included both math and science is the experiment entitled "It's Raining Again". This activity was designed for both 6th and 7th graders, with the scenario that severe flooding in the Midwest has caused several homes to become cut off from the rest of the area by a body of water. The students are to construct a prototype device that will quickly move medical and food supplies across the water to people who are stranded. A "kiddie" swimming pool is used as the prototype pond, and the students will construct prototype rafts or other floating devices from available materials. Once the raft is constructed, the students collect data to determine the maximum quantity of each supply item that can be moved across the pool in three minutes. The data are then treated to determine mean, medium and mode loads, and the data are also plotted as bar graphs. After the completion of the experiment and demonstrations by each team, the students are given a summary questionnaire that evaluates their understanding of what their team did. Evaluation of the students is based on their design plan, teamwork, creativity and workability of the designs.

Table 7 summarizes the features and shortcomings of the Year 2 institute. With the aid of U of A faculty, the 36 math and science teachers created and shared 16 hands-on design-oriented experiments which matched well with State-mandated science and math frameworks. Although Brad Dearing was effective in teaching the design loop method, perhaps more time should have been allotted in the workshop to grasping the design loop process since some of the teachers were new to the UASPP and it was apparent that some of the teachers (and particularly the math teachers) did not fully grasp the techniques for creating and solving the problems.

Table 7. Features and Shortcomings of the Year 3 Institute

Features	Shortcomings
• Math teachers were added to the group of participants, and accounted for 14% of the participants • Seven additional professors were added to the institute staff as technical resources • The teachers were taught the design loop method, including the creation of design briefs, in a mini-review • The teachers created and shared 16 hands-on design-oriented experiments which matched well with State-mandated math and science frameworks	• Although the teachers made significant progress in creating and solving open-ended problems, some teachers still did not fully grasp the concept and will not likely transfer the concept to their classrooms • Math teachers were less comfortable with the design loop process, and will most likely be dependent upon science teachers at their schools for implementation in the classroom • More time should have been allotted in the workshop to grasping the design loop process

Evaluation/Use of Institute Activities

One way to measure the success of the UASPP program is through teacher evaluations of the summer institutes activities. These evaluations were given daily during each summer institute, and consistently showed that the teachers were very impressed with the content of each of the summer institutes, the knowledge and help of the moderators, and the hands-on experiments that they were able to take back to their classrooms. Details of Year 1 and Year 2 institute evaluations were presented by Davis *et al.*[6, 9]

Perhaps a better measure of the success of the program is the use of the institute activities in the classroom. As is noted in Table 8, U of A faculty and staff visited the teachers' classrooms in follow-up activities to observe student use of institute activities in the classroom or to make classroom or multi-classroom presentations. During the 2006-2007 school year, visitations by faculty and staff were by invitation from the teachers, and only 9 teachers were visited by 3 members of the U of A faculty and staff to make classroom or multi-classroom presentations. In the 2007-2008 and 2008-2009 school years, follow-up visits were scheduled by the institute staff, and 19 teachers were visited by 10 U of A faculty/staff in 2007-2008 and 26 teachers were visited by 14 faculty/staff in 2008-2009. Although most of the visits in 2007-2008 and 2008-2009 were to observe classroom activities, U of A faculty/staff also made presentations to classrooms and participated in Science Night activities.

Table 8. Follow-up Visitation Activities

School Year	Number of Classroom Visits	Number of Teachers Visited	U of A Faculty/ Staff Involved	Purpose of Visits
2006-2007	5	9	3	Presentations to classes
2007-2008	22	19	10	Class observations, Science Night, presentations
2008-2009	24	26	14	Class observations, Science Night, presentations

Table 9 shows a summary of the 2007-2008 and 2008-2009 use of the design activities by the teachers, as reported on surveys collected throughout the school year. The teachers were not surveyed for their use of institute activities during the 2006-2007 school year. The activities are categorized as design activities that were presented by the moderator at the institutes, design activities that were developed by the teacher groups at the institutes, and design activities that were developed by the teachers after the institutes. In 2007-2008, 19 moderator-developed design activities were used by the 21 teachers that were surveyed, for an average of 0.9 moderator-developed activities per teacher. Eight of the teachers chose not to use these activities in their classrooms, and two teachers used three moderator-developed activities. In 2008-2009, only 3 moderator-developed activities were used by the 23 teachers that were surveyed, for an average of only 0.1 moderator-developed activities per teacher. Only three teachers chose to use moderator-developed activities, and all three used the ball-sorting experiment from 2006-2007. This lack of use of the moderator-developed activities seems to be a problem but, in reality, it is not. As an indication of the effectiveness of the workshop message, 73 teacher-developed design activities were used by the 21 teachers in 2007-2008, for an average of 3.5 teacher-developed activities per teacher. Three of the teachers chose not to use teacher-developed activities, and one teacher used seven activities. In 2008-2009, 83 teacher-developed design activities were used by the 23 teachers, for an average of 3.6 teacher-developed activities per teacher. Two of the teachers chose not to use teacher-developed activities, and three teachers used nine activities. Best of all, in 2007-2008 34 new design activities were developed and used by the 21 teachers after the workshop for an average of 1.6 new activities per teacher. Three of the teachers did not develop new activities, and one teacher developed six new activities for the classroom. In 2008-2009, 37 new design activities were developed and used by the 23 teachers after the workshop for an average of 1.6 new activities per teacher. Seven of the teachers did not develop new activities, and two teachers developed five new activities for the classroom. Thus, the teachers were very active in using activities that they developed, and in using institute techniques in developing additional activities.

Table 9. Teacher Use of Institute Activities

Institute Activities	Activity Use per Teacher		
	Minimum	Average	Maximum
2007-2008 (21 teachers surveyed)			
Design Activities presented at Workshop	0 (8)	0.9	3 (2)
Design Activities developed by teachers at Workshop	1 (3)	3.5	7 (1)
Newly developed Design Activities	0 (3)	1.6	6 (1)
2008-2009 (23 teachers surveyed)			
Design Activities presented at Workshop	0 (20)	0.1	1 (3)
Design Activities developed by teachers at Workshop	0 (2)	3.6	9 (3)
Newly developed Design Activities	0 (7)	1.6	5 (2)

2009 Institute Plans

Funding from the Arkansas Department of Education begins in 2009 for the new University of Arkansas Engineering and Science Partnership (UAESP). Seventy teachers initially signed up for the first summer institute but, due to limitations in funding, the number was pared to 42 teachers from 17 partner schools (see Table 1). The format for the UAESP institutes and follow-up activities will be very similar to the 2007 and 2008 programs with a few notable changes:

- Due to funding limitations, the workshop will be limited to 6th and 7th grade science teachers from the partner schools. There is a possibility for funding for additional teachers in 2010 and, if funding becomes available, 8th grade science teachers will be added. There are unfortunately no plans for adding math teachers, even though it is realized that a significant need exists for adding hands-on experimentation to middle school math classrooms.
- The State is emphasizing teacher-content knowledge in State-mandated science framework areas for the upcoming summer institutes and follow-up activities. The 2009 institute will focus on energy and mixtures and their separation, the two areas of poorest student performance on benchmark science knowledge tests. Engineering professors with expertise in these areas will be used to increase teacher-content knowledge, and to

serve as resources both for developing hands-on design-oriented experiments and as classroom visitors throughout the school year.

- Evaluation of teacher and student performance has been a weakness of the UASPP program. A consultant has been hired to develop, monitor and evaluate performance test data, and thus evaluation will now be a strength of the UAESP program.

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