AC 2007-1414: ENGINEERING EMPOWERMENT IS MATHEMATICIANS COLLABORATING FOR CHILDREN: E2 = MC2

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ENGINEERING EMPOWERMENT IS MATHEMATICIANS COLLABORATING FOR CHILDREN: $E^2=MC^2$

Abstract

This study describes the development, implementation and evaluation of the first year of a three-year partnership between the Purdue School of Engineering and Technology at Indiana University Purdue University Indianapolis and the Metropolitan School District of Washington Township (MSDWT) located in Indianapolis, Indiana. *Engineering Empowerment is Mathematicians Collaborating for Children* (**$E^2=MC^2$**) is designed to improve mathematics instruction at the kindergarten through ninth grade level (K-9). A one-week intensive Summer Math Academy facilitated by faculty from the Purdue School of Engineering and Technology, MSDWT school district administrators, MSDWT lead teachers and guest presenters from the Institute of Electrical and Electronics Engineers (IEEE) is offered to a cohort of up to thirty MSDWT K-9 faculty. Monthly follow-up seminars are offered throughout the school year to teachers enrolled in the program to assist in supporting teachers in the creation of improved lessons and continued discourse in topics related to mathematics and engineering. This program is designed to increase teacher content knowledge of mathematics, increase teacher use of research-based instructional practices in mathematics, increase teacher understanding of how engineering and engineering technology concepts can be incorporated into lessons to improve student learning, increase the mathematics connections made to real life with a focus on a better understanding of engineering principals, and finally, to develop a partnership between higher education and a public school district so that resources and knowledge can be shared and applied with young students. In addition to a pre-post Teacher Self-Assessment Survey, the IEEE created and delivered a *Teacher In-Service Presentation* Questionnaire that contains demographic information, program question results and a comment section to all study participants who participated in the Summer Workshops. Results of these surveys are discussed and MSDWT student achievement data are provided and analyzed to determine if goals of the program were met. Finally, preliminary results of an independent evaluation of the **$E^2=MC^2$** initiative is discussed and analyzed.

Introduction

Recently, the American Society for Engineering Education (ASEE) has embarked on an ambitious effort to promote and improve K-12 engineering and engineering technology education. Since 2003, the ASEE has created a new K-12 division dedicated to K-12 engineering education, created a guidebook for high school students called *Engineering, Go for It!* that has been distributed to almost 1 million secondary students, created an e-newsletter that reaches 10,000 secondary teachers, guidance counselors, and outreach program leaders, created the EngineeringK12 Center to gather in one place the most effective engineering education resources available to the K-12 community, and created a survey to understand what secondary teachers think of engineering as an academic and career pathway for their students.[1] Finally, ASEE brought together leaders from industry and higher education along with K-12 teachers for a Leadership Workshop on K-12 Engineering Outreach, held just before the ASEE 2004 Annual Conference and Exposition in Salt Lake City, Utah. A paper detailing the results of that

conference and delineating guidelines for how K-12 engineering education works best and defines key challenges confronting the field was published.[2]

Clearly, there is a movement by the engineering and engineering technology communities to gain a better understanding of the K-12 issues that impact enrollment at post-secondary institutions, and to generate research to answer the question of how stakeholders from many levels – K-12 teachers, university professors, industry, and government representatives – can advance the state of engineering and engineering technology education. Coupled with the information from the aforementioned surveys, the ideas and suggestions from conference attendees and current research in the field of K-12 education, Dougless, Iversen and Kalyandurg have developed a set of six guidelines for improving K-12 engineering education and outreach:

1. *Hands-on learning:* Make K-12 science curriculum less theory-based and more context-based, emphasizing the social good of engineering and demonstrating how it is relevant to the real world
2. *Interdisciplinary approach:* Add a technological component to all subjects and lessons, and implement writing guidelines in math and science courses
3. *Standards:* Involve engineering in K-12 lessons that map to state standards for math and science. Further, states should follow the lead of Massachusetts and enact state standards for engineering
4. *Use/Improve K-12 Teachers:* Engage more K-12 teachers in outreach efforts and curriculum writing, and increase teacher salaries to attract the best technological minds to teaching
5. *Make Engineers "Cool":* Outreach to urban schools and females more aggressively, and create more mentors and role models to attract these constituencies
6. *Partnerships:* Create better incentives for all groups to engage in K-12 outreach (especially higher education and industry)[2]

According to Dougless, Iverson and Kaylendurg there is no magical list of recommendations to promote and enhance engineering education in the K-12 world, but these six guidelines emerge from current outreach efforts and seek to move them a step further, offering a broader base for improving the quality, methodology, and reach of K-12 engineering education.[2] A key component to all six of these recommendations is recommendation number four: *Use/Improve K-12 Teachers.* Without quality K-12 instructors in STEM areas, the pathways for students to be a part of post-secondary STEM degree programs will be filled with barriers. With a renewed focus on the quality of secondary STEM instructors, the issue of university involvement in the creation of delivery of professional development for K-12 STEM instructors is an ongoing question.[3]

In an effort to address the issue of professional development for K-9 instructors a partnership between the Purdue School of Engineering and Technology at Indiana University Purdue University Indianapolis and the Metropolitan School District of Washington Township (MSDWT) located in Indianapolis, Indiana was formed. *Engineering Empowerment is Mathematicians Collaborating for Children* (**E^2=MC^2**) is designed to improve mathematics instruction at the kindergarten through ninth grade level (K-9).

Supporting Research

Improving mathematics and science literacy among K-12 teachers of math and science has become a national goal. The report to the nation by the National Commission on Mathematics and Science Teaching for the 21st century identifies professional development as prerequisite for a well-qualified teaching force and encourages teachers to take responsibility for their own professionalism as they work to improve their skills.[4] The need for professional development that provides opportunities for teachers to upgrade content knowledge in mathematics and science and to facilitate teachers in learning how to integrate technology into these subjects was also identified by the commission.[4]

The National Staff Development Council standards advocate professional development experiences that are research-based and that use content to increase student learning and development.[5] Teaching teachers how to conduct math and science inquiry requires hands-on, situation specific experiences, an approach that numerous math and science education researchers advocate.[4,5,6]

According to James Strong in his book *Qualities of Effective Teachers*, certain shared characteristics can be found in classrooms where high levels of learning have the greatest chance of materializing. He states, "An effective mathematics teacher has the ability to facilitate students' ability to understand, analyze, and solve problems. The teacher presents real-world applications of the math concepts to make the application real for students. The teacher facilitates students thinking beyond the paper and the pencil to how mathematics is evident and applied to every day life . . . If a student is having difficulty, the teacher is able to diagnose and remediate the gap in prior knowledge or identify where the student has misunderstood the process and gets the child back on track. Students are asked to compute problems, write about solutions, and discuss mathematics. Mathematics is not just numbers and symbols; it is a language for understanding."[7]

Communication is paramount to success in any profession that deals with people. The teacher's job requires clear articulation of expectations, encouragement, and caring, as well as content knowledge. Research by Strong finds that teaching is far more than just talking about objectives. Effective communication in teaching requires that a teacher have a clear understanding of the subject matter and of how to share that material with students in a way that they come to own and understand it deeply.[7] Elementary teachers have been observed teaching what appears to be a good lesson, but methodologically the teaching exposes the students to only the "surface" of true understanding of the concept. Teachers must have the tools and training to move beyond the current "surface" teaching becomes a thing of the past and teachers go beyond directly teaching content knowledge and skills.[8] Teachers must become adept at facilitating students' own search for knowledge and they can become supporters in helping students use this information successfully, especially in mathematics. Mathematics should be taught in such a way that people not only will be able to use mathematics to solve problems, but also will *want* to use mathematics, and will think of mathematics as a friendly, useful tool, rather than a nemesis to be avoided at all costs.[8]

