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# IMPROVEMENT OF STEM EDUCATION WITH THE INTEGRATION OF DATA-LOGGERS IN THE SHINING STAR PROJECT, 2007-2011 IN SOUTHERN INDIANA

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**Abstract.** This paper describes a regional program that involved directly four middle schools and indirectly a large number of secondary schools in southern Indiana in a partnership with Indiana University Southeast working with middle school science educators to improve STEM education in their classroom. The program predated the Next Generation Science Standards (NGSS); we used the Indiana Academic standards and the National Science Teachers Association Science Standards. This program (2007-2011) raised student standardized exam scores in mathematics, improved participation in the classrooms and encouraged student participation and interest in STEM education. This program was success because the university asked the teachers "what-do-you-want" and "how-can-we-help-you". The Shining Star program spent time researching teacher in-service to maximize our time with the teachers and to promote best practices. We chose to do professional development with educators so they would share what they learned with colleagues and students.

*Keywords:* technology, data-loggers, middle school science-mathematics teaching

## STEM education as a key to the economic future

Science is the key to the nation's economic future in technology and our continued standard of living. Science is the class in which students learn how to use various instruments and measuring devices, manipulate numbers into graphs and then try to write the whole experience into a written report. Knowledge and skills gained in language arts and mathematics come together and form a single discipline of observing and applying natural phenomena into applications. The field of science, technology, engineering and mathematics (STEM) is vital to the nation's future and the public is responding to the status of STEM education by demanding: high stakes testing of students and teachers, greater teacher accountability, and legislative mandates like No Child Left Behind and Race to the Top. Never have schools been under such pressure to demonstrate student learning and mastery of concepts. The call for improvement of science, technology, engineering and mathematics (STEM) education to prepare students for the 21$^{st}$ century workforce by policy-makers affects schools, teacher education and teacher preparation and practices (Dani & Koenig, 2008). Educators and politicians are becoming concerned about the widening digital divide between schools based on Instructional Communication Technology (ICT) trained educators. The digital division that was to bring schools and students closer together is of great concern for urban and rural schools, and is influence by pre-service teacher education and affected by professional development of K-12 educators (Lawless & Pellegrino, 2007).

The outcome of teacher development and gaining experience in ICT is important to the national, state and local initiatives in STEM education and is a perennial goal by federal, state and local education organizations with little resources to implement such a lofty goal. The goal expanded by many science educators to implement and improve ICT and STEM education is based on three facts: practical science helps students to learn; practical science helps students to learn about science, and practical science enables students to do science (McGrath et. al. 1997; Hodson, 1998; Rodrigues et al., 2001). Hodson (1998) goes further in his promotion of ICT education to support computer-based learning, fieldwork and museum-based learning, to supplement components for STEM education. This revolution in school accountability, teacher professional development and student learning in addressing STEM and ICT is taking teaching, learning methodology, and incorporating new technology to new levels.

**I-STEM and Indiana University Southeast**

Indiana University Southeast (IUS) received the opportunity to act on the challenge and positively influence student learning in science and mathematics with funding from the Indiana STEM network. Our regional site at IUS was identified as ISTEM-IUS and part of the Indiana Science, Technology, Engineering and Mathematics (ISTEM) Resource Network initiative that was established in 2006 and partially funded by a $3.4 million grant from the Lilly Endowment, Bio Crossroads, Lumina Foundation and the National Governors Association.[1)]

The Network is a statewide consortium of 18 Indiana higher education institutions dedicated to measurably improving K-12 student achievement in the STEM disciplines. In 2007-2009, the Network focuses on providing research-based professional development for current Indiana math teachers to help meet statewide academic standards. More than 6,000 teachers, who work with more than 150,000 K-12 students throughout Indiana, have participated in ISTEM professional development programs.

The ISTEM state network and the ISTEM-IUS program sought to address the areas of concern in the Indiana Strategic Skills Initiative (SSI) in skills needed by students for the workforce for all Indiana occupations in the future. Skills needing to be developed were identified: critical thinking, complex problem solving, science, mathematics, reading comprehension, and active learning. The Indiana Business Research Center and Indiana Department Workforce Development have projected the skills that will be in highest demand from 2004-2014[2] (Table 1).

**Table 1.** Skills in Highest Demand for all Indiana Occupations, 2004-2014

| Rank | Skill | Index |
|---|---|---|
| 1 | Reading Comprehension | 100.0 |
| 2 | Active Listening | 97.1 |
| 3 | Critical Thinking | 94.3 |
| 4 | Speaking | 91.4 |
| 5 | Coordinating | 88.6 |
| 6 | Active Learning | 85.7 |
| 7 | Instructing | 82.9 |
| 8 | Monitoring | 80.0 |
| 9 | Writing | 77.1 |
| 10 | Time Management | 74.3 |

When the ISTEM network was conceived, the emphasis was to help Indiana achieve its vision to be a national leader in student academic achievement in STEM disciplines and the quality of its workforce. To do that, the ISTEM Network and the ISTEM-IUS program focused on the following goals: (i) articulation of a vision for science, technology, engineering, and mathematics education in Indiana that broadens awareness of the need for STEM literacy and supports high quality programs of instruction; (ii) mobilization of expertise and leveraging of resources that reach all K-12 children in Indiana, to foster comprehensive and challenging programs of instruction in STEM by distributing tools and learning methods and providing technical assistance to educational leaders (including principals and teachers).

