SUMMER PROGRAMS TO IMPROVE SCIENCE, MATHEMATICS, ENGINEERING, AND TECHNOLOGY EDUCATION IN K-12 SCHOOLS

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1. INTRODUCTION

Teaching elementary and secondary students in science, mathematics, engineering, and technology has always been challenging, and the challenges of such a career are becoming even more significant as we progress into the 21st century. Three primary aspects of the field make it difficult to achieve and maintain excellence:

- The interdisciplinary nature of these fields requires individuals to develop a wide variety of expertise or to team with others of diverse education and experience. (Mulholland, 2002)
- The fields change so rapidly that teachers must continually engage in professional development and continuing education to maintain their currency. (Davis, 2003)
- Students' perception of these fields is generally negative, which decreases their motivation to learn the subjects. (McDuffie, 2001)

Fortunately, several strategies have been developed to support teachers facing these challenges. Among the most important of these innovative teaching and learning strategies are:

- Inquiry-based teaching and learning, in which students learn the subject by performing their own investigation using experimental methods and team-oriented problem-solving techniques. (Akerson and Dickinson, 2003; Barman, 2000; Smith and Wesley, 2000)
- Cooperative efforts by elementary and secondary teachers with university professors and practitioners in the field. (Moreno, *et. al.*, 2001; Barnett, *et. al.*, 2002; Porter, 2002; Cannon and Sandler, 2000)
- Dedicated summer workshops that enable teachers to develop new knowledge and to reinforce existing capabilities. (King, 2002; Levitt and Manner, 2001; Moore, 2001)

For the past eight years, Valparaiso University has been utilizing these three strategies by presenting K-12 teachers with the opportunity to participate in a series of on-campus summer workshops in which they learn about science, mathematics, engineering, and technology through hands-on experiments that they can then take back to their own classrooms. These workshops have focused on allowing the teachers to develop lesson plans that are connected to the experiments being conducted and in building cross-disciplinary relationships. It is the goal of these workshops to allow elementary and secondary teachers to spark an interest in their students about pure and applied sciences through the use of state-of-the-art hands-on experiments.

2. THE PROJECT FOR SCIENCE, MATHEMATICS, AND ENGINEERING (PSME)

The Project for Science, Mathematics and Engineering (PSME) was initially funded in 1996 by the Lilly Endowment as part of a broad initiative to increase the number of Indiana high school students attending college, graduating from college, and remaining in Indiana to work after college graduation. From its inception, PSME focused on science and mathematics education by offering outreach programs for secondary teachers and their students. The project specifically targeted urban and rural school districts with low college-bound populations, but also served faculty and students from suburban secondary schools. The program components begun under the Lilly initiative included three major efforts:

- ***The Secondary Science and Mathematics Teacher Enhancement Program*** brought teachers to Valparaiso University for up to two weeks to participate in classroom and laboratory activities in biology, chemistry, astronomy, mathematics or engineering during the summer. This program focused on strategies to rejuvenate teaching and learning. The program also included experiential and hands-on activities, including exposure to scientific instrumentation that teachers used in their classrooms during the school year.

- ***PC-Based Interactive Guides to Technical Careers*** motivated secondary school students to pursue technological careers and to pursue a college education that would prepare them for careers in science, technology and engineering. The guides included an Engineering Home Page that links interested students to guidance resources available on the Internet as well as an interactive CD-ROM, titled *Time Engineers*, which was completed in 2000. *Time Engineers*, designed for students in grades 7-10, allowed secondary students to explore and apply engineering principles in a game environment.

- ***The Initiative for Schools, Industries and the Sciences (ISIS),*** which is still operating and now includes a professional development training component for K-12 teachers**,** provides training and modern scientific instruments and technology to participating teachers in Northwest Indiana schools. This unique program, as originally conceived, reinforces the connection between science learned in classrooms and real-world applications.

2.1. Integrating Engineering into Secondary Education: The PSME Workshops.

As part of this effort, Valparaiso University's College of Engineering conducted summer workshops every summer from 1999 to 2002. These one-week summer workshops were funded by the university's PSME grant and were available for science, mathematics, and technology teachers in grades 7 through 10. The three main objectives of the workshops were to:

1. *Provide an introduction to the engineering profession.* Many teachers do not have a clear understanding of what engineers do. By learning about engineering, they could provide their

students with information about careers in the field and could show how what they are studying now can be used in the real world.