Research on Computer Based Laboratories for teaching mathematics is encouraging. According to Van Dyke, by introducing the Computer Based Laboratory (CBL) tool, teachers will be able to witness that by using a tool to help students (and teachers) visualize a relationship between quantities, algebra can be embraced at an early age.[9] A CBL assists students in thinking on an abstract level and it allows the teacher to introduce important concepts without requiring algebraic notation. Using the motion detector apparatus with the CBL makes a very abstract idea become concrete and even fun. In this particular study it was noted that using a tool such as the CBL "brought equations and variables to life for many students who solved problems easily but who had not given previous thought to the possibility of an underlying connection with a real situation."[9]

The computer component of professional development is crucial so that teachers can practice their technology skills beyond the school day. Integrating computers into the mathematics curriculum provides many "higher-order" learning opportunities for students. It gives students real life problems to solve and gives them insights into the methods that real mathematicians use in the quest for answers.[10] A strong correlation has been found between the number and types of technologies used in a classroom and teacher access to his or her own computer beyond the school day. An additional factor that impacts integration is the number of technology training workshops teachers have attended.[10] Research has given numerous ways computers can positively affect the learning environment in a classroom and by increasing computer use in the mathematics classroom elementary professional development programs can:

- Provide concrete and immediate visual representations to math concepts, as a way of improving students' conceptual understanding;
- Use computer technology as an instrument for implementing new and "higher order" goals embedded in the standards of the National Council of Teachers of Mathematics (NCTM);
- Use interactive software to support an inquiry model of learning where students function as co-manipulators, rather than inactive recipients, of concepts and information;
- Integrate computers, inquiry methods of learning, and cooperative learning to create a new classroom dynamic that puts more responsibility in the hands of students;
- Provide students with experiences that are project-based;
- Use multiple math teaching strategies in response to multiple student learning styles, and
- Use computer technology as a tool for teachers to have anytime access to online resources (i.e. multimedia presentations, best practices, help line).[10]

Many studies emphasize the importance of a teacher's knowledge of school mathematics to be critical in the effectiveness of the teacher in instructing students. If a teacher's own knowledge of the mathematics taught in elementary school is limited to procedures and low-level skills, we cannot expect his or her classroom to have a tradition of inquiry mathematics.[11] Relationships developed between elementary, secondary and post secondary instructors are also an important component in helping teachers bridge the gap of mathematical knowledge they may have, giving them a "non-evaluator" to confidentially help them develop an understanding that they can pass along to their students. Bringing in an outside partner and giving teachers on-going access to this partner can also help teachers make the "real world" connections with each mathematics skill so that learning becomes more meaningful to students.[11]

Finally, if students are going to pursue mathematical ideas in depth, real choices about how they will spend their time in the mathematics curriculum must also be made. Students must learn a great deal more mathematics than what we considered sufficient in the past, and we must make room for more and deeper mathematics in our daily lessons.[12] It is the teacher's job to understand the mathematics in existing materials in order to match curricula with students. "This requires a more in-depth knowledge of various topics of mathematics, how concepts grow and become more robust, how to solve classic mathematics problems, and the ability to analyze instructional materials for the quality of their mathematics."[13]

The School Corporation Needs Assessment

As with any quality, long term, organizational change, a needs assessment was performed using a variety of inputs. Vast amounts of data are gathered and reported each school year to meet various federal, state and local requirements. A synopsis of the needs assessment performed for MSDWT is included to give the reader context regarding this particular public school corporation.

The Washington Township community is one of racial, religious, social, ethnic, economic, cultural, and academic diversity. Recent demographic shifts have caused a marked increase in poverty and a change in the racial balance. The Hispanic population alone has increased by 30% each of the last three years and current census data and birth records indicate that this trend will continue. Although the district average for the Hispanic population has grown from approximately 7.5% to 11% since 2003, one individual school grew from 20.7% to 34%. School enrollment figures reveal that the minority (non-white) enrollment now exceeds the once majority (Caucasian) population. This demographic characteristic has tremendous meaning to the district's efforts to meet *No Child Left Behind* (NCLB) expectations.

In addition to the growing Hispanic population, the district is experiencing significant changes in socio-economic status as reflected by the free/reduced lunch statistics. In 2003, four of the eight elementary schools had a free/reduced lunch rate of between 50% and 58%. In 2006 the rate increased for all four schools to over 60% and continues to rise. It should also be noted that 85% of those receiving lunch assistance are minority students**.** In 2003, 54% of the third graders passed ISTEP+ Mathematics at Harcourt Elementary School and only 44% of the African American students and 59% of the Hispanic students passed. Harcourt's poverty rate was 58.8%. It is now 68%. In 2003, 65% of Northview Middle School eighth grade students passed ISTEP+ Mathematics and only 41% of the African American students and 14% of the Hispanic students passed. Northview's poverty rate was 47%, but has increased to over 54%.

The achievement gap is also reflected in student performance in the classroom. There is a strong link between performance in the classroom and performance on state assessments. District findings indicate that low performance and poor grades are often due to a lack of study skills; a lack of understanding of major concepts in the areas of number sense, problem solving, and algebra; or a negative attitude about the usefulness of the mathematics to be learned, thus resulting in failure to complete assignments and homework. Research also indicates that children of poverty face numerous risk factors**.**[14] In the school setting they include, in addition to low achievement levels: low standardized test scores, behavior problems, higher school suspension rates, low self-esteem, negative peer pressure, and minimal parent involvement. These students come from families with a higher percentage of single parents and/or parents with a lack of

formal education. The data for MSDWT students supports these research findings. These obstacles and conditions challenge our efforts to provide the essential academic and life skills necessary for children to achieve and prosper in the 21st century. Our teachers must address these issues in their classroom every day in order to assure all students learn.[14]

Mathematics concepts and skills have been identified by all of the district's K-9 schools as a school improvement focus and an important goal for meet requirements of Indiana's Public Law 221. Several schools have identified instructional classroom strategies as an additional school improvement focus. District school climate audits done by the *DeWitt Institute for Professional Development* indicate that teachers expressed a desire for more staff development in working with the changing student population. They also indicated that they are stressing the importance of inquiry and problem solving and having students develop a "can do" attitude towards expressing ideas, doing research, and inquiry. Students expressed a desire to make learning fun by being more actively engaged in doing mathematical activities that are meaningful.

According to the district's Human Resource reports, we do not have teachers who are formally defined as not meeting *No Child Left Behind*'s definition of a highly-qualified teacher. However, 18% of our elementary teachers and 29% of our middle school mathematics teachers have been in the district less than two years, most new to the teaching profession. In order to improve student achievement, all mathematics teachers must possess strategies to help student's value mathematics and strategies to help them acquire the skills necessary to do mathematics. All teachers should understand mathematics beyond the level they are teaching, should know how students learn mathematics, and should know how to help students learn mathematics.

Based on our data analysis, there is a specific need for staff development activities that will help teachers increase their depth of understanding of mathematical concepts in particular in the areas of communicating and reasoning mathematically, algebraic reasoning, problem solving, and number sense in order to make the mathematical concepts meaningful and to assure student success. Research indicates that students learn best when the curriculum is relevant to the students and the task are aligned to the students' world. There is also a need to enable teachers to develop further expertise in teaching strategies as they apply to the reluctant learner, uses of technology, and other essential elements of teaching.