The participating ISTEM universities were charged to set up their programs, and to establish partnerships with local school corporations, businesses, governments and citizens. Many sites engaged in developing workshops, seminars for teacher professional development, student STEM events, sponsorship of STEM opportunities, and others that responded to local concerns concerning STEM education. The 2007-2009 ISTEM-IUS's program was flexible and met the needs of the stakeholders. A third of our advisory board consisted of local business and community leaders. At IUS, we sought to invest long-term for our stakeholders in anticipation of program shifts for long lasting impact for students.

In 2009, the ISTEM Network shifted its focus on to Algebra readiness on direction from the Indiana Department of Education. This was most likely due to pressure created by the 2003 Trends in International Mathematics and Science Survey (TIMSS) that showed American schools in slight increase in both mathematics and science. The performance on the TIMSS encouraged policy makers to move to how science is done to science content knowledge. The TIMSS supporters advocate the development of deep understanding through an emphasis on concepts, models, and theories (Dani & Koenig, 2008). Many programs throughout the nation have retreated from an active process of teaching concepts, problem solving skills to teaching to the exams. The immediate result of teaching to the exam is that students are short-changed, and politicians and the media acting to symptoms and shortsighted solutions threaten the future of STEM related professions.

**STEM, Indiana University Southeast and our stakeholders**

At IUS, we surveyed our stakeholder school corporations to determine the direction and planning of the long-term programing that would benefit our schools. A comprehensive survey sent to over 80 math and science educators in our service area and 42.5% were returned (31 science teachers and 3 mathematics teachers). We tabulated the input and then proceeded to the establishment of the Shining Star Project. The results of the 34 returned surveys helped us in deciding the professional development opportunities, summer workshops and purchases of education materials to be shared with the Wilson Education Service Center. The Wilson Education Center, Charlestown, IN, is an education support facility that provides professional development, technology support, supplemental educational service, cooperative purchasing and distribution center for member school districts in southeastern Indiana.

The survey included 25 difference schools from 12 school corporations being represented by 24 high school teachers and 10 middle school teachers, in rural (18), suburban (4) and urban schools (3) in southern Indiana. The grant was restricted to only Indiana school corporations. We queried the teachers on their academic area, grade level, use and availability of technology, personal subscriptions to periodicals, magazines, newsletters and related materials to science and mathematics, and their use of, and areas of interest in STEM education and information.

Overwhelmingly, the surveyed educators wanted IUS to commit to meaningful education reform that would improve STEM education in a long-term commitment. The educators emphasized that they wanted to see professional development, resource purchases, new and applicable technology workshops, and better professional development that would continue to enhance STEM education. Fig. 1 shows the suggestions offered by the surveyed teachers.

The teachers were queried on media use in their teaching; we found about half (19) of the surveyed STEM educators responded that they personally subscribed to, and regularly read, any periodicals, magazines, newsletters etc., that were specifically related to science or science education. On internet access, 23 science educators consulted it a minimum of two to three times a week. None of the mathematic teacher's survey reported extensive internet usage. The response of the teachers of the survey ISTEM-IUS Teacher Interest Survey and its analysis guided our program and advisory board to scheduling the ISTEM-IUS Program sponsored events as shown in Table 2. The ISTEM-IUS program reached multiple times out to nearly 300 educators in 42 public and private schools that would impact over 57,000 students throughout southeast Indiana (Table 2). This was one of the most effective and far-reaching outreach programs on what the science education program at Indiana University Southeast had ever embarked.

The ITEM-IUS Project addressed the following professional development actions in response to the initial teacher surveys distributed at the beginning of the ISTEM-IUS program: (A) ISTEM-IUS purchases from Carolina Biologic Supply Company, 24 GEMS Science Kits for the Wilson Center for distribution of inquiry-based laboratories that require minimum in-service education for secondary science teachers to use in the Southeastern Indiana region. The kits contain guides that supported teachers with the information they needed to be successful with each unit, including background information, preparation support, step-by-step lesson instructions, and anticipated outcomes. These kits supplied additional content, reading resources, writing ideas, assessment options, and extensions to help students further explore lesson concepts. We received support from our local representatives for teacher in-service was provided at our campus and on request at the school sites; (B) Two professional development workshops were held in the spring of 2008. The first March Middle School Madness utilized local authorities: Dr. Claude Baker, Dr. John Doyle, Dr. Glen Mason of Indiana University Southeast; and Ms. Darina Hollenbeck of Greater Clark Schools, Jeffersonville, Indiana, addressing concerns of middle school teachers. The Carolina Biological Supply Company demonstrated and provided professional development to the participants their GEMs Kits: Acid Rain, Ocean Currents, and Plate Tectonics. Registered participants were from 10 public school corporations and four private schools; (C) The April Science Symposium featured national and international educators: Dr. Tom Tretter, University of Louisville; Dr. Jeff Weld, University of Northern Iowa; and Dr. Robert Yager of the University of Iowa. Carolina Biological Supply Company demonstrated and provided professional development to participants using the kits purchased from the Wilson Education Center: Global Warming, Crime Lab and Schoolyard Ecology. Registered participants were from 15 public school corporations and 3 private schools; (D) In June 2008, we sponsored a one-week workshop: "Integrating Technology in the Science and Mathematics Classroom" at the University of Indiana Southeast. The following groups: ISTEM-IUS, Lab Aids-SESUP, Fourier Systems and the IUS School of Education, partnered on this project. To establish the Shining Star program the ISTEM-IUS program purchased student data-loggers for use in the workshop for teacher professional development; (E) In June 2009, we sponsored our second summer workshop the ISTEM-IUS program, Fourier Systems and the IUS School of Education formed a cooperative relationship for a one-week workshop. This workshop was attended by 16 teachers from Indiana and Kentucky, and utilized master teachers from the Greater Clark Schools to introduce how to use the data-loggers for use in their existing curriculum; (F) A conference for the 2009 fall semester emphasized "Inquiry, Discovery, and Constructivism for Science and Mathematics Learning" with a focus on elementary school learners. 40 participants from the Elementary Science and Mathematics methods classes (pre-service teachers) and 12 elementary and middle school teachers from three school districts were in attendance. This conference was sponsored by the Indiana University Southeast School of Education, since the state level STEM network had switched all funding to algebra readiness programs.