2. *Present activities that demonstrate engineering concepts in the areas of civil, mechanical, and electrical/computer engineering.* Teachers in mathematics and science are always looking for examples they can use to illustrate fundamental principles and at the same time make them interesting to students.

3. *Facilitate interaction between teachers in the areas of science, mathematics, and technology.* The activities and examples presented during the week were designed to demonstrate that engineering spans a number of disciplines and that teachers in these different disciplines could work together to teach a specific topic or area.

The workshop was structured so that the teachers were able to learn about the three main engineering disciplines (civil, mechanical and electrical/computer) using a combination of lectures, discussions, field trips, and hands-on activities. An entire day was spent on each of the different engineering disciplines, allowing the teachers to see both the breadth and depth of a discipline in an uninterrupted block.

Monday was focused on general engineering and an introduction to the topic of engineering design. The teachers were given an overview of the field of engineering and then participated in a design activity that introduced them to some of the fundamental concepts associated with engineering (including optimization of resources, cost, and time). The three main disciplines were presented on Tuesday, Wednesday, and Thursday. Each of these days followed a similar structure. First, the teachers were given an overview of the basic mathematical and scientific concepts associated with the discipline. These initial technical presentations were designed to be at a level that could be understood by an educated person who is unfamiliar with the field. Then the teachers participated in a number of hands-on activities to reinforce the concepts that they had learned.

Some of the activities presented were an introduction to trusses using K'nex and the West Point Bridge Designer, a simple computer aided drafting and design (CADD) activity, tensile testing using drinking straws, an intruder alert electronic circuit design, simple sound monitoring using an oscilloscope, and rapid prototyping of electronic circuits. These activities were each carefully selected to be easily adapt to the teachers' classrooms after the workshops were complete.

At the end of each day, teachers spent time learning how to use the *Time Engineers* interactive software (Johnson, 2000). As mentioned earlier, this software was developed as the second component of the PSME grant and was used to motivate students to study engineering. Also during these three days there were typically two field trips to local engineering industries to illustrate engineering in practice. On Friday, the teachers worked on developing lesson plans and participated in group discussions about how to use the concepts and activities they had just seen to enhance their mathematics and science classes.

During this four-year period, over 40 secondary school teachers from Northwest Indiana attended these workshops. The teachers came from a variety of schools (ranging from small rural schools to large urban schools) and taught a range of subjects (from AP chemistry to Algebra I to high school technology). To ensure teachers would attend the workshop, the grant provided funds for all meals and housing, and each teacher received a small stipend along with one hour of graduate level credit upon successful completion of the workshop.

Overall, the teacher's response to the workshop was overwhelmingly positive. Not only did they leave the workshop with a better understanding of what engineers do, but they also took with them practical examples of fundamental engineering principles that they could use in their own classroom. When they were contacted six months after the workshop, many teachers had or were planning to incorporate what they learned into their classes.

Eight Valparaiso University engineering faculty assisted with this project during its four years of operation. These faculty helped organize the workshops as well as developed and presented the lessons and activities that were in their discipline. At times, developing the activities for the workshop was a challenge because the faculty had to take into account the education of the teachers as well as frame the engineering activities so that students in middle and high school could use them to learn about engineering concepts. Through all of their time and effort, the engineering faculty who participated gained a better understanding of secondary education, which was an additional benefit of this project.

2.2. Assessing the Outcomes of the 2002 PSME Engineering Workshop.

At the end of each engineering workshop, participants were asked to complete an evaluation form that included both formative and summative evaluations of the workshop objectives and activities. For each question, they were asked to respond using a five-point Likert-scale question. The results of these responses were then averaged to determine the performance index for that item, which can range from a score of 1 (very negative) to a score of 5 (very positive). For the most recent engineering workshop (in 2002), there were seven participants who completed this survey, which had 26 questions.

The first seven questions asked participants to evaluate their own ability to complete each of the workshop objectives:

1. Describe what engineering is.
2. Describe the differences between the primary disciplines of engineering.
3. Identify enrichment activities that will promote engineering in your classroom.
4. Develop a list of available resources about engineering for your students.
5. Develop an action plan that will be used at your school to stimulate minority student interest in engineering careers.
6. Identify the preparation needed for an engineering career.
7. Enhance the topics in your curriculum with engineering activities.

For each question, they could choose from one of five responses:

1 = "Not able"
2 = "A little bit"
3 = "50-50"
4 = "Pretty Sure"
5 = "Confident"

The average responses on these seven questions are shown below in figure 1 for participants in the 2002 PSME Engineering workshop.