Description of the Project

In March of 2005, the Metropolitan School District of Washington Township (MSDWT) received $364,140 grant from the Indiana Department of Education for the 2004-05 Mathematics and Science Partnership Grant for K-9 Mathematics Initiatives. This grant is for a three-year period, and the Purdue School of Engineering and Technology at Indiana University Purdue University Indianapolis serves as a partner with MSDWT in the design, writing and implementation of this grant and receives a sub-grant payment of $77,273. In examining the MSDWT needs assessments and specific areas of mathematics in need of improvement, representatives from MSDWT and IUPUI created a professional development program for K-9 MSDWT faculty so that no child would be left behind in the learning process. Below is a description of the program.

In the $\mathbf{E^2=MC^2}$ program, the Purdue School of Engineering and Technology, the Mathematics/Technology Department of MSD Washington Township, and district classroom teacher leaders plan together each spring from 2005 through 2007 for the Summer Math

Academy, which is held in June of the corresponding year. This academy is a week long intensive training on the articulation of Indiana Mathematics Standards (K-9) with a focus on problem solving, algebraic thinking, number sense, and communicating and reasoning mathematically. The IUPUI Partners bring to the training the research knowledge of connecting these various math concepts and ideas to real world skills. In addition, there is a focus on improving math content knowledge of teachers. Practical examples of how knowledge and experience in these mathematical areas can open doors for students are shared, with site visits to the University campus made available to tour various departments of the Purdue School of Engineering and Technology to make an even deeper connection between instruction and the applications of mathematics. In addition, a project goals correlation to the action plan was created to delineate the assessed need, project goal to address that need and the project activity to meet the specific goal (Appendices I and II)

A very important part of this professional development is the follow-up of support. IUPUI has created a website for teachers (www.engr.iupui.edu/emc2) that is available for all IUPUI and MSDWT faculty, parents, students, and stakeholders. This website and the university faculty assist teachers in developing appropriate real world problem solving tasks within their lessons and help teachers improve their math content knowledge. The University provides online training seminars in conjunction with action research support in creating case studies in mathematics to help to ensure the best possible instruction for students. IUPUI also offers participants graduate credit for successful completion of the Summer Math Academy at reduced teacher expense. Monthly, full day and after school seminars are also an integral part of follow-up support through this program. Lessons are shared, reviewed, and discussed with improvements made as needed. These lessons are published on the website for future reference and to share with others. Guest presenters are brought in for additional staff development on the focus standards and best instructional practices. Teachers are given reflection time and also time to share their experiences as the year unfolds.

MSD of Washington Township is responsible for the ordering and maintaining of all purchased equipment. The Summer Math Academy is housed, at no expense to the program, in the MSDWT H. Dean Evans Community Education Center with follow-up sessions rotating to the various schools of participants and the Purdue School of Engineering and Technology. After each intensive year of professional development, a new cadre of lead teachers joins in planning and facilitating the next year's cohort. Once the three years of the Title II Grant are complete, a pool of approximately ninety teachers will be available to select from to lead future staff development initiatives. Ideally, after the initial three years, all middle school mathematics teachers will have completed the year-long staff development, except for the new hires in the fourth year. Approximately three eighths of the elementary faculty in each school will have also completed the program. All participants will have received a laptop computer and digital camera to their instruction long after the grant money is expended. These tools will be an incentive to continue to use technology with students since it is required to incorporate each regularly into the mathematics instruction in order to maintain ownership. This is the same policy MSDWT has used in past years for the technology academy and it has been extremely motivational and successful. It will be important to extend our work beyond the three-year period so that as our student population continues to change to include a more "at-risk" student-body, all teachers can incorporate new studies and apply additional knowledge of how to help students succeed in the

area of mathematics. All students must achieve to their potential, and to do that, teachers need continued support from teacher leaders and university and business partners. Therefore, the project outcomes (Table 1) are designed around these concepts.

Initial Outcomes (Year 1):
• Increase in teacher content knowledge (pre/post surveys, focus groups, self-assessment, observations) • Increase use of best instructional practices (pre/post surveys, focus groups, self-assessment, observations) • Increase in teacher collaboration (pre/post surveys, focus groups, interviews, observations) • Increase in the use of technology to support teaching, student learning and assessment (district's Use of Technology Self-Evaluation Rubric, observation) • Increase level of student achievement (grades, course completion, ISTEP+, district's benchmark assessment)
Outcomes (Year 2)
• Increase level of student achievement (grades, course completion, ISTEP+, district's benchmark assessment) • Increase in students demonstrating skill in communicating and reasoning mathematically (classroom assessments, ISTEP+, benchmark assessments) • Increase in students demonstrating problem solving skills (classroom assessments, ISTEP+, benchmark assessments) • Increase in the number of mathematics teacher leaders (observation) • Continued increase in teacher content knowledge (pre/post surveys, focus groups, self-assessment, observations) • Continued increase in the use of best instructional practices (pre/post surveys, focus groups, self-assessment, observations) • Continued increase in teacher collaboration (pre/post surveys, focus groups, interviews, observations) • Continued increase in the use of technology to support teaching, student learning and assessment (district's Use of Technology Self-Evaluation Rubric, observation)
Outcomes (Year 3)
• Increase student enrollment in advance level mathematics courses (class schedules) • Continued increase in student achievement in mathematics (grades, course completion, ISTEP+, district's benchmark assessment) • Continued increase in students demonstrating skill in communicating and reasoning mathematically (classroom assessments, ISTEP+, benchmark assessments) • Continued increase in students demonstrating problem solving skills (classroom assessments, ISTEP+, benchmark assessments) • Increase in the number of mathematics teacher leaders (observation) • Decrease in the number of students earning a D and/or an F in mathematics (grades) • Continued increase in teacher content knowledge (pre/post surveys, focus groups, self-assessment, observations) • Continued increase in the use of best instructional practices (pre/post surveys, focus groups, observations) • Continued increase in teacher collaboration (pre/post surveys, focus groups, self-assessment, interviews, observations) • Continued increase in the use of technology to support teaching, student learning and assessment (district's Use of Technology Self-Evaluation Rubric, observation)

Table 1: Project Outcomes Over a Three-Year Period

Project Results Year One: Summer 2005

The **$E^2 = MC^2$** grant has a total of three goals:

- Goal #1: Teachers in the program will increase their use of research-based instructional practices in mathematics, as measured by a pre-post Teacher Self-Assessment, observations, lesson plans, and focus groups.

- Goal #2: Teachers in the program will increase their use/integration of technology with students (i.e., used at appropriate times), as measured by a pre-post Teacher Self-Assessment, observations, focus groups, lesson plans.
- Goal #3: Teachers participating in the program, in conjunction with IUPUI partners, will develop and create mathematical tasks, activities, and applications (i.e., connected to the real world, developmentally appropriate and standards based), as measured by observations, focus groups, lesson plans (submitted three times/year).

