AC 2010-177: K-12 TEACHER PROFESSIONAL DEVELOPMENT EFFECTIVELY OFFERED BY STEM FACULTY FROM A RESEARCH UNIVERSITY

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K-12 Teacher Professional Development Effectively Offered by STEM Faculty from a Research University

Abstract

As part of an extensive University − K-12 partnership program in STEM (science, technology, engineering and math) disciplines, more than 20 faculty members at Clarkson University have developed and taught summer institutes and workshops for area middle and high school teachers. The goals of these interventions are to provide rigorous and state-of-the-art STEM content knowledge, to model effective and active teaching strategies, and to prepare the teachers to bring the new STEM content into their classrooms. The 5-day summer institutes provide rigorous content and hands-on activities for the teachers. The objective of this paper is to describe the development and assessment of the institutes.

The design of the institutes was based on educational research that has documented key features of professional development and careful evaluation of prior professional development activities in the region. The optimal partnership was defined as one where teachers partner with working scientists, mathematicians, and engineers who have sophisticated equipment in laboratory work space, computing facilities and other resources of higher education. During the past two years, approximately 250 individuals attended 22 institutes; some of the teachers attended multiple offerings. The efficacy and impact of these institutes has been assessed through pre- and post content knowledge or capability tests, evaluation forms, and peer-review of lessons developed as an outcome of the institutes. For all institutes, evaluations indicated a statistically significant increase in STEM content knowledge and evaluations were remarkable. The transfer of this knowledge by the teachers into classroom lesson plans and activities, and the peer review of that outcome are on-going.

Introduction

Clarkson University is committed to supporting and enhancing the quality of public school education in the rural and economically struggling northern region of New York State. The need in this "North Country" for educational assistance is consistent with those identified in several recent analyses of STEM (science, technology, engineering, math) education in our country. Beginning with the 1995 Trends in International Mathematics and Science Study (TIMSS), it has been apparent that the average American 8th grader has lagged behind the world in science and mathematics achievement.[1,2] Concerted national efforts to improve our educational system have made a difference. The recently reported 2007 TIMSS results[3] show substantial improvement in both science and math scores at the 4th and 8th grade levels. There is, however, room for continued improvement: 8th grade scores have not improved as much as 4th grade; scores for boys in science at the 8th grade level are still significantly higher than for girls; and the scores for students from minority populations and students from schools where 50% or more of the students receive free lunches are significantly below the National averages. The results also show that few of our students truly excel in math and science courses. In the 8th grade, only 10% of students in science and 6% in mathematics reach the "TIMSS advanced international benchmark."

The unique problems facing rural schools are also generally accepted and well documented. The recruitment and retention of highly qualified teachers is foremost among those problems. Two of the primary reasons for this are: geographic and social isolation, and scarcity of professional development opportunities.[4] These two obstacles merge in a teacher's work environment leading to "professional isolation," cited by novice teachers as a leading cause of migration out of the education field or relocation to more populated areas.[5 6-7] The percentage of teachers who have never participated in collaborative professional development or in-depth study in the subject area of their teaching assignment was significantly higher for rural teachers than for their counterparts in large town or city school districts.[8] Dwyer et al.[9] state that the "idealism of younger teachers fades as they are confronted with the realities of a …geographically and culturally isolated district." The evidence clearly defines the need for rural school districts to grow their capacity for effective geographic boundary-spanning professional development that improves teachers' knowledge and strengthens their ability to apply STEM concepts.

As part of an extensive University - K-12 partnership program[10] in STEM disciplines, more than 20 faculty members at Clarkson University have developed and taught summer institutes and workshops for middle and high school teachers. These professional development (PD) activities are part of broader regional efforts to improve student performance that have been funded primarily by NYSED and NSF. The goals of these PD interventions are: to provide rigorous and state-of-the-art STEM content knowledge; to model effective and active teaching strategies; and, to prepare teachers to bring the new STEM content into their classrooms. The 5-day summer institutes provided rigorous content and hands-on activities. The institutes offered during the summers of 2008 and 2009 included topics ranging from robotics to nanotechnology to computer graphics. The objective of this paper is to describe the development, assessment and success of the institutes with a particular focus on those institutes with engineering content.