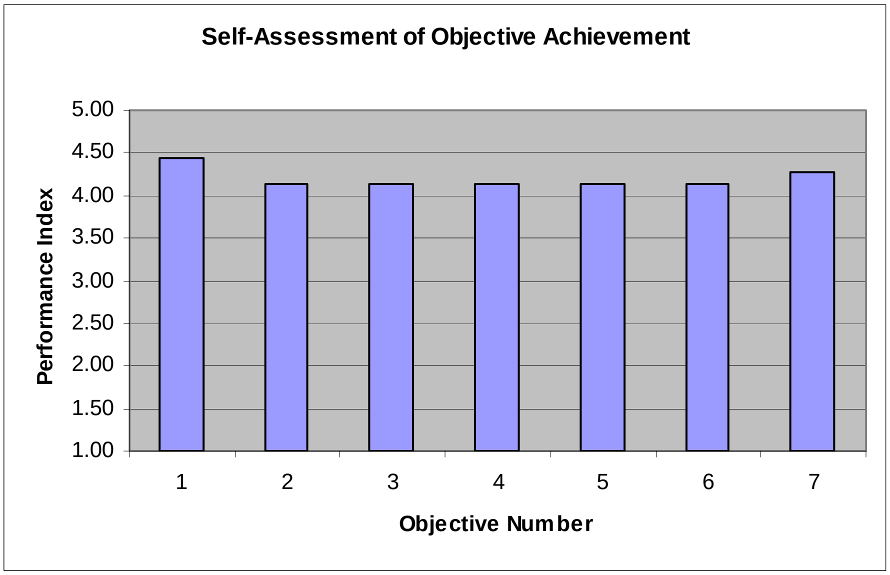

Figure 1: Self-assessment of 2002 engineering workshop objectives.

The overall average of these seven questions was 4.2/5.0, which demonstrates that the workshop substantially achieved its objectives.

The next 26 questions asked participants to evaluate the value of each daily activity (1=low to 5=high) and how well it was conducted (1=unsatisfactory to 5=excellent). For clarity, these responses have been grouped together into discipline-specific categories in figure 2 to illustrate the average response given for all activities associated with a particular discipline.

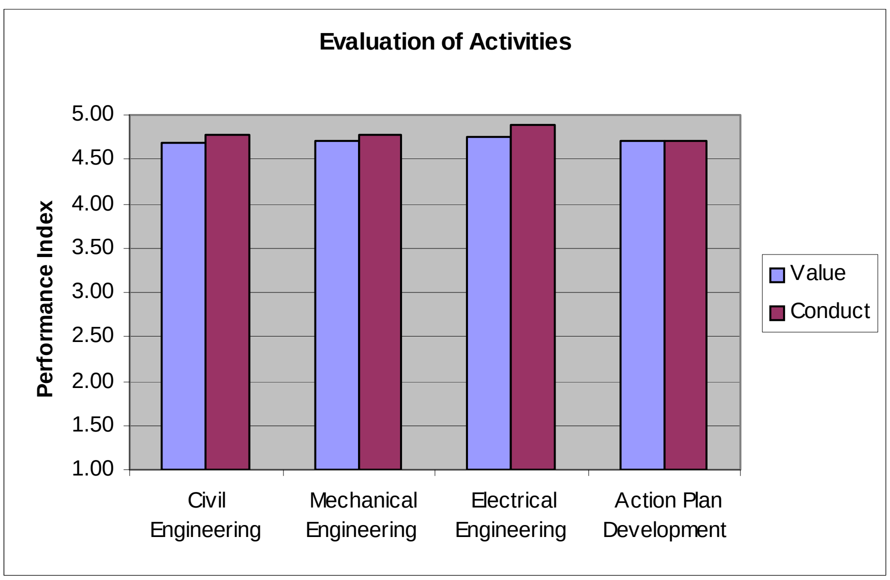

Figure 2: Evaluation of daily activities associated with each discipline.

As seen in figure 2, participants rated each category of activity as both very valuable and conducted very effectively, showing that the activities selected for each discipline were both appropriate for the topic and were implemented very effectively. The overall average rating for the value of the activities was 4.70, and the overall average for how well the activities were conducted was 4.79.

