University of Arkansas Science Partnership Program: Lessons Learned In Evaluating Year One

Shannon G. Davis[1], Carol S. Gattis[2] and Edgar C. Clausen[3]

College of Education and Health Professions[1]/College of Engineering[2]/
Ralph E. Martin Department of Chemical Engineering[3]
University of Arkansas

Abstract

The University of Arkansas Science Partnership Program began in 2006 and focuses on the professional growth of 6th, 7th and 8th grade science teachers through three summer institutes and follow-up activities. Teachers are teamed with engineering faculty to improve teaching skills and to increase teachers' use, understanding and application of laboratory exercises. The Partnership Program consists of three parts: 1) instruction at the institutes using a number of hands-on activities that will be used in the classroom; 2) follow-up activities at the middle and junior high schools and; 3) evaluation, both during and after the summer institutes.

In evaluating Year 1 of the program, several important lessons were learned:

- Arkansas Science Curriculum Frameworks are structured with minimal overlap from grade to grade, making it difficult to structure activities that fit equally well in each middle school grade levels.
- Despite the imperative to directly align experiments with the Curriculum Frameworks, teachers and students thoroughly enjoyed experiments with an engineering theme.
- None of the teachers used all (or a majority) of the experiments from the Year 1 institute.
- Some teachers requested the complexity of the lab activities be increased for specific subject areas and for specific grade levels.
- The level of participation in the follow-up activities and the amount of provided materials used in the classroom as a direct result of the institute suggested that many teachers did not play a large enough role in the development of the activities and experiments used.

The impact of these lessons on the content and organization of the summer institute will be the focus of Year 2. The Year 2 Institute will teach the participants to design their own experiments using a backward design teaching method, emphasizing results-driven outcomes. The philosophy of this approach focuses on three components: 1) a clear set of desired results by identifying goals for students, identifying the specific information students will understand and what students would be able to do as a result of the learning activity; 2) identification of assessment evidence, allowing teachers to develop performance tasks to evaluate student results; and, 3) creating a learning plan that includes activities for students, enabling them to achieve the desired results.

This approach allows us to address the lessons learned in Year 1, because the approach will work regardless of the framework standard or grade level. This approach also allows teachers to use

engineering problem-solving techniques as experiments, which they preferred most during the Year 1 Institute. If the teachers learn to *design* an activity, they will be more likely to use it in the classroom. The approach allows teachers to determine the level of experiment complexity to best fit their grade level. Last, this approach forces the teachers to take ownership of the created experiments so they will be more interested in follow-up activities and in utilizing such approaches in their classroom.

Introduction

The National Science Foundation has recognized that we must introduce students to engineering and science in middle school (or even earlier) if we are to attract more students to engineering and reverse the trend on the national crisis of too few students entering the engineering discipline.[1] Most 6th, 7th and 8th grade students do not know what engineering is, and do not recognize engineering as a viable career option. Furthermore, research tells us that women and minority students are drastically underrepresented in the engineering fields.[2] To more effectively prepare students in their pursuit of an engineering degree, students should be encouraged to take the appropriate math and science sequences that now typically begin in middle school or junior high, so that ultimately they will have the math, chemistry, calculus and physics that prepares them for an engineering major.

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 that help to form the base for the engineering discipline. This University of Arkansas Science Partnership Program is a three-year Summer Institute program funded by the Arkansas Department of Higher Education which focuses on the professional growth of 6th, 7th and 8th grade science teachers from 23 schools in the NWA-ERZ. The Program teams teachers with engineering faculty to improve teaching skills and to increase the teachers' use, understanding and application of selected laboratory exercises. It includes classroom/laboratory instruction, follow-up activities at the schools, and evaluation, both during and after the institute.

During Year 1 in the Summer of 2006, the Summer Institute was operated as an all inclusive workshop for all of the 6th, 7th and 8th grade science teachers. This concept created problems, as detailed below, since some of the experiments were more appropriate for 6th grade teachers, for example, while others were more appropriate for teachers of other grade levels. This lesson, as well as other lessons learned from evaluations and follow-up activities, was used in formulating and preparing the workshop for Year 2. The purpose of this paper is to summarize the workshop activities and lessons learned from the Year 1 workshop, and to present an outline of the proposed Year 2 workshop which seeks to incorporate responses to these valuable lessons.

The Year 1 Institute

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 the full three years.