Goals #1 and #2 were measured by giving teachers in the 2005-2006 cohort an instructional practice survey (see appendix III). This cohort consisted of 37 classroom teachers; 24 elementary teachers and 13 middle school teachers. Of the 37 classroom teachers, 24 were considered elementary teachers and taught in grades kindergarten through five and 13 were considered middle school teachers and taught in grades six through eight (Figure 1)

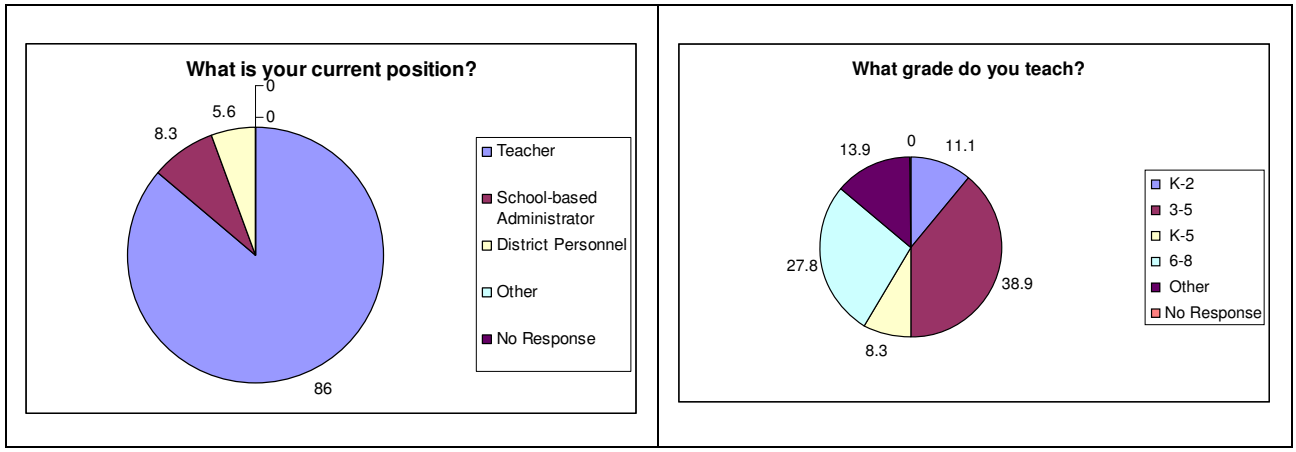

Figure 1: Demographic Data on Cohort Members

Over one-fifth (21%) of the cohort participants has taught 3 years or less, nearly half (46%) had taught from 4-10 years, a smaller portion (16%) had taught 11-20 years, and nearly the same percentage (16%) had been teaching more than 21 years. Twenty-one of the thirty-seven cohort members completed the requirements for TECH 581: Applications for Technical Mathematics, offered by the Purdue School of Engineering and Technology at IUPUI. The 2005-2006 cohort contained teachers from all MSDWT middle and elementary schools as well as 8 additional administrators (Figure 2).

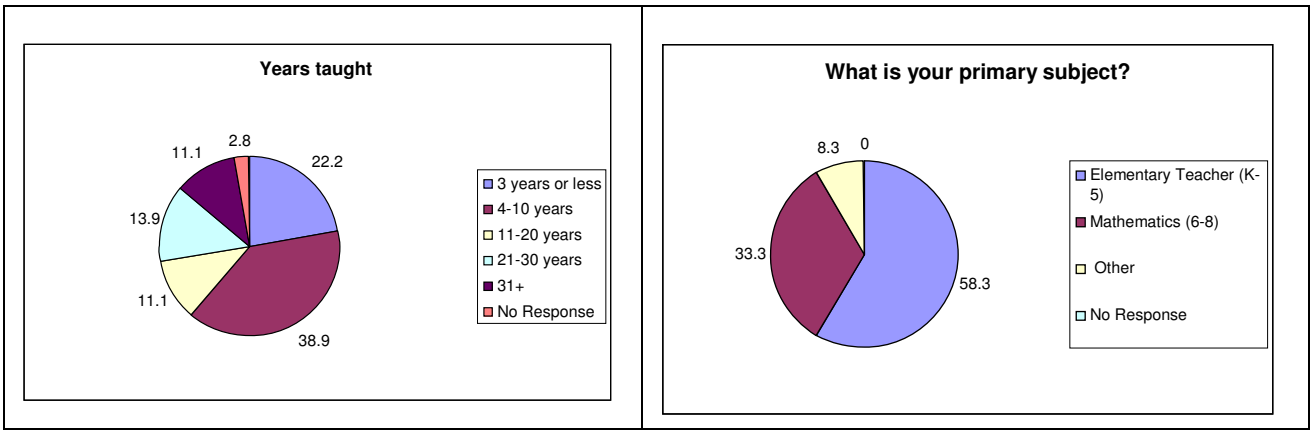

Figure 2: Demographic Data of Cohort Members

The pre-test (Figure 3) was given to all 37 cohort members shortly after being accepted into the academy in May of 2005 and revealed some interesting findings. The instrument asks specific questions regarding teacher's instructional practices in eight areas: mathematical reasoning, communicating mathematically, problem solving, algebraic thinking solving, number sense solving, real world connections, technology integration and online resource utilization. The pre-test results indicate that 83% of respondents always/often used mathematical reasoning as an instructional practice in their classrooms. In terms of communicating mathematically and number sense solving, 93% and 96% of respondents used this as an instructional strategy always/often. Lesser numbers of respondents used problem solving (79%), real world connections (76%) and algebraic thinking solving (76%) always/often as instructional strategies. The lowest percentages of respondents used technology integration (42%) and online resources (41%) as instructional strategies always/often.

The pre-test revealed that the greatest strengths of research best practices used by MSDWT teachers were in the areas of mathematical reasoning, communicating mathematically, problem solving, algebraic thinking solving, number sense solving and real world connections. Pre-test results suggested that teachers always or often use these techniques as instructional strategies for their students from 76% to 96% of the time (Figure 4). While this news was encouraging, the two areas that needed the most improvement were technology integration and online resource utilization. Less than half, 42% and 41% respectively, of the MSDWT faculty reported using these techniques as instructional strategies to assist student learning.