3. THE INITIATIVE FOR SCHOOLS, INDUSTRY, AND THE SCIENCES (ISIS)

The Initiative for Schools, Industries and the Sciences (ISIS) is a professional development and technology loan program originally developed for secondary science teachers in 1996 as one of three program components under PSME. Over the years, the program has expanded its horizons to also include both secondary mathematics teachers and elementary teachers. Since its inception, 173 teachers and 23,432 students have participated in the program from 49 schools located in 28 school districts throughout six counties in northwest Indiana (Lake, Porter, LaPorte, Newton, Jasper and Starke).

The professional development training programs for secondary teachers are two-week graduate level summer courses at Valparaiso University. Although specific topics vary each summer, the courses are technology-based and focus on inquiry-based learning approaches in teaching science and mathematics that are aligned with the Indiana Academic Standards. During the summer courses, teachers learn to use advanced scientific instruments, equipment, and computer technology, and they develop inquiry-based lesson plans and projects using technology that will be implemented during the academic year.

The types of instruments and equipment available to participating teachers include the following:

- Infrared spectrometer
- Ultraviolet-visible spectrophotometer
- Atomic absorption spectrometer
- Gas chromatograph/mass spectrometer
- High performance liquid chromatograph
- Gel electrophoresis apparatus
- Vernier LabPro data acquisition system

The program objectives are to engage teachers in high quality professional development activities to enhance their content knowledge and expertise, to improve their skills in using technology-supported inquiry-based learning to teach science and mathematics, and to ensure their use of academic standards to improve student achievement.

Teacher access to the advanced technology necessary for state-of-the art scientific experimentation is a unique feature of ISIS. Once teachers have been trained in the appropriate use of a particular instrument or piece of equipment, the program administrator, who is also a licensed secondary science teacher, delivers it directly to the teacher's classroom. The administrator also provides technical and pedagogical support in the teacher's classes. Follow-up training sessions are held with participating teachers during the school year and in subsequent summers to encourage and support ongoing sustained professional development.

3.1 Integrating Technology and Science into Secondary Education: The ISIS Workshops.

As part ISIS program, a two-week summer workshop was presented to secondary teachers from northwest Indiana with the intention of helping those teachers to learn how to use appropriate technology in their classrooms. The program was designed to engage secondary teachers (those teaching in grades 7 through 12) in high-quality professional development activities that would:

- *Enhance their content knowledge in science.* Many teachers feel ill prepared to meet the imagined rigors of teaching science and working with current technology. The hands-on activities were designed to provide experience with technology and to demystify teaching of science.

- *Improve their skills in using inquiry-based learning approaches that incorporate sophisticated technology in teaching science.* Increasingly, teachers are being asked to present many and varied topics utilizing techniques designed to address the variety of learning styles found in today's elementary and secondary classrooms. Inquiry-based instruction is being considered to address many of these learning styles, and more professional development in teaching strategy is required to enhance teaching

- *Ensure their use of Indiana's Academic Standards and Curriculum Frameworks to improve instructional practices and student achievement.* A standards-driven curriculum has become a critical issue for teachers to face. Indiana assessments for student achievement are designed around the Indiana's Academic Standards and Curriculum Frameworks. In order to increase student achievement on these assessments, teachers must be fluent in the Indiana Academic Standards.

- *Model sound pedagogy and strengthen teacher's overall effectiveness in teaching science to diverse populations.* Modelling of inquiry-based instruction and the use of technology in the classroom allows the participants to understand the excitement their students will feel when introduced to these techniques. Multiple hands-on activities were utilized to demonstrate the enthusiasm these activities generate.

- *Train and support leaders in science education.* Participants in this workshop were selected for their enthusiasm and leadership abilities. The participants were engaged in this activity to generate a core group of good teachers who would serve as trainers in their buildings helping the program to grow geometrically.

The workshop focused on the use of hands-on activities and technology to enhance student learning in secondary classrooms along with aligning activities with the Indiana Academic Standards. Activities included instruction on how to use scientific instruments and equipment along with group discussions, sharing ideas, and the development of action plans for implementation during the 2003-2004 school year. The last day of the workshop, teachers presented their work to the class, and they had opportunity to network and discuss ideas for implementation. All activities were presented using inquiry-based instructional techniques and were designed to stimulate the development of lessons in the teachers' own classrooms. Participants responded very well to these activities and the model being utilized.

An important element of this workshop is the technology loan and in-school support provided by the ISIS program. As described above, the program administrator delivers scientific instruments and equipment to teachers at their own schools based on the teacher's individual needs and requests. As part of the ISIS program, teachers are also provided with technical support and instructional assistance in the classroom.