Program Goals and Assessment

The overall STEM Partnership program includes outcomes for and assessment of teachers and their students. Only the teacher assessment components that are relevant to the summer institutes and their direct impacts on the teachers are included in this paper. The summer institutes contributed to three of the primary goals of the STEM Partnership program (Table 1). Several tools were used to assess these goals, including pre- post content surveys, an 84-question teaching attributes and behaviors survey, and peer-review of learning experiences developed from the summer institutes.

Table 1: Goals and program components related to the summer institutes for teacher professional development.

Goal	Relevant Program Components
Goal #2: Increase the development and implementation of effective instructional strategies for all students including interventions targeted to reach at-risk students.	Effective instructional strategies included in summer institutes. Learning experiences prepared and used by teachers.
Goal #3: Improve teachers' content knowledge of mathematics, science and / or technology.	STEM content of summer institutes
Goal #4: Develop more rigorous mathematics, science and/or technology lessons that are integrated and aligned with State and local academic content standards and with the standards expected for postsecondary study in engineering, mathematics, and science.	Learning experiences (lesson plans) as outcome of the summer institute

Designing Summer Institutes for Teachers

The design of the institutes was based on educational research that has documented key features of professional development and careful evaluation of prior professional development activities in the region. The regional teachers and administrators indicated they need to:

1. Expand teacher content knowledge in STEM;
2. Use instructional technology as a classroom tool;
3. Integrate STEM into learning experiences;
4. Integrate higher level thinking skills and authentic learning into coursework; and,
5. Investigate and question our world through STEM.

The results of this needs assessment and student achievement data provided clear direction for the institute goals and activities. The optimal partnership was defined as one where teachers partner with working scientists, mathematicians, and engineers who have sophisticated equipment in laboratory work space, computing facilities, and experience with applications of STEM subjects to solve relevant and real world problems.

A total of 22 institutes were offered during the summers of 2008 and 2009 through a STEM Partnership grant funded by NYSED. Table 2 highlights the engineering and computer science oriented institutes. Many of these institutes closely align with the faculty instructor's research area and utilized research equipment and laboratories on our campus. For example, in the *Finding NANO* institute, the participants made nanoparticles and observed them through a scanning electron microscope.

Rigor and relevance

Project-based learning[11] and the rigor and relevance framework developed by Willard R. Daggett of the International Center for Leadership in Education[12] provided a common schema for our STEM Institutes. Daggett extended Bloom's Taxonomy to add a second dimension (Figure 1), thereby providing an excellent framework to capture the "rigor and relevance" that hands-on and project-based learning can bring to STEM education. The Rigor and Relevance Framework describes two continuums: the Knowledge Taxonomy and the Application Model. The Knowledge Taxonomy describes the hierarchy of thought processes. The Application Model focuses on action and application. This model compels teachers and students to apply their knowledge to real-world situations, resulting in greater student engagement and therefore more effective learning. Throughout our institutes, we challenged teacher participants to reach towards quadrant D and to develop learning experiences that would move their students in that direction.