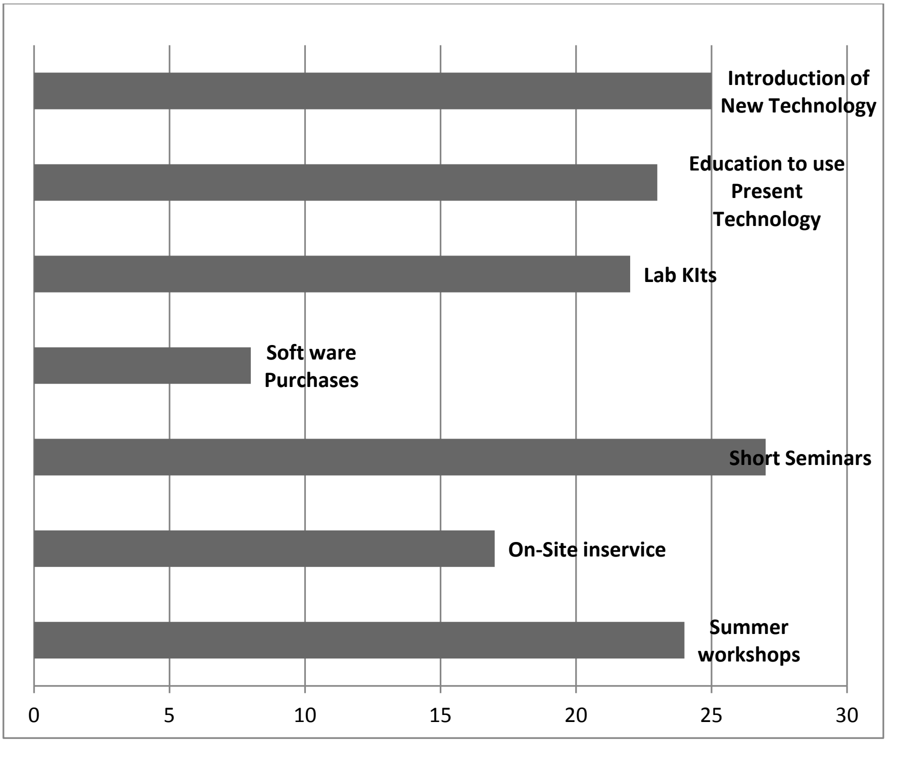


**Fig. 1.** Suggested priorities for ISTEM-IUS program survey by queried educators, n=34 (majority of suggestions had multiple requests)

**Table 2.** ISTEM-IUS program impact

| Event | Number of Teachers Participating each in event | Number of Schools Participating each in event | Students Reached by ISTEM-IUS by full-time teachers |
|---|---|---|---|
| March Science Madness 2008 | 35 teachers, 12 IUS student teachers | 10 public, 4 private schools | 10,919 |
| April Science Symposium 2008 | 43 teachers, 12 IUS student teachers and 12 IUS faculty | 15 public, 3 private schools | 12,325 |
| June ISTEM – Shining Star Workshop 2008 | 18 teachers | 7 public and 2 private schools | 8,424 |
| June ISTEM – Shining Star Workshop 2009 | 16 teachers, 5 Education Students | 6 public and 3 private schools | 8,725 |
| Discovery, Inquiry and Constructivism in the Elementary Classroom, 2009 | 12 teachers, 40 IUS student teachers | 8 public and 3 private schools | 11,000 |