A needs assessment instrument was devised to identify teacher quality and professional development needs for schools with respect to the teaching and learning of science. The instrument was designed and administered by personal interviews with science teachers or the lead mentor teacher in the science area. The first section of the instrument addressed current teaching status, and showed that 100% of the polled respondents taught in the academic subject and grade level for which they were trained and licensed. Therefore, all science teachers in these schools met the State's definition of a highly-qualified teacher.

The second section of the needs assessment addressed the teaching and learning of science. Possible professional development topics based on the Science Curriculum Frameworks for grades six through eight were listed on the assessment tool, and teachers were instructed to rank those topics in order from their greatest need to their least important need. All respondents marked lab activities as one of their top three priority needs. The top two lab topics of greatest need were Arkansas Landforms and Newton's Three Laws of Motion. Predict Weather Conditions and Solubility Rates tied for third. Various other topics were also marked including: Mean, Median, Mode; Charts, Graphs, Stem and Leaf Plots, Physical and Chemical Changes, Effect of Force on Direction and Speed, Geological Events, Potential and Kinetic Energy, and Predicting Weather Conditions.

The authors reviewed numerous potential laboratory experiments for inclusion in the summer institute. Each potential experiment was carefully reviewed for safety, grade level appropriateness and alignment with the Science Frameworks. Approximately ten laboratory activities were developed for the Year 1 Institute.

The Workshop

A summary of the Year 1 laboratory experiments and other workshop activities is shown in Table 1. The daily sessions (3-4 hours) were conducted in the classroom (as opposed to a laboratory), since the classroom is most often the setting for experimentation in middle and junior high schools. Each of the teachers was given all of the supplies required to carry out the laboratory activities (including the nonconsumable items), a notebook containing background material and suggestions for each experiment, a detailed equipment list for each experiment, and a list of experimental procedures and any safety issues that should be addressed when implementing an experiment. 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.

Table 1. Workshop 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 activities of Day 1 of the workshop included an introduction of the participants, a discussion of the purpose and organization of the workshop, a discussion of the State mandated high school science frameworks and how the workshop activities fit into these frameworks, an overview of the experiments and safety training by the Chemical Engineering Department Safety Officer. Even though the workshop experiments were designed to be safe and the teachers will ultimately use the experiments in a classroom setting, a safety mindset is of paramount importance in participating in any "hands-on" activity. This safety mindset was passed on to the teachers, and was to be implemented into their classroom activities as well. Day 1 also included a short experiment that was most suitable for classroom demonstration on the liquefaction of soil during earthquakes, which was taken from The Exploratorium (http://www.exploratorium.edu/faultline/activezone/liquefaction.html). This experiment was of particular interest to teachers and students from this part of the country due to the recent publicity of the New Madrid fault in Northeast Arkansas and Southeast Missouri.

Following teacher testing for science content knowledge on Day 2, the Day 3 activities were directed toward understanding the behavior of acids and bases. The pH of common household items (tap water, dishwashing liquid, lemon juice, vinegar, bottled water, a soft drink, milk, buttermilk, vegetable juice, drain cleaner, ammonia, baking soda solution, etc.) was predicted and then measured using pH paper and a pH meter. The ball sorting exercise of Day 4 was an engineering design, problem solving and optimization exercise in which the teachers designed and constructed a sorter to sort balls of different sizes (BBs, marbles, ping pong balls). The teachers were given a number of items for use in the construction of the ball sorter, and each item had a cost associated with its use. The goal was to design the most efficient sorter while spending the least amount of money. In Day 5, a mold terrarium (from The Exploratorium, http://www.exploratorium.edu/science_explorer/mold.html) was constructed in an effort to investigate living systems, specifically the growth of mold varieties on common household food items.

The fermentation of table sugar by yeast (purchased in a local supermarket) to produce ethanol was investigated on Day 6. Aerobic fermentation to produce CO_2 and cells (as in the rising of bread) was contrasted with anaerobic fermentation to produce less cells, CO_2 and ethanol (as in the brewing industry) by this facultative organism. On Day 7, the densities of a various solids were obtained by finding the ratios of the measured masses and volumes. Simple batteries were constructed on Day 8 using different metals as electrodes, along with fruits and vegetables as electrolyte solutions. Connecting these batteries in series enabled the teachers to power a small light bulb. Finally, the teachers learned about chemical reactions and reaction rates in Day 9 by observing two reactions: the reaction of baking soda and vinegar to produce salt, CO_2 and water; and the fading of phenolphthalein in basic solution. Final testing and evaluation occurred on Day 10.