Presenters for this workshop were selected from university faculty and from outstanding classroom teachers who are well known for expertise in and utilization of the scientific instruments and technology in their classrooms. Presentations by teachers experienced in the use of technology in real classrooms were extremely well received. At times, inexperience with and intimidation from the use of technology was a challenge to be overcome. The accessibility and enthusiasm of the presenters was a strong element in meeting this challenge. Change is difficult, but the interest and enthusiasm of the participants indicate that this challenge will be met with a determination for improving their instruction and their students' learning.

3.2. Assessing the Outcomes of the 2003 ISIS Workshops.

This workshop was evaluated using a tool very similar to the one for the engineering workshops. Again, students were asked to respond to a variety of questions that assessed their achievement of the workshop objectives as well as the value and conduct of the daily activities.

The first seven questions asked participants to evaluate their own ability to complete each of the workshop objectives:

1. Enhance your content knowledge.
2. Improve skills using technology.
3. Use academic standards in lessons.
4. Use technology-based hands-on activities in classroom.
5. Implement lesson plans developed in workshop.
6. Help to encourage other teachers to use technology.
7. Improve student performance.

Participants could respond to each of these objectives using the same five-point scale outlined in section 2.2 for the engineering workshop objectives. Figure 3 shows the average responses to these seven self-assessment questions for the 2003 ISIS workshop, the most recent time this program was offered. The average response to these seven questions was 4.11, which indicates that the workshop participants felt that they had substantially achieved the workshop learning objectives.

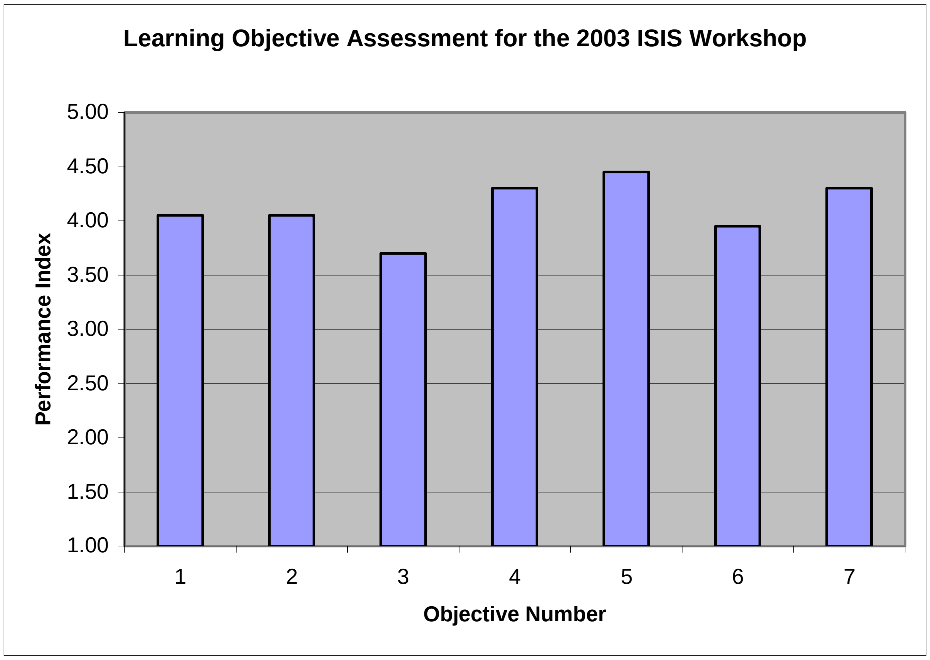

Figure 3: Self-assessment of the 2003 ISIS workshop objectives.