Table 2: Engineering and computer science-oriented STEM Institutes

Summer Institute	Faculty Instructors and Research expertise	Offered in 2008	Offered in 2009
FIRST Lego Robotics	J. Carroll, Elec.Engrg. (robotics)	X	X
Jr. Legos for the Classroom	C. French, M. Montgomery (HS Science/math teachers)		X
FIRST Tech Challenge Robotics Workshop for 7th-12th Grade Teachers	J. Carroll, Elec.Engrg. (robotics)		X
VEX Robotics	J. Carroll, Elec.Engrg. (robotics)	X	X
Level II Vex Robotics	J. Carroll, Elec.Engrg. (robotics)	X	
Finding NANO	J. Moosbrugger, Mech. Engrg. (solid mechanics/mat'ls), R. Partch, Chemistry (colloid chem..)	X	
Computer Graphics	B. Helenbrook, Mech. Engrg (numerical methods – fluids); P. Turner, Math (applied math, algebra, geometry, vectors)	X	
Cyber civics (2008); Switched-on Social Studies (2009)	J. Matthews, Comp. Sci. (computer security); J. Owens (PhD student)	X	X
Prometheus Integrated Math and Science	D. Beck, Communication (Graphics, creative arts); D. Wick, Physics. (Physics Educ.)	X	X
Real Solutions to Real Problems: Middle School Students Save the Day	K. Fowler, A. Luttman, Math (Numerical methods, algebra, geometry, problem solving)		X
Integrated Math and Physics - The Roller Coaster Camp	D. Wick, Physics. (Physics Educ.), M. Ramsedell, Physics (Physics of motion) K. Fowler, Math (Applied math, motion)) P. Turner, Math (Algebra, Geometry, curvature)		X
Energy Literacy: An Integrated Math, Science, and Technology Institute	S. Powers, Env. Engrg (env. impacts of energy systems), K. Visser, Mech. Engrg (wind power); J. DeWaters (PhD candidate)	X (winter)	X

The relevance that project-based education provides is also important for broader impacts. It targets a wider range of student learning styles than a more traditional pedagogy involving lectures and rote learning.[13] For example, many women capable of pursuing engineering careers opt for a liberal arts college instead, because they perceive it as offering a more "interesting or relevant environment,"[14] whereas their perception of "relevance" in engineering coursework is a large factor in keeping women enrolled in engineering.[15] A holistic or project-based learning approach to engineering and science brings relevancy and connectivity to their coursework and to the outside world.

Teaching middle and high school STEM teachers to utilize active teaching strategies to move into a higher quadrant of the rigor and relevance framework was a new challenge for many of our university faculty members. Staff from Clarkson's Office of Educational Partnerships (OEP) worked closely with the teams of faculty teaching each institute to prepare them to engage institute participants at an appropriate level and with appropriate pedagogical techniques. Annual meetings for the university faculty focused on the goals of the institutes and the expectations of all institutes to address the five points listed above. A self assessment worksheet was developed by OEP staff and used by the institute instructors to help ensure that effective teaching strategies leading towards rigor and relevance were utilized throughout the institutes. The check list items are included in Table 3.

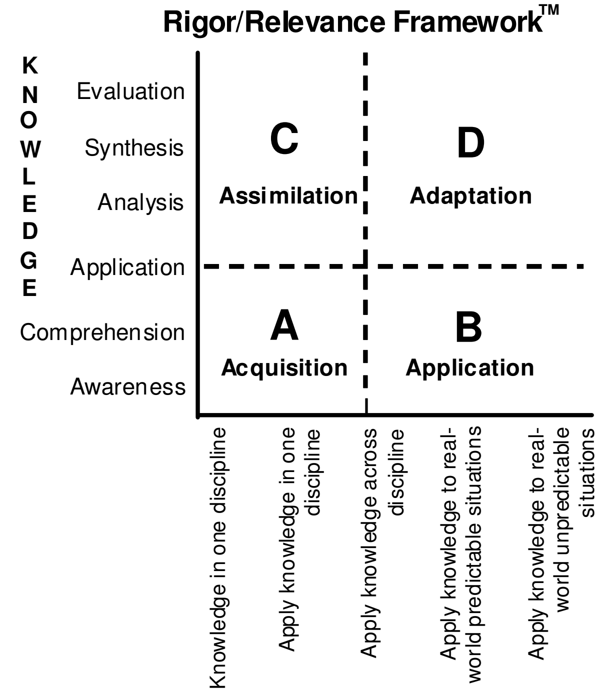

Figure 1: Daggett's Rigor and Relevance Framework[12] (adapted and used with permission from Daggett, W.R., *Achieving Academic Excellence through Rigor and Relevance*, Report prepared by the International Center for Leadership in Education - © 2005, Int'l Center for Leadership in Education)