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 topic 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, in which the teachers compared anaerobic growth and production of ethanol vs. aerobic growth, and CO_2 production during ethanol production both with and without agitation. The moderator 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 was also discussed, as well as how this would affect its ultimate use in their classrooms. Finally, the teachers evaluated the presentation and the experimental investigation.

In addition to the daily general laboratory activities, specific blocks of time were scheduled for curriculum mapping, as well as horizontal and vertical alignment among participants. Dr. Heidi Hayes Jacobs advocates collecting real-time information about what is actually taught to create curriculum maps.[3] Teachers had real-time information to develop maps with other grade-level teachers to align the activities to the Science Frameworks for each grade level. This activity ensures smooth transitions between grade levels in order to avoid gaps and overlaps in the curriculum.

The Year 1 Institute concluded with a session on scientific action research, which focused on data collection by the teachers and subsequent data analysis and potential uses of the analysis by the school for future curriculum planning. Day 10 also included a discussion of the follow-up activities that would be conducted during the upcoming school year.

Evaluation

The success of the program is being measured by the performance of participating teachers and their students on standardized assessment tests, and by teacher evaluation of the workshop experiments. The teacher assessment was developed at the University of Louisville, Center for Research in Mathematics and Science Teacher Development, and will be administered both at the beginning and at the end of each workshop. Students will be tested each spring using the Iowa Test of Basic Skills (ITBS) as an assessment of student performance, as part of the State's required accountability testing system. Assessment results from the Year 1 Institute were not yet available at the time this manuscript was prepared.

Results from the evaluation of the daily workshop experiments by the participating teachers are shown in Table 2. The teachers were asked to evaluate the alignment of the activity with the Arkansas Science Curriculum Frameworks, the quality of the presenter (moderator), whether or not they planned to incorporate the activity into their classroom curricula, whether or not they felt like they knew whom to contact for further information, whether the resources from the experiment would be useful to them in the future, and whether the time spent on vertical alignment of the experiment into the curriculum frameworks was useful. Evaluations were obtained for each of the experiments using a 1-5 rating system, where 5 indicates that they strongly agree.

Table 2. Evaluation of Daily Experiments

Evaluation Statement	Experiment/Evaluation							
	A	B	C	D	E	F	G	H
Lab activity is directly aligned with the Arkansas Science Curriculum Frameworks	4.7	4.5	4.8	3.8	4.6	4.7	4.9	4.7
Presenter was knowledgeable regarding the topic presented	4.4	4.9	5.0	4.8	5.0	4.9	4.3	5.0
I will incorporate the activity into my curriculum	4.2	4.2	4.8	3.7	4.4	4.3	4.5	4.6
I know who to contact with questions about this activity, especially as it relates to implementation in my classroom	4.7	4.9	4.9	4.8	4.8	4.8	4.6	5.0
Resources provided during this activity will be useful to me in the future	4.5	4.7	4.9	4.0	4.8	4.7	4.8	4.7
The time provided for vertical alignment was useful to me	4.4	4.6	4.8	4.5	4.8	4.7	4.9	4.8

Experiments:
A. Earthquakes
B. Acids and bases
C. Ball sorting
D. Mold terrarium
E. Ethanol production
F. Densities of solids
G. Batteries
H. Chemical reactions

Evaluation:
5—Strongly agree
4—Somewhat agree
3—Don't know
2—Somewhat disagree
1—Strongly disagree

Perhaps the most important assessment statements relate to the willingness of the teachers to incorporate the activity into their curriculum and the perceived usefulness of the activity for future use. In general, all of the activities scored well in these (and other) areas. However, the ball sorting activity rated highest in both of these areas (4.8 and 4.9, respectively), and the mold terrarium rated lowest (3.7 and 4.0, respectively). Comments from the ball sorting activity included "Excellent high inquiry opportunity" and "Thanks. I think I'll start the year with this activity". Comments from the mold terrarium experiment included "Doesn't specifically fit, but I can make it work" and "Most closely aligned to 5th grade frameworks".