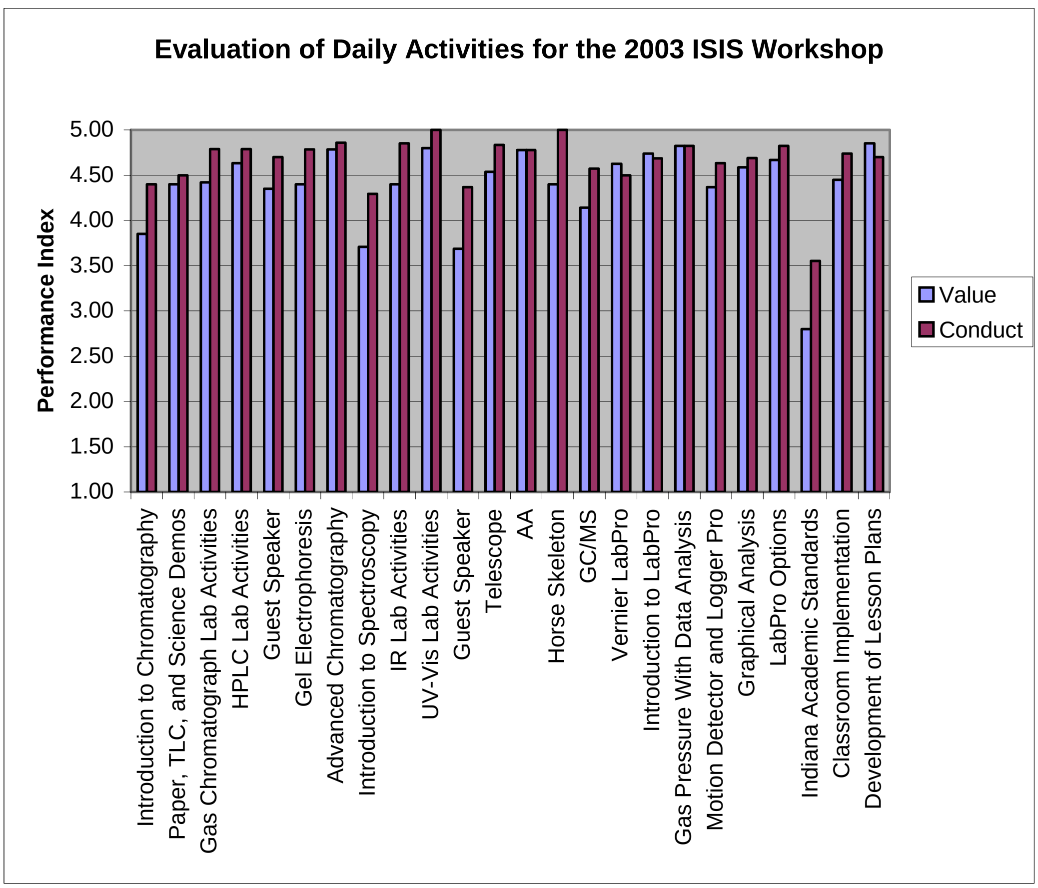

Figure 4: Evaluation of daily activities for the 2003 ISIS workshop.

Figure 4 shows the participants' assessment of the value and conduct of the 24 individual activities that composed the ISIS workshop. The average ratings for these activities were 4.37 (value) and 4.67 (conduct), showing that the activities were both valuable and conducted well. All activities received very good scores except for "Indiana Academic Standards," which was facilitated by an instructor from outside the university.

3.3 Integrating Technology and Science into Elementary Education: The ISIS-ET Workshops.

During 2004, Valparaiso University, the School District of East Chicago, the Challenger Learning Center of Northwest Indiana (CLC), and the Indiana Dunes Environmental Learning Center (IDELC) launched ISIS-ET (Initiative for Schools, Industries and the Sciences for Elementary Teachers) for elementary teachers (those teaching in grades K through 6).

The initial motivation for creating this project was the discovery of low assessment scores in science in the East Chicago School Corporation. Concern and apprehension for low student achievement and its corresponding effect upon the lives of the students from East Chicago has generated a need and dedication to improve the teaching and learning of science in these elementary classrooms.

ISIS-ET is structured in the same manner as ISIS in terms of graduate level coursework, and participants receive university credit for the course ED 690: Integrating Technology in Elementary Science Classrooms. As part of the course, participating teachers complete one day of training at the Challenger Learning Center, and they are able to take their own students to the CLC during the school year. Beginning in summer 2005, teachers will also complete one day of training at the IDELC with the option of taking their students there during the school year.

The first two-week ISIS-ET summer workshop was presented to elementary teachers from the East Chicago School Corporation in summer 2004. The program objectives were similar to the ISIS program, but with a special emphasis on the multidisciplinary nature of science as taught in elementary classrooms. As with the other two programs presented here, the experiments and activities were selected and designed in such a way that participants could take them directly back to their own classrooms without significant modification.

Participants of this workshop are expected to attend two one-day follow-up sessions during the 2004-05 school year and to attend a three-day follow-up workshop in the summer of 2005. Classroom implementation issues and resulting changes in student achievement and interest in science will be emphasized in this session. Two interdisciplinary inquiry-based projects using technology are required. The first project was developed by each teacher during the two-week workshop in summer 2004, and an outline of the second project will be due at the completion of the three-day summer session in 2005. It is being emphasized to all involved that this activity is ongoing and will be supported for an extended period of time.