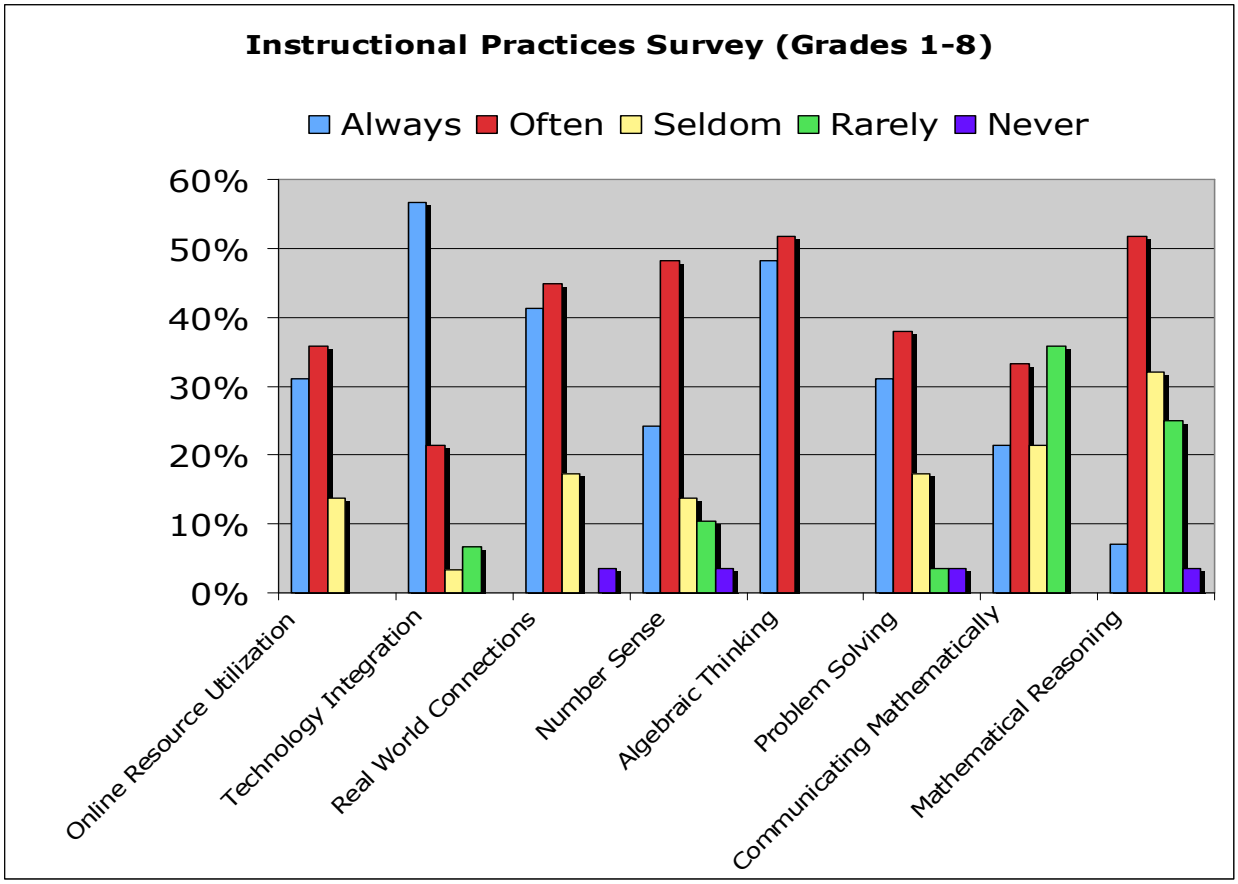

Figure 3: Instructional Practices Pre Test Given to 2005-2006 Cohort

The post-test was given to members of the 2005-2006 cohort shortly after completing the one-year academy in May of 2006. The identical survey was given to the cohort members and the results of the post-test showed improvement in all eight areas with the most dramatic improvement in the areas of technology integration and online resource utilization (Figure 4). Respondents reported using technology integration always/often as an instructional strategy only 42% of the time in the pre-test and that number increased to 71% in the post-test. A more dramatic increase from 41% in the pre-test to 75% in the post-test was measured in the area of online resource utilization as an instructional strategy. Two areas, communicating mathematically and number sense solving went from 93% and 96% respectively in the pre-test to 100% in the post-test.

Of the eight instructional strategies listed on the survey given to cohort members, the post-test revealed that respondents used mathematical reasoning, communicating mathematically, problem solving, algebraic thinking, number sense and real world connections always/often as instructional strategies from 85% to 100% of the time (Figure 4). These percentages indicate a significant improvement as a result of MSDWT faculty participating in the one year math academy.

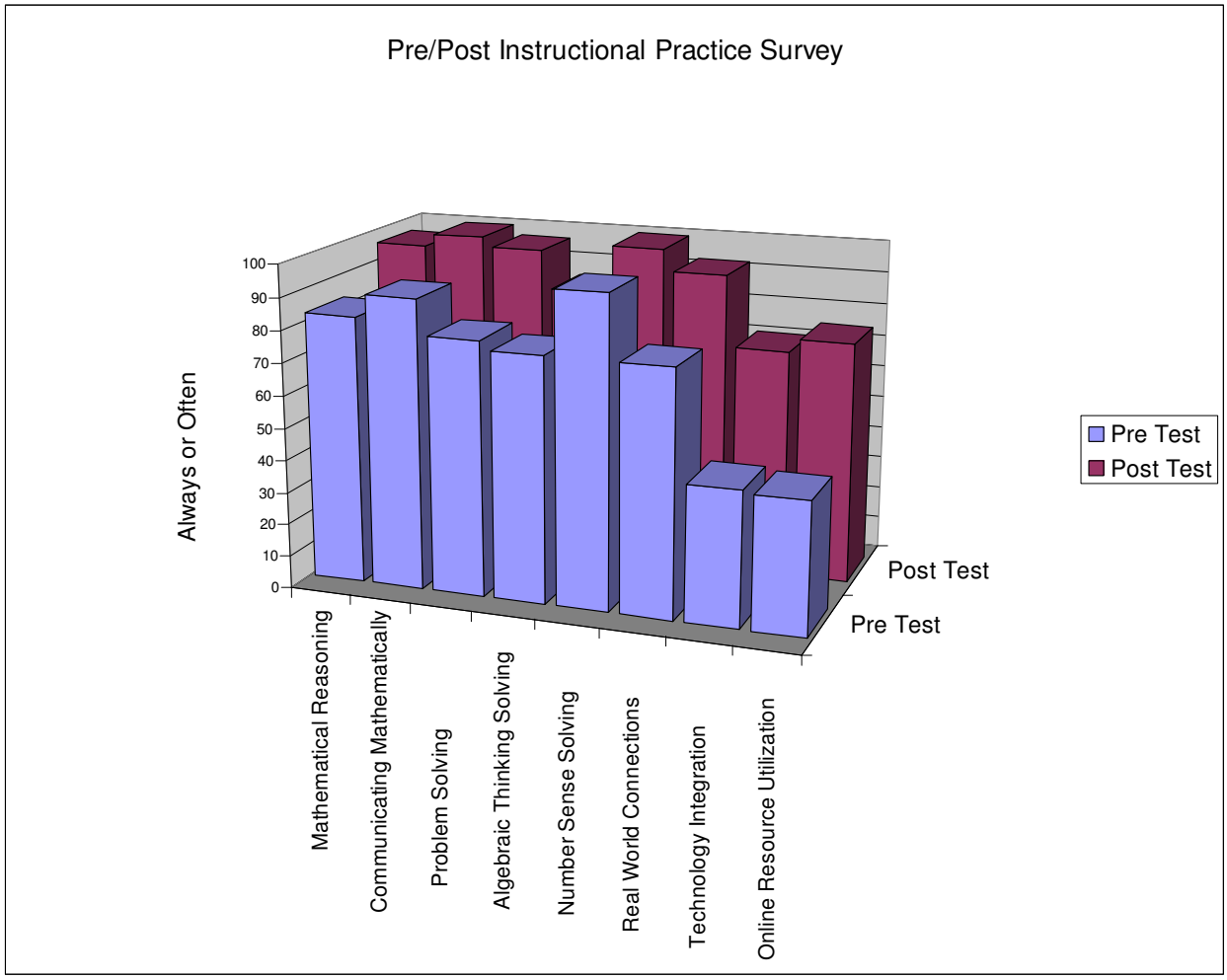

Figure 4: Instructional Practices Pre-Test/Post Test Survey

During the 2005 Summer Academy, the School of Engineering and Technology at IUPUI held a workshop facilitated by Douglas Gorham, Ed.D., of the Institute of Electrical and Electronics Engineers (IEEE). This workshop was designed to provide academy cohort members with skills to use real world applications in the teaching of mathematics. A variety of research based, hands-on, activities were used by Dr. Gorham during this workshop to:

- Increase technological literacy of the participants
- Add to the technical knowledge base of the participants
- Provide tools for teachers at the k-9 level to increase the technological literacy of their students

Dr. Gorham issued an IEEE developed survey to all participants at the end of the workshop and the findings indicated that all goals were met (Appendix IV). When asked if the program added to their technical knowledge base, 90% of participants strongly agreed or agreed. Encouragingly, when asked if they would use the concepts presented in their own classrooms, 89% of respondents indicated that they would. The topics presented were perceived as helpful in terms of increasing both student and teacher technological literacy according to 96% of the

respondents. Finally, the academy participants overwhelmingly enjoyed the "hands-on" concept as 100% of respondents indicated they strongly agreed or agreed with this method of delivery for the workshop (Figure 5).