The ITEM-IUS Project addressed the following professional development actions in response to the initial teacher surveys distributed at the beginning of the ISTEM-IUS program: (i) ISTEM-IUS purchases from Carolina Biologic Supply Company, 24 GEMS Science Kits for the Wilson Center for distribution of inquiry-based laboratories that require minimum in-service education for secondary science teachers to use in the Southeastern Indiana region. The kits contained guides that supported teachers with the information they needed to be successful with each unit, including background information, preparation support, step-by-step lesson instructions, and anticipated outcomes. These kits supplied additional content, reading resources, writing ideas, assessment options, and extensions to help students further explore lesson concepts. We received support from our local representatives for teacher in-service was provided at our campus and on request at the school sites; (ii) Two professional development workshops were held in the spring of 2008. The first March Middle School Madness utilized local authorities: Dr. Claude Baker, Dr. John Doyle, Dr. Glen Mason of Indiana University Southeast; and Ms. Darina Hollenbeck of Greater Clark Schools, Jeffersonville, Indiana, addressing concerns of middle school teachers. The Carolina Biological Supply Company demonstrated and provided professional development to the participants their GEMs Kits: Acid Rain, Ocean Currents, and Plate Tectonics. Registered participants were from 10 public school corporations and four private schools; (iii) The April Science Symposium featured national and international educators: Dr. Tom Tretter, University of Louisville; Dr. Jeff Weld, University of Northern Iowa; and Dr. Robert Yager of the University of Iowa. Carolina Biological Supply Company demonstrated and provided professional development to participants using the kits purchased from the Wilson Education Center: Global Warming, Crime Lab and Schoolyard Ecology. Registered participants were from 15 public school corporations and 3 private schools; (iv) In June 2008, we sponsored a one-week workshop: "Integrating Technology in the Science and Mathematics Classroom" at the University of Indiana Southeast. The following groups: ISTEM-IUS, Lab Aids-SESUP, Fourier Systems and the IUS School of Education, partnered on this project. To establish the Shining Star program the ISTEM-IUS program purchased student data-loggers for use in the workshop for teacher professional development; (v) In June 2009, we sponsored our second summer workshop the ISTEM-IUS program, Fourier Systems and the IUS School of Education formed a cooperative relationship for a one-week workshop. This workshop was attended by 16 teachers from Indiana and Kentucky, and utilized master teachers from the Greater Clark Schools to introduce how to use the data-loggers for use in their existing curriculum; (vi) A conference for the 2009 fall semester emphasized "Inquiry, Discovery, and Constructivism for Science and Mathematics Learning" with a focus on elementary school learners. 40 participants from the Elementary Science and Mathematics methods classes (pre-service teachers) and 12 elementary and middle school teachers from three school districts were in attendance. This conference was sponsored by the Indiana University Southeast School of Education, since the state level STEM network had switched all funding to algebra readiness programs.

The result of these professional developments renewed interest in STEM education and opportunities for many of the participants, and brought numerous networking opportunities for all participants and the university. All of the STEM education activities predated the discussion of the Next Generation Science Standards (NGSS), but geared to assist our teachers to addressing the Indiana Academic Science Standards (IASS) appropriately. Experts came to our campus to share their expertise and stories to inspire the participants. The participants' utilization of the Wilson Education Service Center had improved since the conferences after schools learned about the GEMs science kits being housed there. To encouraged future emphasis and continued teacher in action in STEM education, ISTEM-IUS events provided student teachers and pre-service education students the opportunity to interact with classroom teachers in an informal environment.

**The Shining Star Project**

Indiana University Southeast formed this partnership with Greater Clark Schools Corporation and other schools in southeast Indiana. The ISTEM-IUS program established the Shining Star Project to promote science, technology, and literacy in several of the middle and senior high schools in the Clarksville Community School Corporation, New Albany-Floyd County School Corporation, and Greater Clark School Corporation after the I-STEM Network funding was used to fund Algebra readiness. The Shining Star Project continued to reach over 5,000 students after the ISTEM program had ceased to address science education.

The Shining Star Project promoted science and mathematics learning, with applications, and appreciation with the assistance of science educators using data-loggers. The driving force to institute the Shining Star Project at the middle school level was two-fold. First, the middle schools have a solid measurement instrument to track learning progress, the Indiana Stateside Testing for Educational Progress Plus (ISTEP+). The ISTEP+ is an annual test designed b to measure students' mastery of basic educational skills, such as, reading, writing and mathematics. Before 2009, it was administered in the fall: beginning the 2009-10 with school year, it was administered in the spring. All students in grades 3 through 8 take the ISTEP+ each spring, with language arts and math covered in each test. Additionally, students in grades 4 and 6 are tested in science, and students in grades 5 and 7 are tested in social studies.[3)] Second, there was a large pool of educators and principals (all participants in the ISTEM-IUS professional development activities) ready to participate in this project in schools that offered diversity and academic need.

Teachers were recruited for the Shining Star Program from the participating schools and applied for the summer workshops offered at IUS learned how to integrate the data-loggers into their existing curricula and meeting the Indiana Academic Standards in Science. They were selected on their willingness to use the data-loggers, appropriateness of the classes and need for professional development and/or for re-licensure. The professional development program emphasized (a) guided inquiry activities, (b) participants' own exploration within the range of given tasks, (c) instructors' guidance on the processes of inquiry and technology, and (d) discussions of ways to bring their inquiry experiences in their classrooms. The selected teachers agreed to move their classroom teaching from a teacher-centered, textbook driven program to that of a constructivist inquiry-based student centered learning model.

The Shining Star teacher participants followed the listed guidelines: (i) Complete a one-week professional development workshop at IUS entitled "Integrating Technology in the Science Classroom; (ii) Attend an in-service session prior to the start of the school year and throughout the school year; (iii) Submit tri-weekly reports to the ISTEM-IUS/Shining Star program director about the use and application of the data-logger system in their classes. See appendix; (iv) Cooperate with all assessments related to the Shining Star Program; (v) Teachers were provided technical support by Fourier-Systems; (vi) IUS provided academic support for teachers using existing curriculum.