The overall teacher response to the workshop was overwhelmingly positive, and the participants have demonstrated continuing enthusiasm and confidence during the first half of the 2004-2005 school year. The administrator of the ISIS-ET program has reported that the volume of requests for equipment and assistance under this program has been overwhelming.

3.4. Assessing the Outcomes of the ISIS-ET Workshops.

As described above, the ISIS-ET workshop was first offered in the summer of 2004, and the assessment tool to measure the objectives and daily activities was nearly identical to that used in the PSME and ISIS workshops. Figure 5 shows the participants' self-assessment of their achievement of the program learning objectives, which were identical to those for the ISIS workshop in section 3.2.

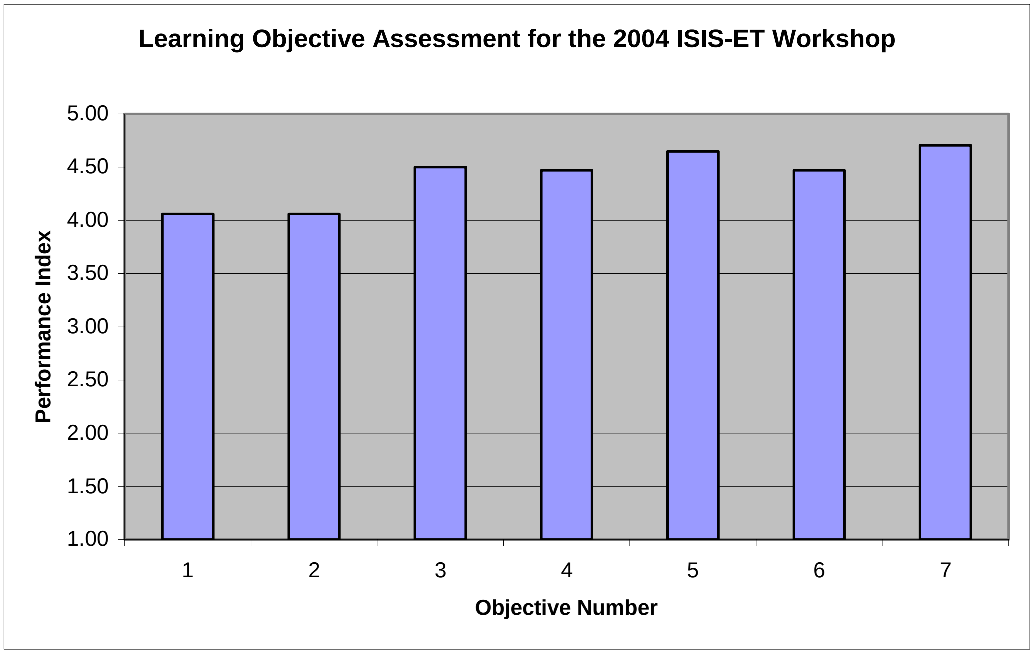

Figure 5: Self-assessment of the 2004 ISIS-ET workshop objectives.

The average self-assessment for these seven objectives was 4.41, demonstrating that the ISIS-ET workshop was even more effective at achieving their learning objectives with elementary teachers than the ISIS workshop had been with secondary teachers.

Figure 6 shows an assessment of the 17 activities that composed the 2004 ISIS-ET workshop.