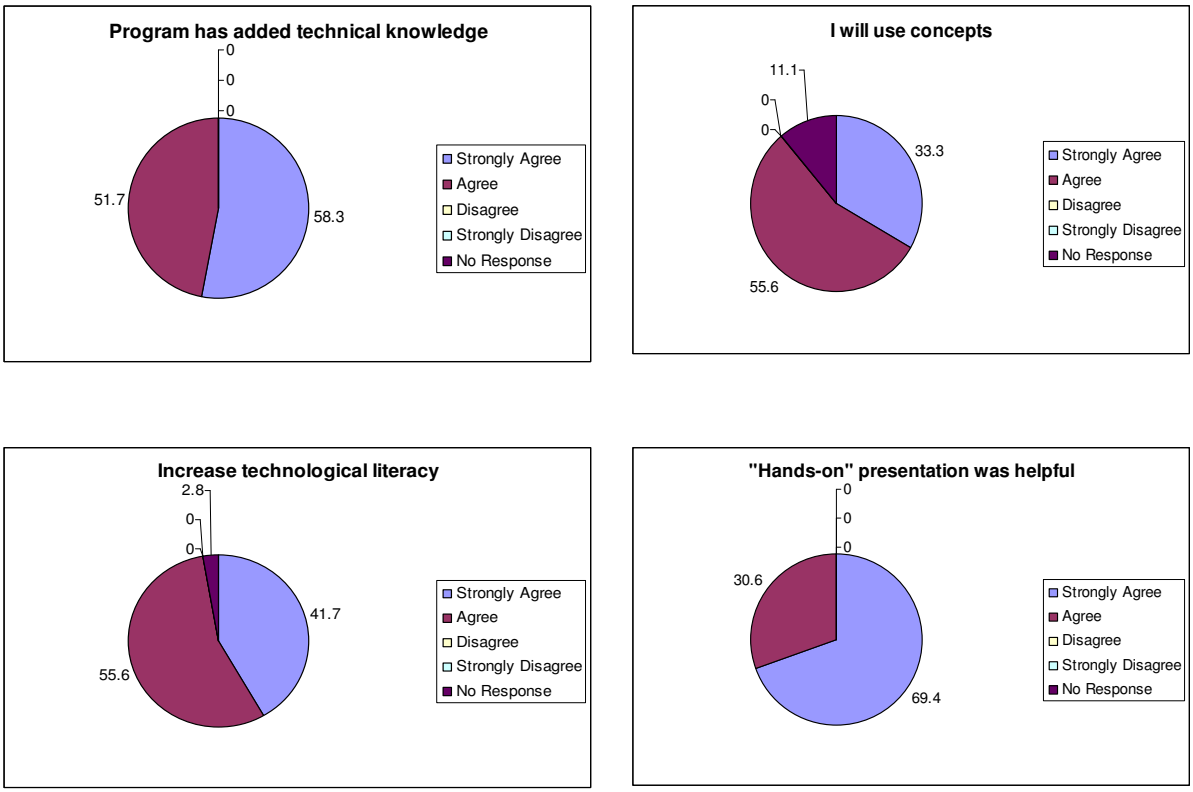

Figure 5: Results of the IEEE Survey

In addition to a series of programmatic questions, the IEEE survey asked all study participants at what grade level should technologically oriented in-service programs be presented and how many technologically oriented in-service should be offered to teachers (Figure 6). Nearly half of the respondents (47%) believed that technologically oriented in-services should be presented at all grade levels. Nearly 25% of the respondents indicated that technologically oriented in-services should be delivered at the K-2 or 3-5 grade levels respectively, and 5.6% believed that these kinds of in-services should be delivered at the K-5 grade level. Just over 11% of the respondents believed that technologically oriented in-service programs should be presented at the 6-8 grade level and another 2.8% felt that they should be presented at the 3-8 or the 3-12 grade levels.

When asked how many technologically oriented in-service topics should be offered, 30.6% of respondents believed 1-2 per year would be sufficient. An additional 30.8% felt 3-4 topics per year should be offered. Nearly 17% of the academy participants wanted 5-6 technologically oriented in-services offered per school year, and 2.8% felt more than 7 per year should be offered.

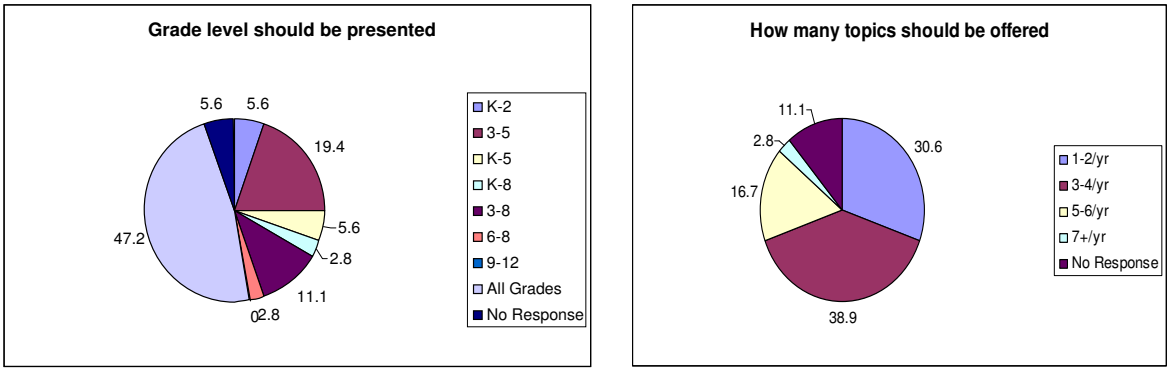

Figure 6: Results of the IEEE Survey

Conclusion

The conclusions of the 2000 report titled, "Before It's Too Late: A Report to the Nation from the National Commission for Mathematics and Science Teaching for the 21st Century," headed by commission chair John Glenn, contained a primary message; American students must improve their performance in mathematics and science if they are to succeed in today's world and if the United States is to stay competitive in an integrated global economy.[16] The secondary message from the report points in the direction of a solution: the most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching.[16] According to this report and the research by the new ASEE K-12 Division, better STEM teaching is grounded in improving the quality of teacher preparation and in making continuing professional education available for all teachers currently in the profession.[2,16]

The partnership between the Metropolitan School District of Wayne Township and The Purdue School of Engineering and Technology at IUPUI addresses this issue of K-12 professional development in STEM areas. Data gathered for this study provide evidence that the **E^2=MC^2** goals delineated below were met:

- Increase in teacher content knowledge (pre/post surveys, focus groups, self-assessment, observations)
- Increase use of best instructional practices (pre/post surveys, focus groups, self-assessment, observations)
- Increase in teacher collaboration (pre/post surveys, focus groups, interviews, observations)
- Increase in the use of technology to support teaching, student learning and assessment (district's Use of Technology Self-Evaluation Rubric, observation)
- Increase level of student achievement (grades, course completion, ISTEP+, district benchmark assessment)

The pre-post test results and the results from the IEEE survey reveal improvement in all areas surveyed. A summary report of the 2005-06 Academy by *INSIGHTS* consulting president Teresa Jump, Ed.D, also revealed that all program goals were met or exceeded. Dr. Jump performed an analysis of the pre-post test survey results, lesson plan reviews and focus groups and found:

- Lesson plans improved over the year by balancing spiral review, direct instruction, writing, and problem solving into daily lessons
- Increased use of best math instructional practices in eight areas of the Instructional Practices Survey
- Increased awareness of best instructional practices in mathematics
- Increased integration of innovative technologies in math instruction
- Increased technological literacy
- Increased networking, support, exchange of ideas/sharing, problem solving, etc. among teachers
- Increased opportunities to attend state and national conferences and workshops
- Increased willingness to provide teacher in-service based on their newly acquired knowledge, skills, and experiences[15]

In addition, Dr. Jump's final report found that the strengths of the Academy included:

- Strategic focus on math and technology for elementary and middle schools
- Strong partnership with IUPUI-School of Engineering & Technology
- Follow-up on-line coaching and support (year-long) for teacher participants
- Development of teacher leaders of mathematics instruction and mathematics content knowledge at each elementary and middle school who can be used as resources to other faculty in their building
- Strong district leadership and support for project
- Participation in district, state, and national conferences and workshops
- Budget for teachers to attend state and national meetings[15]

Finally, the summary report gathered achievement data from the corporation in an effort to create baseline data for years two and three of the study. It should be noted that the district's math scores are stable or slightly declining while student demographics are increasing in diversity and poverty (with a growing Hispanic ESL population). The data is offered in this report to share a baseline for comparative future scores (Table 2).