Additional evaluation questions were posed in order to learn what the participants thought of the Institute in general. The participants were asked whether they felt presenters were knowledgeable, whether the resources provided were useful for the future and whether they learned something from this Institute they would use in their classroom. Of the 24 respondents, 20-24 agreed that the presenters were knowledgeable, the resources were helpful, and they would use what they had learned in the classroom. Some of the open-ended responses included "Dr. Clausen has been great. Everybody involved has been wonderful." Also, "The partnership between the College of Education and the College of Engineering was great. I think there is a lot we can learn from each other." Finally, "Resources have been great. The people and the materials will help me out a lot."

Lastly, we asked the participants if they felt they knew who to contact with questions, if they would recommend this activity to others and whether or not they would like to see similar activities presented in the future. With the exception of one respondent, all participants understood who to contact with questions, would recommend the Institute to others and would definitely like to see such activities provided in the future. Some of the open-ended responses included the comments "Working with peers is very helpful. One gets different perspectives from the different grade levels and even people from your own grade level but from different schools." Also, "I would highly recommend this to others."

Follow-Up

A number of follow-up activities occurred after the completion of the Year 1 workshop including:

- Engineering faculty and staff participation in extracurricular "Science Nights" and invited technical presentations/demonstrations at several of the participating schools
- Visits to middle school and junior high classrooms by Program mentors to assess the teachers' use of the laboratory activities, to provide assistance in preparing or performing the experiments, to obtain feedback on the use of the workshop activities and to collect teacher comments on the workshop and what they would like to see in future institutes
- Informal get-togethers to discuss the teachers' use of hands-on activities
- Regular and occasional phone calls and e-mails from Program mentors and staff to provide assistance to the teachers in the form of additional hands-on activities, clarifications and advice
- Data collection by science teachers and a program evaluation

These follow-up activities provide the additional time needed for inquiry, reflection, mentoring and sustaining the long-term practice of including hands-on laboratory activities in the classroom.

Observations/Lessons Learned

In evaluating Year 1 of the program though formal evaluations and follow-up activities, several important lessons were learned. First, because of the way in which the Arkansas Science

Curriculum Frameworks are structured with minimal overlap from grade to grade, it is very difficult to structure workshop activities which fit equally well in each of the middle school grade levels. The teachers were often challenged by the moderators to find ways to make a particular activity fit into their grade level curriculum when the fit was not obvious. There were also times when the activity was appropriate for any grade (the ball sorter activity), but the teachers were then challenged to make sure that the activity would fit within their frameworks while being easy enough for sixth graders and complex enough for eighth graders.

Second, despite the imperative to directly align experiments with the Arkansas Curriculum Frameworks, teachers and students thoroughly enjoyed experiments with an engineering theme. As was noted earlier, the ball sorting activity rated highest in both teacher willingness to incorporate the activity into the curriculum and the perceived usefulness of the activity for future use. Third, in speaking to teachers during follow-up meetings, it was found that none of the teachers used all (or a majority) of the experiments from the Year 1 Institute. Many of the simpler experiments (earthquakes, acids and bases, density) were incorporated into lesson plans, but the teachers avoided experiments such as ethanol production, perhaps because they did not have a high comfort level with using a perceived "complicated" experiment.

Despite this last comment, some teachers requested the complexity of the lab activities be increased for specific subject areas and for specific grade levels. Many participants had helpful suggestions during follow-up discussions with regard to what types of lab activities would be helpful in subsequent Institutes. Finally, the level of participation in the follow-up activities and the amount of provided materials used in the classroom as a direct result of the Institute suggested that many teachers did not play a large enough role in the development of the activities and experiments used. Perhaps the teachers should play a larger role in the selection, design and development of experiments in order to develop a sense of "ownership" in the experiments.

The workshop moderators also learned some valuable lessons from observing the teachers in a classroom setting. Classroom facilities vary significantly by school district—larger districts do not necessarily have better facilities. Money for instructional activities is always at a premium, and many of the teachers provide this money out of their own pockets. All of the teachers teach multiple classes, and repetition of material can be boring. Sixth to eighth grade students can be a challenge to handle and, unlike college, discipline is always an issue. But perhaps the most exciting thing that the teachers conveyed to the moderators is their genuine interest in the students, and their desire to provide the best possible instruction to shape and challenge young minds.