The professional development was based on research by Rodrigues et al. (2001), Shymansky et. al (1983) who advocated that hands-on inquiry is an effective way to learn science and develop teaching skills. The focus of using the data-loggers was to develop inquiry learning, and through the in-service of teachers in constructivist inquiry, teachers were able to teach students to develop critical thinking skills to identify and solve problems (Choo, 2005; Colburn, 2004). This understanding guided the formation of the summer workshops and professional development opportunities. We used the teachers' applications, the ISTEM Survey and the teachers' curricula to guide us in the structuring of the summer workshops. Rodrigues et.al (2001) emphasizes the successful integration of ICT must be meaningful, planned in advanced and the tasks to be well scaffolded with appropriate assessment that is clear to all parties. We presented the challenge to design an effective professional environment to introduce the data-loggers. We wanted to avoid the pitfalls of traditional programs that had been offered and failed.

Our professional development, workshops and in-the-field visits combined all the strategies discussed and we made extensive use of teachers guiding their peers to use the data-loggers and to share instructional strategies. Teachers were brought into the Shining Star summer workshop project because they had experience implementing it into their classrooms and could share common experiences and more importantly, they were known colleagues. Too often education reform initiatives fail because teachers and administrator are not active participants.

The new approach to learning science with technology with the inclusion of the data-loggers was the application of microcomputer-based-laboratory (MBL) technology in an inquiry based curriculum designed or adapted by the participants and the Shining Star Program staff.

Data-loggers were chosen as the primary instrument of technology to be used by the Shining Star schools. We chose data-loggers as they were unique, generated student curiosity and provided technology with transferrable skills for the students. Data-loggers are powerful, and an inexpensive learning tool which allows students to take them to the learning sites as a hand-held computer with electronic probes, interfacing boxes, and software that can measure and collect data (Choo. 2005; Hollenbeck, 2003; Krajcik & Layman, 1992). Data-loggers used by students have shown growth in responsibility and interest in science investigations. Choo (2005) reported results from the TESSI (Technology-Enhanced Secondary Science Instruction) project in the United Kingdom showing the students worked more independently in their science investigations. Pedretti et al. (1999) reported significant changes in the class and instructional practices with the integration of technology. On comparison of several data-loggers, the hand-held device that was selected for the Shining Star Project was the Nova 5000: a data logger with the capability of mini PC (word-processing, spreadsheets, Internet access), with multiple probe-ware advantage, (a student can measure temperature, motion, force, pH, sound, light, and many other science phenomena with relative ease) little required in-service, and the willingness of Fourier-Systems to provide generous professional support.

**Teachers and the Shining Star Project**

Shining Star Project encouraged participating teachers to play a pivotal role in creating the atmosphere that allowed students to investigate science with and ICT and MBL capabilities. Research by Hollenbeck (2003), Krajcik & Layman (1992), Pedretti et al. (1999), determined that the effectiveness of teaching with data-loggers could be determined by the teacher's comfort level and understanding of how the data-loggers are integrated into existing curriculum. To promote the use of data-loggers for science inquiry, it is critical that teachers are aware of the benefits of the technology as well as its relevance to pedagogy, and be supported and guided in their technology integration. IT-based activities with clear and concrete curriculum focus which support and enhance learning can lead to their initial adoption and integration into departmental schemes of work and teachers' lessons (Newton, 2000). The teachers were given the data-loggers, probes and manuals for their summer vacation to use them and experiment with the equipment as they saw fit. This extended practice, with technical support from the vendor, provided an easy transition for the teachers to integrate and use the data-loggers in their classes. Providing time over the summer for teachers to design data-logging activities with their curriculum was a significant support structure to encourage the adoption of the data-loggers. Conversations with participating teachers confirmed our predictions when they were queried "Did the professional development influence the degree in which you used the data-loggers?" Over 90 percent of the teachers agreed that the professional development was very important. The remaining 10 percent said it was "critical". All the teachers reported that the in-service provided over the summer workshops and being able to take the data-loggers and probes home over summer vacation was important so that they were able to use them and get comfortable to use them in the classroom with confidence.

This portable technology offered the student: (i) Enhanced inquiry based learning as embraced by the national and state curriculum standards; (ii) The ability for students to work as "real scientists;" (iii) Experience real science situations; (iv) Engagement in problem-solving activities; (v) Improvement of graphing and data analysis skills (Choo, 2005; Hollenbeck, 2003; Novak et al., 2002; Pedretti et al., 1999).

The data-loggers used by the science teachers in this project were viewed as a portable scientific laboratory that the students used to engage themselves in learning science by doing real science as described in the constructivist learning model by Yager (1991), Choo. (2005), Hollenbeck, (2003), Krajcik & Layman (1992). Table 3 shows how the teachers used the data- loggers in their regular class activities.