State Standardized Test Scores in Mathematics **AVERAGE DISTRICT PERCENT PROFICIENT**					
	2005	**2006**	**2007**	**2008**	
Elementary	80.7%	81.0%			
Middle	80.3%	77.3%			
High School	68.0%	67.5%			

Table 2: Baseline Data for Future Study and Trends

In closing, the summary report prepared by Dr. Jump stated:

> "In summary, Project **$E^2=MC^2$** has successfully met each of its project goals (thus far) to help advance the application of best instructional practices in mathematics for elementary and middle schools. The staff have developed and implemented a high quality professional development model for teachers with a university partner (IUPUI). Innovative technologies have been integrated into classroom lessons. Teachers in the cohort became an active "learning community," sharing and exchanging ideas, solving problems, and supporting each other while teaching new lessons and utilizing new instructional practices. Additionally, teacher participants have made presentations to their colleagues at their individual schools. Project **$E^2=MC^2$** staff and partners are excited to launch year two of the grant project as they continue their efforts to empower teachers to learn and grow in mathematics and engineering education."[15]

It is clear that year one of the **$E^2=MC^2$** has met targeted goals and has built a strong foundation for future student success. Data were gathered using an instructional practices survey, an IEEE survey and a summary report by an external consulting agency. Triangulation of data is necessary to lend validity and reliability to findings and these data triangulate well. More importantly, baseline data has now been collected for student achievement which bodes well for future study of this unique program in years two and three.

As the STEM crisis continues in our country, the kinds of partnerships between K-12 schools, universities and engineering professional organizations will continue to thrive. **$E^2=MC^2$** is a unique program that shows promise and must be examined even more closely to determine impact on student learning in STEM areas. Ultimately, increased student achievement is the goal of any professional development partnership, and the results of years two and three of the **$E^2=MC^2$** project must be analyzed to determine the complete effectiveness of the initiative.

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Appendix I

MSD Washington Township
Teacher Mathematics Summer Academy 2005

Monday June 20	Tuesday June 21	Wednesday June 22	Thursday June 23	Friday June 24
Whole Group 1. Describe purpose of Grant 2. Introduce Facilitators 3. Article Review 4. Cup stacking Activity 5. Issue Tools/Angel 6. Flip Chart Jigsaw Activity	**Whole Group** **Introduce Camera** 1. Number Sense Photo Scavenger Hunt/Picture Downloading 2. Lesson Collaboration/ Peer Coaching Video 3. Best Practices Handout	**Whole Group** 1. Card Activities **Small Groups** 2. Continue Grade Level Breakouts - Algebra **Whole Group** 11:30 Leave for IUPUI 12:00 Arrive at IUPUI	**Whole Group** **1.** IUPUI Reflection 2. Problem Solving ▪ 4-Step Model ▪ 5 Cognitive Levels ▪ Charades **Small Groups** 3. Grade Level Breakouts – Problem Solving Relate to Textbook Language ▪ Vocabulary ▪ Multiple Standards with focus on Algebra./Number Sense/ Communicating and Reasoning	8:30 Leave CEC 9:00 Arrive at IUPUI Focus on developing 3 or 4 lessons/labs to use with our students.
Lunch	**Lunch**	**Lunch at IUPUI**	**Lunch**	**Lunch at IUPUI**
Small Groups 7. Grade Level Breakouts – Number Sense <u>Elementary</u> ▪ Fractions ▪ Multiples ▪ Factors ▪ Decimals ▪ Rounding <u>Middle School</u> ▪ Fractions ▪ Decimals ▪ Percent **Whole Group** 8. Reflection	**Whole Group** *4. What's On My Plate?* Activity **Small Groups** 5. Grade Level Breakouts- Algebra <u>Elementary</u> ▪ Patterns (Repeat/Growing) ▪ Functions ▪ Equations ▪ Graphing linear Equations ▪ Substitution <u>Middle School</u> ▪ Patterns ▪ Functions ▪ Graphing Equations **Whole Group** 6. Reflection	IUPUI Laboratory Visit 3:00 Leave to CEC 3:30 Arrive at CEC	**Breakouts Continue** **Whole Group** 4. Web Site Connections/Surfing/ Book marking, *United Streaming* 5. Reflection	12:30 Leave IUPUI 1:00 Arrive at CEC Reflect on IUPUI visit. **Grade Level Teams** Using the *Guide for Daily Mathematics Instruction* and other resources, create a quality lesson that includes at least one of the three focus standards. **Whole Group** Reflection/Wrap-up

Appendix II

Project Goals Correlation to Action Plan

Assessed Need	Project Goal(s) to Address Need	Project Activity to Meet Goal
Staff development activities are needed to help teachers increase their depth of understanding of mathematical concepts, particularly in the areas of communicating and reasoning mathematically, algebraic reasoning, problem solving, and number sense in order to make the mathematical concepts meaningful and to assure student success.	Goal 1: All teachers participating in the program will increase their knowledge in problem solving, communicating and reasoning mathematically, algebraic thinking, and number sense as measure by a pre- and post-assessment.	1. Summer Math Academy to increase teacher knowledge base of mathematics 2. Online learning to strengthen areas of weakness in mathematics knowledge 3. On-going access to IUPUI Engineering and Technology faculty to tutor or answer questions 4. University sponsored hot-line for teachers and students
An increase or reform is needed in instructional strategies in the teaching of mathematics to better reach the educational needs of the districts diverse student population.	Goal 2: All teachers participating in the program will increase their knowledge and understanding of how students learn by focusing on research-based practices of teaching as measured by observable classroom practices and students' demonstration of their understanding of math concepts.	1. Summer Math Academy to study models of best practices and to practice effective coaching 2. Online learning opportunities to view videos of model teachers and to study useful resources 3. Peer coaching and modeling 4. Applied Science and Engineering problem/task development for use in the classroom 5. Monthly seminars for participants to follow up on teacher training
Staff development is needed for teachers to crate mathematics tasks for students that have a real world connection so that learning can be both fun and meaningful.	Goal 3: All teachers participating in the program, in conjunction with our IUPUI partners, will learn to develop and create mathematical tasks, activities and applications connected to the real world that are developmentally appropriate and standards based. A minimum of one new task per semester will be used the first school year with an increase of one per month the second year.	1. Summer Math Academy to learn how to integrate real world mathematics applications 2. On-going access to IUPUI Engineering and Technology faculty for continued support and feedback 3. Monthly seminars to share newly developed tasks that incorporate real world applications 4. University sponsored hot line for teachers and students
Teachers need to develop further expertise in teaching strategies as they apply to the reluctant learner, uses of technology, and other essential elements of teaching	Goal 4: All participating teachers will increase their use of technology with students so that technology is being used 100% of the time when appropriate.	1. Summer Math Academy for training on hardware and software applications 2. On-going access to IUPUI Engineering and Technology faculty for technology assistance 3. Monthly seminars for follow-up technology training and sharing student work that involves technology 4. University sponsored hot-line for teachers and students