Year 2 Institute Plans

The impact of these observations and lessons learned will be reflected in the content of the Institute in Year 2. The Year 2 Institute will teach the participants to design their own experiments using a backward design teaching method, emphasizing results-driven outcomes. The Institute will be presented by Dr. Brad Dearing of Illinois State University. The philosophy his approach focuses on three components: 1) a clear set of desired results by identifying goals for students, identifying the specific information the students will understand and what the students will be able to do as a result of the learning activity; 2) identification of assessment evidence, allowing teachers to develop performance tasks to evaluate student results; and, 3) the creation of a learning plan that includes activities for students, enabling them to achieve the desired results.[4] An outline of the Year 2 workshop is shown in Table 3.

Table 3. Year 2 Engineering Design Workshop Activities

Day 1	
- Introductions	- Overview/Agenda
- Needs Assessment—Why are we here?	- What is an Engineering Design Problem Solving?
- Types of problems	- What is a "Design Brief"?
- Daily Feedback	
Day 2	
- Pre-Test	- Group/Teamwork Activity—Toxic Popcorn Activity
- Creating Design Briefs	- Examples
- Daily Feedback	
Day 3	
- Group/Teamwork Activity	- Work through a design problem
- Present design solutions	- Daily Feedback
Day 4	
- Group/ Teamwork Activity	- Analysis of buoyancy designs—How could the solutions be better? How could the problem be written better?
- Ties to Arkansas Curriculum Frameworks	- Daily Feedback
Day 5	
- Group/Teamwork Activity	- Construct a design brief activity
- Daily Feedback	
Day 6	
- Finish Design Briefs	- Gather materials
- Daily Feedback	
Day 7	
- Design Brief Swap	- Daily Feedback
Day 8	
- Continue Design Swap	- Daily Feedback
Day 9	
- Post-Test	- Present Results
- Daily Feedback	
Day 10	
- Design problem solving in your classroom	- Resources Exchange
- Overall Feedback Survey	

Highlights of the proposed Year 2 workshop include the implementation of the IDEAL (I = Identifying Problems, D = Defining Problems, E = Exploring Alternatives, A = Acting on a Plan, L = Looking at the Effects) approach to problem solving, tying experiments to the

Arkansas Curriculum Frameworks (forensics, tissue engineering, a bacterial bottle washer for the Life Science Framework; a Rube Goldberg apparatus, generator-motor, musical instrument for the Physical Science Framework; water bottle rockets, Estes rockets, constellation finder for the Earth and Space Science Framework), having teachers design their own experiments and swapping designs with other teachers. This approach will allow the Program mentors to address the lessons learned in Year 1, because the approach will work regardless of the framework standard or grade level. The approach also allows teachers to use engineering problem-solving techniques as experiments, which they preferred most during the Year 1 Institute. If the teachers learn to *design* an activity, they will be more likely to use it in the classroom. The approach allows teachers to determine the level of experiment complexity to best fit their grade level. Last, this approach forces the teachers to take ownership of the created experiments, so they will be more interested in follow-up activities and in utilizing such approaches in their classroom.

Bibliography

1. Gabriele, Gary A. "The Future of NSF Engineering Education Programs." National Science Foundation. www.nsf.gov.
2. Gabriele, Gary A. "The Future of NSF Engineering Education Programs." National Science Foundation. www.nsf.gov.
3. Jacobs, H., 1997, *Curriculum Mapping and Alignment Across the Discipline,* Alexandria, VA.
4. Wiggins, G., McTighe, J., 2005,*Understanding by Design*, 2nd Edition, ASCD Publishing.

SHANNON G. DAVIS
Dr. Davis is the Director of Research and a Research Assistant Professor in the College of Education and Health Professions. She conducts research in the area of education policy, school-based interventions, minority political attitudes in the area of education, organizational behavior and political psychology. She has taught courses in these areas and has been at the University of Arkansas for ten years.

CAROL S. GATTIS
Dr. Gattis is an Associate Professor of Industrial Engineering and Director of Recruitment, Retention, Honors and Diversity for the College of Engineering at the University of Arkansas. In this latter role, she directs and develops new programs for the college-wide efforts in recruitment, retention and diversity.

EDGAR C. CLAUSEN
Dr. Clausen currently serves as Professor and the Ray C. Adam Endowed Chair in Chemical Engineering at the University of Arkansas. His research interests include bioprocess engineering (fermentations, kinetics, reactor design, bioseparations, process scale-up and design), gas phase fermentations, and the production of energy and chemicals from biomass and waste. Dr. Clausen is a registered professional engineer in the state of Arkansas.