The institutes were all designed for five day (35 h) contact time. Instructors used lecture and computer presentations to scaffold the necessary knowledge base and application of STEM topics in the hands-on and inquiry-based activities that they shared with the teachers. Time was allotted in all workshops for participants to brainstorm and process how their new knowledge and skills could be adapted into the learning experiences and activities they would bring to their own classrooms. All institute participants were expected to prepare a "learning experience" document over the course of the following academic year. These learning experiences were assessed through a peer-review process adapted from the NY State Academy of Teaching and Learning (NYSATL).[16] The criteria for evaluation are presented in Table 4. For each criterion a rubric identifying basic, emergent, proficient and distinguished attributes was developed and used. The Assessment Plan and Reflection criteria were also adapted from NYSATL,[16] the remaining criteria were deemed important for our internal STEM Partnership goals and the assessment of Learning Experiences developed through the Summer Institutes.

Table 3: Self assessment checklist components for institute instructors to challenge participants to reach a higher level of rigor and relevance in STEM Institutes

Effective Strategies: Institute participants are asked to…	
Brainstorm	Classify data
Work in cooperative pairs/teams	Complete analogies
Participate in simulation/role play	Revise notes and or correct errors
Engage in reciprocal teaching	Analyze errors in logic
Summarize verbally	State support or proof for solution
Summarize in writing	Analyze a perspective
Generate a mental picture	Generate and test a hypothesis
Make (create) physical models	Predict outcomes if variable(s) change
Draw pictures or pictographs	Rate/rank solutions and test them
Engage in kinesthetic activity	Ste personal learning goals
Complete a graphic organizer	Assess their own progress
Identify similarities and differences	

Participants

A total of 80 teachers participated in the summer 2009 NYSED STEM Partnership institutes and 190 teachers participated in the 2008 institutes. Teachers also participated in NSF Research Experiences for Teachers (3), an NSF I-Test institute (19), and a variety of workshops and coaching experiences (robotics, JETS, Science Olympiad, etc.) that were also conducted at Clarkson University, but not under the same standards and expectations defined in Table 3. The teacher participants were primarily science teachers (33%) from the 18 school districts in the St. Lawrence-Lewis Board of Cooperative Educational Services (SLL-BOCES) district. Others were certified in mathematics (21%); technology (13%) and areas other than math, science or technology (30%; library, social science, English language arts, etc.).

Overall Results

During 2008 and 2009, approximately 250 individuals attended institutes; some of the teachers attended multiple offerings. The efficacy and impact of these institutes has been assessed through pre- and post content knowledge or capability tests, evaluation forms, and peer-review of lessons developed as an outcome of the institutes. In all cases, the statistically significant increase in STEM content knowledge gains and evaluations were remarkable for each of the institutes.