Teachers guided the students by leading them in initial experiences accompanied with careful question scaffolding and discussion. Teachers self-reported, and their school administrators observed, and observations by Shining Star staff showed students participated in class the modeled inquiry learning behaviors. The teachers reported students asked important and meaningful questions about their lab activities as described by researchers (Choo, 2005; Hollenbeck, 2003; Novak et al., 2002; Pedretti et al., 1996). The transition from teacher-centered instruction to student-centered learning occurred as desired. Teachers reported the transition was easy with the application of the data-loggers. The teachers encouraged students to ask sub-set questions that they can research, design and conduct their own investigations incorporating their technology tools. As predicted by Pedretti et al. (1996) and Choo (2005) the Shining Star teachers reported frequently the students wanted to take their laboratory experiences one step further and wanted to take their learning to a higher level. All reported that prior to the data-loggers, students wanted to do the required work only and very seldom ever took the lab activity any further than required. The National Science Education Standards[4)], American Association for the Advancement of Sciences benchmarks[5)] and the Indiana Academic Standards for Science[6)] all support the use of data-loggers in learning science, and teachers reported that their students would heartily endorse them. Table 4 reported use of the data-loggers indicated that the data loggers were used more frequently by the science teachers than the mathematics teachers. When the mathematics teachers (all at the middle school level) used the data-loggers, it was in conjunction with the science teachers at one of the school site, it is important to report that students in all schools in the Shining Star Project greatly improved in graphing abilities. Even though the mathematics teachers did not use the data-loggers as frequently as the science teachers as indicated by data from Table 4, there was growth in their academic area as well. A definite but, welcomed unexpected outcome result in the ISTEP+ exams was in the mathematics exams taken by the students in the school corporations involved in the Shining Star Project.

All teachers surveyed reported that student participation was better with the interactive curriculum and the use of data-loggers to provide the students "real world" applications with real questions and authentic assessments to evaluate their learning. The common teacher comments shared are: (i) Last year my groups loved them. They asked to use them during the last days of school; (ii) We have been learning basic mathematical functions such as metric conversions, significant figures, and scientific notation with the data-loggers; (iii) The students finally learned to construct and read graphs; (iv) I can't believe how much my students are on task and are really engaged in the activities; (v) The use of the data-loggers actually saves on prep time, because all I have to do is check to see if they are charged, I have the right probes and I am ready; (vi) The wireless connects to the Internet, gives students quick feedback, and they enjoy working with them. Students can use electronic resources (i.e., reference books, web sites) in class with the data-loggers and get instant feedback; (vii) The wireless function allows the students to engage in research, enables them to find solutions, retrieve additional information and share results with peers; (viii) Students are totally engaged with the machine and can see result in real time; (ix) Students are enthused about having technology that does real measurements, and frees up time in lab to do more.

**Table 3.** Data-loggers use in your class

| Grade Level | Activity | Class Used |
|---|---|---|
| Probe Applications Reported by Middle Schools | Acceleration<br>Electrical Currents (Amperes, Resistance and Voltage)<br>Distance<br>Graphing<br>Force measurement<br>Light sensitivity<br>Magnetic field detection and mapping<br>Photosensitivity<br>Photo-gates<br>Ph. Analysis<br>Pressure<br>Pulse<br>Respiration,<br>Smart pulleys<br>Temperature | Grades 6, 7 and 8 |

**Table 4.** Reported use of the data-loggers N=34

| | Several times a day | Once a Day | Two to three times a week | Once or less times a week | Never |
|---|---|---|---|---|---|
| Science N=31 | 3 | 11 | 14 | 6 | 0 |
| Math N=3 | 0 | 0 | 0 | 3 | 0 |

**Students and the Shining Star Program**

Students used the data loggers to gather real time information, and teachers can take the students where the science activity is occurring. Choo (2005) found that in order to capitalize on the time freed by the use of data-loggers, teachers must scaffold students' learning by encouraging critical thinking and discussion about the data in connection with their prior science knowledge or theories. Teachers noted in the surveys that they found themselves preparing in advance, probing and open-ended questions to encourage students to formulate their responses and guiding lab and post-lab discussions. Teachers were observed and reported that they would probe students about issues such as if the experiment is fair, what would they expect to happen next, the impact of varying experimental conditions, and what controls would be useful. However, to engage students in productive discussion, the teacher found themselves actively preparing students with the vocabulary to discuss and describe the graphs, e.g. patterns and trends, slope, maximum and minimum values, how one variable is dependent on another. The data-loggers are used in various settings: in the classroom, the laboratory or outdoors to solve problems or investigate questions. As the students gather the data, they develop a greater appreciation of how science solves problems. They develop a more in-depth understanding of science concepts, process skills, and experience using technology. All of the teachers reported that the students enjoyed graphing with the data-loggers, being able to manipulate the appearance of the graph and downloading the graph into their lab reports. An even greater skill discovered by the teachers and consistent with the research with the use of data loggers was analyzing data (Krajcik & Layman, 1992).Graphing is a difficult skill for many younger students to master. The data storage ability of the MLB allows the students to focus on analyzing the graph and the concepts represented by the graph. Students understand the information, because they constructed, and observed the conditions of the graph as data is collected. Brassell (1987), Hollenbeck (2003), Krajcik & Layman (1992) and Linn et al. (1987) report that the longer the delay in the graph production, the less the student will understand the graph and concepts that should have been learned. Allowing students access to real time graphing allows the students to modify their initial experiment enabling them to see how their experiment may be changed or the how variables can be changed to modify their experiment.