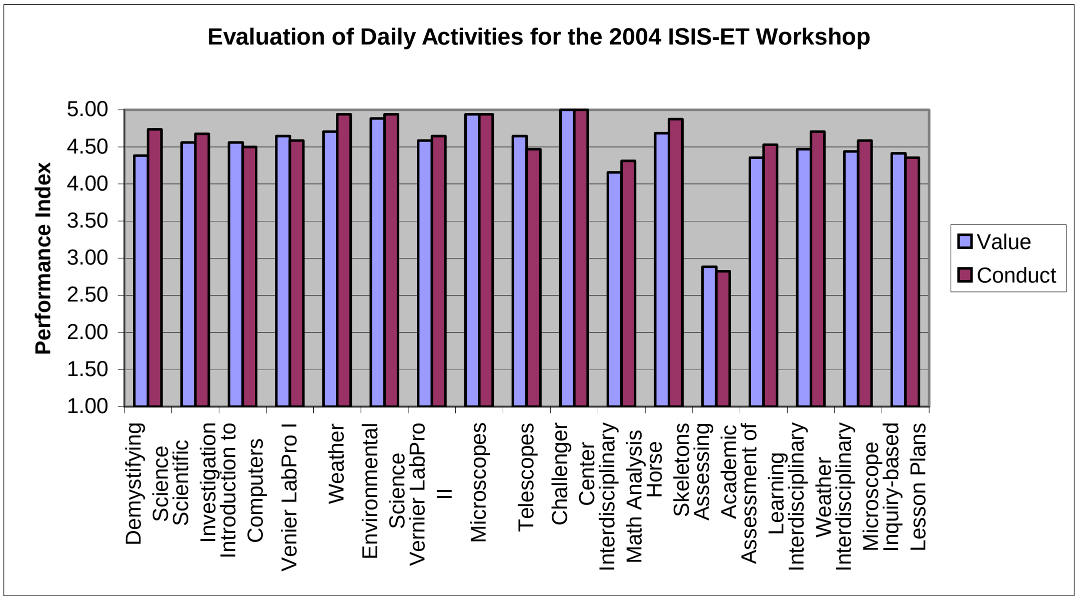

Figure 6: Evaluation of daily activities for the 2004 ISIS-ET workshop.

The average assessment for these seventeen activities was 4.49 (value) and 4.57 (conduct). All scores are all very good except for the activity "Assessing Academic Performance," which was facilitated by an instructor from outside the university and is being revised for the next round of workshops scheduled for summer 2005.

4. LESSONS LEARNED

Having conducted many workshops designed to integrate science, mathematics, engineering, and technology into both elementary and secondary classrooms, the faculty and staff involved in this project have learned several important lessons that can prove to be valuable for others considering a similar workshop.

- The ISIS and ISIS-ET programs involve the training and use of highly sophisticated instrumentation and equipment that is normally not available for secondary teachers and students to use in their classrooms. Based on our years of experience with this program, we know that the technical and pedagogical support that the University provides for teachers in the classroom is not only unique, but it is also a critical element of our success. Even with this extensive support, ongoing sustained professional development is necessary to ensure that teachers know what to do when instruments fail or other difficulties arise with the use of technology. This type of expertise only comes with practice and confidence, and as a result, a great deal of time must be devoted to troubleshooting and problem solving the equipment during the on-campus workshops.

- It is essential that teachers have adequate time in these summer courses to prepare lesson plans that they will be able to implement in their classrooms as well as having the opportunity to network and collaborate with their own faculty colleagues once they are back in their schools.

- Assessing the impact of this program on student learning and achievement is one of the greatest challenges of this program. Assessment strategies and methods to document student learning must be presented during the workshops so that the participants will be encouraged in incorporate them into their lesson plans. As can be seen from the two low-scoring responses in figures 4 and 6, it is important that these presentations be performed by outstanding education faculty who have a high degree of expertise and enthusiasm for the topic.

- A great deal of the success of these programs comes from the interest and enthusiasm brought by the teachers attending. While it has been observed that teachers early in their career generally have a higher degree of such enthusiasm, the best way to attract only interested participants is to be certain that they have to volunteer to attend the workshop. A single disinterested and unenthusiastic teacher who was forced to attend the workshop could easily ruin the experience for every other person there.

- One of the primary reasons why teachers in the ISIS and ISIS-ET workshops were so actively involved in the workshop activities is that they knew they would have the opportunity to borrow the very scientific apparatus they were using in order to demonstrate it to their own students. If at all possible, such an opportunity can be very important for increasing motivation and participation in the workshops.

5. CONCLUSIONS

In this paper, the authors have described the need for cooperation between university science, mathematics, and engineering faculty and the K-12 teachers who are preparing students for those undergraduate programs. It is absolutely essential to help ensure that these teachers have all the support and education necessary to teach such essential topics to their students, many of whom will themselves become university students in a very short time.

We have presented one possible framework for such cooperation, a series of summer workshops in which university faculty prepare and model activities for K-12 teachers that they can then bring directly back to their classes. Such workshops have been run for several years at Valparaiso University, and their assessment results demonstrate that they have been very successful at achieving their learning objectives. Furthermore, it has been shown that the activities composing those workshops are found to be very valuable to the participants and that they are conducted effectively.

Similar activities could be conducted at other universities across the country, which would ensure a wide variety of high-quality continuing education opportunities for K-12 teachers. It would also help each university to establish a closer relationship with schools their area, which would provide many benefits for the university, the local schools, and the students attending each.

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