Appendix III

INSTRUCTIONAL PRACTICES IN MATHEMATICS
TEACHER SELF-ASSESSMENT

Date: _____ Grade Level: K-3 _____ 4-5 _____ 6-8 _____

CATEGORY	Almost daily 4	Weekly 3	Bi-monthly 2	Monthly or less 1	Never 0
Mathematical Reasoning I have my students engage in drawing logical conclusions and justifying their answer as well as their solution process. I regularly vary my instruction to reinforce student reasoning both inductively and deductively.					
Communicating Mathematics I regularly engage my students in discussing mathematics, reading mathematics, writing mathematics, and listening to mathematical ideas.					
Problem Solving I have a thorough knowledge of problem solving strategies and the steps to problem solving. I regularly give my students open-ended problems to solve and extended problem-solving projects involving mathematics. I ask students to investigate and formulate questions from problem situations.					
Algebraic Thinking I regularly require my students to recognize and describe patterns; identify and use functional relationships; and develop and use tables, graphs, and rules to describe situations. I routinely use variables to express relationships.					
Number Sense I instruct students in ways to develop number and operation sense. I regularly encourage my students to apply various estimation strategies in all areas of mathematics. I reinforce student understanding of the meaning of key concepts such as place value, fractions, decimals, ratios, proportions, and percents.					
Real World Connections I regularly assist my students in connecting mathematics to other subjects and to the real world. I also assist students in connecting topics within mathematics and share how to apply the mathematics to solve real world problems.					

CATEGORY (continued)	Almost daily 4	Weekly 3	Bi-monthly 2	Monthly or less 1	Never 0
Technology Integration I actively seek new ways to appropriately incorporate technology into my instruction to expand the mathematics that can be taught and enhance student learning. I teach my students to create and edit documents using a variety of software applications. I encourage my students to employ appropriate technologies to support communication, data analysis and problem solving proficiencies. I use technology to help address individual student needs. I have my students use calculators for complex calculations and problem solving when appropriate.					
Online Resource Utilization I frequently use online resources such as *Angel*, mathematics websites, interactive textbook links, classzone.com, and eduplace.com. I use online technology to get expert advice, view instructional videos, download resources, collaborate with peers, and post my teacher-created lessons.					
Understanding and Implementing Researched-Based Best Practices in Mathematics Instruction **Overall Rating Average:** (Total Points/8)	I am a great role model for other to view best practices in the teaching of mathematics	I often incorporate best practices in my mathematics instruction and am continually growing in this area.	I am making progress but I still have a ways to go. I understand what the best practices of instruction are, but need to incorporate them more into my instruction.	I am at the beginning stages in applying best practices in mathematics instruction with my students.	I haven't started applying best practices in mathematics instruction with my students.

COMMENTS

Appendix IV

Washington Township Math Academy Workshop
IEEE Teacher In-service Program Presentation Questionnaire Results
30 June 2006

As part of IEEE's Teacher In-Service Program, the IEEE and the Central Indiana Section contributed to a week long workshop for teachers in grades K-8. This workshop is part of an Indiana Department of Education grant with the Washington Township Schools in conjunction with Indiana University Purdue University at Indianapolis.

To promote STEM two hands-on activities were presented to 37 educators from Washington Township, IN on 30 June 2006. Many thanks go to Ken Reid and Chris Floyd for their participation. The topics presented included: "Design and Build a Better Candy Bag" and "Design and Build Your Own Robot Arm."

37 participants (100.0%) completed a twelve-item questionnaire. An item summary of the results of the questionnaire follows and are reported in raw numbers and percentages. In addition, comments from participants are included.

Section I-- Demographic Information

Item #1—What is your current position?

	#	%
Teacher	35	94.6
School-based Administrator	1	2.7
District Personnel	1	2.7
Other	0	0.0
No Response	0	0.0
Totals	37	100.0

Item #2—If you are a teacher please indicate what grade level(s) you currently teach.

	#	%
K-2	6	16.2
3-5	15	40.5
K-5	4	10.8
6-8	10	27.0
Other	2	5.4
No Response	0	0.0
Totals	37	99.9

Item #3— Please indicate how many years you have taught in your current school district: (include the current year as one)

	#	%
3 years or less	8	21.6
4-10 years	17	45.9
11-20 years	6	16.2
21-30 years	4	10.8
31+	2	5.4
No Response	0	0.0
Totals	37	99.9

Item #4—What is the primary subject area you currently teach?

	#	%
Elementary Teacher (K-5)	23	62.2
Mathematics (6-8)	11	29.7
Reading	1	2.7
Other	**2**	**5.4**
No Response	0	0.0
Totals	37	100.0

Section II—Program Question Results

Item #5—This program has added to my technical knowledge base.

	#	%
Strongly Agree	13	35.1
Agree	24	64.9
Disagree	0	0.0
Strongly Disagree	0	0.0
No Response	0	0.0
Totals	37	100.0

Item #6—I will use the concepts presented in my classroom instruction.

	#	%
Strongly Agree	17	45.9
Agree	18	48.6
Disagree	1	2.7
Strongly Disagree	0	0.0
No Response	1	2.7
Totals	37	99.9

Item #7—Today's topics will increase my student's level of technological literacy.

	#	%
Strongly Agree	21	56.8
Agree	15	40.5
Disagree	1	2.7
Strongly Disagree	0	0.0
No Response	0	0.0
Totals	37	100.0

Item #8—The "hands-on" presentation was helpful to me in understanding the concepts discussed.

	#	%
Strongly Agree	26	70.3
Agree	10	27.0
Disagree	0	0.0
Strongly Disagree	0	0.0
No Response	1	2.7
Totals	37	100.0

Item #9—This presentation has increased my level of technological literacy.

	#	%
Strongly Agree	9	24.3
Agree	24	64.9
Disagree	3	8.1
Strongly Disagree	0	0.0
No Response	1	2.7
Total	37	100.0

Section III—Additional Questions

Item #10—Please list additional in-service topics that would be of benefit to you.

- "Something involving chemistry or electricity"
- "An examination of the different types of engineering pictures/examples of their craft"
- "Any physical science"
- "The hands-on act. make it real to me, so more of those would be beneficial"
- "I would like a weekly/monthly email about new hands-on projects"
- "Electricity lessons demonstrated"
- "What can you do with an engineering degree?"
- "Scientific process"
- "An in-service on the careers available in engineering"
- "Info on camps for my students"
- "Electricity and engineering careers"
- "Electricity; general engineering career"
- "Hands-on math lessons based upon Indiana Standards"

Item #11—What grade level should technologically oriented in-service programs be presented?

	#	%
K-2	2	5.4
3-5	7	18.9
K-5	1	2.7
K-8	1	2.7
3-8	2	5.4
6-8	2	5.4
9-12	0	0.0
All Grades	22	59.5
No Response	0	0.0
Total	37	100.0

Item #12—How many technologically oriented in-service topics should be offered?

	#	%
1-2/yr	8	21.6
3-4/yr	27	73.0
5-6/yr	1	2.7
7+/yr	1	2.7
No Response	0	0.0
Total	37	100.0

Section IV—Comments From Participants

- "Nice job—well done & fun"
- "I really enjoyed it. I would love to have people come out to the classroom"
- "Thanks! It was a great day!
- "Thanks"