**Participating schools and the Shining Star Program**

Middle schools were used in the Shining Star Program because they were able to provide us with quantitative data from the annual ISTEP+ exams administered by the Indiana Department of Education and qualitative data from the teachers involved in the program. Prior to 2007, the ISTEP exam was administered in the fall, and after considerable debate, the exam was placed in the spring semester. The middle schools discussed are all within the same school corporation, which is one of the most diverse school corporations in southern Indiana. One middle school, Middle School 1 represented in Table 5 is the smallest in student population, and is rural. The second school, Middle School 2, is in a larger rural community but student population is from numerous subdivisions and has suburban environment. The other two schools, Middle Schools 3 and

4, are in urban population areas and are very diverse in student populations, economics, and have language diversity present. All the middle schools involved that had used the data-loggers in their curriculum reported success similar to the expectations in reports by Brassell (1987), Choo (2005), Hollenbeck (2003), Krajcik & Layman (1992), Linn et al. (1987) and on the manufacturer's website.[7] The success of the data-loggers in the classroom depends on the willingness of teachers to use them, support by the school administration, teacher professional development, and on the manufacturer's providing teacher professional development, and technical support to the school districts.

**Table 5.** Middle School 1

| Year / Subject | 2007 | 2008 Data-loggers introduced | 2009 | 2010 | State (2010) Averages |
|---|---|---|---|---|---|
| Math | 81 | 74 | 75 | 87 | 74 |
| Science | 54 | 56 | 55 | 58 | 58 |

**Table 6.** Middle School 2

| Year / Subject | 2007 | 2008 Data-loggers introduced | 2009 | 2010 | State (2010) Averages) |
|---|---|---|---|---|---|
| Math | 74 | 71 | 66 | 80 | 74 |
| Science | 57 | 57 | 56 | 38 | 58 |

The first school, Middle School 1, used the data-loggers, in Table 6. It has always ranked well in the ISTEP exams in math and science. The data-loggers were used only in the science classrooms for the first two years and the increase in science scores was modest but each year saw an improvement. In 2010, the mathematics teacher and science teacher started to co-teach several units together and both areas improve. The mathematics teacher cited the graphing skills learned by the students, and students being able to conceptualize the data in concrete terms. The two science teachers thought the data-loggers were most successful in helping students master graphing skills and interpreting data, which strengthen their understanding of science and this, improved their performance in mathematics.

This trend repeats in all the schools represented in the Shining Star program. We expected growth in science, but the greatest growth was in mathematics. The ISTEP exams in science did not emphasize graphing skills to the extent of the mathematics exam. Middle School 1 is a rural school, located in a rural community of 560, and serves the surrounding area. The student body is not very diverse and is predominately rural residents. The community has very high standards for the school and its students. The Shining Star program was quickly embraced and all the science and math teachers were involved and made extensive use of the data-loggers and the science kits purchased by the ITEM-IUS project. The improvements gained by the students were modest, yet they achieved the state average in mathematics in all three years, and science in one.

The second middle school (Table 6) is a school located in a rural community of 6,000 that attracts students from many middle class and upper class families in rural subdivisions; it has more of a suburban population than rural population. The students are from non-farming populations and the majority of families are commuters to a regional population center for service, manufacturing and other employment. The community expectations for the school are high and are represented well in the ISTEP scores. The math scores were lower in 2009 because of the change in the mathematics exam according to school officials, and after a year of using the data loggers, the scores improved in 2010, where they exceed the state average. Science scores are inconsistent and on conversation with the faculty, they believe the change in the curriculum resulted in the significantly reduced score in 2010. On discussion with a Department of Education official, the inconsistent scoring in the math and science categories represented in the tables for 2009 and 2010 was due to changes in the exam questions. School staffing has remained stable and the student body had no significant changes.

**Table 7.** Middle School 3

| Year / Subject | 2007 | 2008 Data-loggers introduced | 2009 | 2010 | State (2010) Averages |
|---|---|---|---|---|---|
| Math | 74 | 64 | 62 | 74 | 74 |
| Science | 47 | 54 | 50 | 52 | 58 |

Middle School 3 represented in Table 7 has a very diverse population with a large number of free and reduced lunch qualifying students. The principal reported that there a large number of single parent families and families in economic stress in the service district. Despite the challenges that many of the students have outside of class they perform well on mathematics but science is not as successful. One teacher reported that students do not see the value of science so much time is spent trying to connect science to their lives. When the data-loggers were introduced to the class, students received data-loggers with enthusiasm and started to see the connections of science to the world outside of school. Another teacher in this building reported that they had very few disciplinary problems when the data-loggers were being used as the students associated the data-loggers with real equipment that would help them in college and with jobs. The science scores saw modest decrease and a modest gain in the year that the ISTEP science exam was made more rigorous. All of the science teachers were participants in the Shining Star program and half of them were teacher-trainers during the second summer workshop. The attitudes of the students were so enthusiastic and evident to the school; the principal led the local parent- teacher association to buy additional data-loggers with their own resources.

| Year / Subject | 2007 | 2008 Data-loggers introduced | 2009 | 2010 | State (2010) Averages) |
|---|---|---|---|---|---|
| Math | 74 | 71 | 66 | 80 | 74 |
| Science | 57 | 57 | 56 | 38 | 58 |

**Table 8.** Middle School 4

| Year / Subject | 2007 | 2008 Data-loggers introduced | 2009 | 2010 | State (2010) Averages |
|---|---|---|---|---|---|
| Math | 47 | 51 | 44 | 44 | 74 |
| Science | 55 | 51 | 64 | 62 | 58 |

Urban Middle School 4 in Table 8 has a larger student body and correspondingly with greater diversity and a large transient population. Middle School 4 has the highest population of free and reduced lunch qualified students and special population enrollment. This school is unique: its building has an open wall concept; the majority of classrooms have no walls or doors. This concept presents a challenging environment to teach in, yet, the faculty is successful in their work. The school is committed to team-teaching in grade groups and reaching each student.

There was no real reason offered by the faculty provided to explain the continued drop in performance for the mathematics exams, the mathematics exam was made more challenging by the state but the school had the opportunity of adjust as the others. The mathematics faculty remained the same, as the mathematics curriculum. In Middle School 4, this was the only school that the only the science teachers utilized the data-loggers. The mathematics teachers were offered access and in-service to use the data-loggers but chose not to use the data-loggers. Science scores of the students at Middle School 4 improved in the second year with the use of the data-loggers, but dropped two percent the third year when the more rigorous science exam was implemented. The teachers at School 4 shared similar conversations with the Shining staff about student interest in using the data-loggers in class and the enthusiasm of using them. The students enjoyed the authentic experience of collecting data and analyzing the graphs they were able to make.

**Conclusion**

The assessment of the Shining Star Program is multi-faceted: data sources included field notes, video recordings, artifacts, and survey responses. Analysis of participants' discourse identified many instances in which the program helped the teachers deepen their understanding of inquiry-based teaching. The findings are presented as three assertions: (A) all the elements incorporated in the program contributed positively to participants' engagement in inquiry; (B) connections between participants' sensory experiences and graphical representations of data led them to have new understanding of the phenomena under the investigation, and (C) there were strong connections between their experiences about inquiry and teaching strategies that they wanted to incorporate in their classrooms (Tosa & Martin, 2010).

The three-year project was successful even though the science scores did not dramatically increase, but the unintended improvement in the mathematics scores was welcome. Part of the reason why the science scores did not improve on the ISTEP exams is due to the nature of the questions and the changing format of the exam. What is important is the qualitative data offered by teachers and students of the renewed interest in science and science activities. The improvement in student critical thinking skills is very important as we move to more technology-driven society requiring analysis of large amounts of data.

Despite the well-established benefits of using data-loggers for science learning, and studies of data-loggers in UK as well, local schools are not moving to adopt data-loggers for science teachers despite the ease of use of hardware and software (Bannasch & Tinker, 2002; Rogers & Wild, 1996; Tan et al., 2005; Choo, 2005). One school in the Shining Star purchased additional data-loggers on their own initiative. The motivation for teachers to adopt technology is greatly influenced by physical, socio-political and educational limitations of their community. Another factor shared in adopting new technology is the lack of time. Some of the Shining Star educators shared this concern in adapting the data-loggers into their teaching: as they would have to learn how to perform the laboratory in advance, anticipate troubleshooting and student responses. Choo (2005) reported that it was a significant constraint by 86-88% of primary and secondary science teachers in their use of IT in a survey carried out in the UK in 2000. Tan et al. (2005), in their study on the use of data-loggers in Singapore's secondary schools and junior colleges, 84% of the 593 respondents ranked the time spent on setting up data-logging activities as the number one deterrent to the use of data-loggers. For the Shining Star educators, it was significant but they believed the student response to using the data-loggers made the time issue a trivia concern.

Other challenges that effected the Shining Star teachers using the data-loggers in their schools included limited access to the resources and equipment (we lacked the funds to purchase all the probes to have a complete program), occasional glitches with the equipment, lack of support structures such as local technical support, and the initial low confidence level of teachers in using these tools for science learning. These problems were not unique to the Shining Star Program. In programs conducted by Newton (2000), Tan et al. (2005) and Choo (2005) in Singapore and the UK, science teachers encountered difficulties like an inadequate number of notebooks or computers deployed for science learning, time taken to acquire loan IT equipment, technical problems with the data-loggers and time constraints to complete the syllabus. Findings also showed that teachers, especially those who are not very IT perceptive, feel they lack the necessary skills to use data-loggers and design appropriate lesson activities to facilitate science learning.

The data logger company provided the Shining Star program excellent support service. One teacher commented that they even flew down from Chicago to adjust and calibrate here dataloggers. High quality support service is essential to a successful ICT program. Companies supplying IT equipment have an easy time selling to IT-savvy teachers who recognize the use of data-loggers as an opportunity to experiment with new ideas and develop new teaching strategies, but many teachers face practical constraints and uncertainty about the pedagogical relevance and scope of using data-loggers (Newton, 2000; Osborne & Hennessy, 2003). The success of the data-loggers in the classroom depends on the willingness of teachers to use them; support by the school administration, teacher professional development, and on the manufacturer's providing teacher in-service, technical support, and affordability to all school districts. It will take initiatives like the ISTEM-IUS Program and Shining Star Program to develop networks for professional development and support to provide STEM education for our students. The Shining Star program was a success based on student performance on exam scores, but more importantly, on the interest generated by students engaged in constructivist-inquiry learning. Nothing sums up the interest created by Shining Star like a teacher telling other teachers that her students wanted to get the data-loggers out on the last day of school one more time. STEM education has to be relevant and involve all the senses. The Shining Star Program did just that.

**NOTES**

1. http://www.indianascience.org/strategicplan.pdf
2. http://www.doe.in.gov/assessment/istep-grades-3-8
3. http://www.doe.in.gov/
4. https://www.csun.edu/science/ref/curriculum/reforms/nses/nses-complete.pdf
5. http://www.project2061.org/publications/bsl/online/index.php
6. http://www.doe.in.gov/standards/science
7. www.fourieredu.com

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