Table 4: Assessment criteria for learning experiences

Criteria
Problem Statement(s) *The problem statement(s) that frame the development of the lesson(s) or unit are clearly stated and of an authentic real-world nature requiring math, scientific and/or technological problem solving rigor on the part of the students*
Essential Question(s) for Learning *Question(s) that promotes inquiry and suggests different plausible responses yet supports the unit addressed in the learning experience*
Assessment Plan *An assessment plan that is clearly aligned with state standards and includes strategies and varied techniques used to collect evidence of student progress toward meeting the stated learning standards and performance indicators. Pre, post and formative assessments with timely feedback for student improvement are part of the overall plan.*
Assessment Tools *The assessment tools used to document student progress (e.g., scoring guides, rating scales, rubrics, checklists, teacher-made tests, and observation forms) are effectively used to promote rigorous student learning. Copies of these assessment tools are accompanied by examples of student work that anchor performance to the levels of developing proficiency/skill and also demonstrate what exemplary work looks like.*
Integration of Mathematics, Science and Technology *The integration of technology, math and science enhances the lesson and challenges students to engage in rigorous learning activities that are clearly relevant beyond the classroom. Integrated activities are authentic with real-world applications that provide students with multiple hands-on opportunities regardless of their initial skill level.*
Reflection *The reflection narrative clearly explains why this lesson was developed for the specific learning standard(s), performance indicator(s),and core curriculum; It includes what was learned from implementing this lesson; how the lesson was reviewed and what was learned from the review; how it reflects current scholarship in the teacher's field and "best" classroom practice; how the lesson prepares students for life outside of school; how was the lesson received by students accompanied by some analysis of the assessment data generated.*

The quantitative analysis of results for the summer 2008 institutes has been completed; the analysis of the summer 2009 assessment results is on-going. Table 5 summarizes our findings to date. This table explicitly identifies a subset of the project outcomes directly related to the summer institutes and the evidence that the outcomes have or have not been met to date.

All sub-outcomes for Goals #2-4 that were direct outcomes of the summer institutes were met with one exception. The peer-review and web-based publication of learning experiences that the teachers developed at the completion of the institutes have been slower than anticipated. At this time, over 150 learning experiences have been published on-line. The learning experiences that have been peer reviewed have been excellent, with a majority of them exemplifying the project/inquiry-based and integrated STEM attributes our STEM Institutes are trying to improve (Tables 3, 4).

The increase in the participants' STEM content knowledge has improved significantly. 93% of the teacher participants who completed content knowledge tests before and after the 2008 Summer Institutes had improved scores. Only one institute with only 5 participants did not meet the overall goal that 70% of participating teachers will show a statistically significant improvement in their pre- and post- test scores. Three of the five teachers in that institute improved substantially. These pre/post summer institute assessments were developed by the university faculty instructors of the summer institutes. Statistical analysis showed that they had high reliability and validity.

Benefits to University Faculty

The university faculty have become involved in the summer PD institutes for STEM teachers for a variety of reasons. For some, it provides a means of pay for summer months, but most are involved because they recognize the need to improve the STEM knowledge of all U.S. students. An annual survey of the impact of the partnership on faculty institute instructors suggests that this experience was a bit of a "reality check" where they received a more realistic understanding of the level at which NY State teachers are functioning in the content areas. They also indicated that they gained an appreciation for the continuum of skill and content knowledge that exists for instance when you have an elementary teacher, a middle school teacher and a high school teacher bringing their specific expertise and background to a workshop. It was an introduction in many cases to differential instruction.

Faculty members have also benefited from their exposure to K-12 outreach activities by integrating their experiences and lesons learned into their research grants, especially NSF. For example, an asst. professor from Mechanical Engineering who has been involved in our robotics outreach activities was recently received an NSF CAREER award that integrates K-12 outreach, and another professor has a new NSF CCLI grant that includes a high school component as a follow on to the Finding NANO institute.

Table 5: Goals, outcomes and assessment evidence (2008).

Goal / Outcome	Evidence
Goal #2: Increase the development and implementation of effective instructional strategies for all students including interventions targeted to reach at-risk students.	
80% of Summer Institute Participants will report that they were satisfied with the quality of professional development (PD) and reported that it improved their instructional skills	96.4% of Summer Institute Participants (n=144) reported that they were satisfied with the quality of PD and 98.2% indicated that they planned to use the content in their instruction.
80% of administrators report a positive impact on the school organization from the MST activities	All administrators (n=60) have indicated a positive impact of MST activities on their schools.
90% of participating teachers report using at least 2 new effective instructional strategies	94% of teachers (n=127) indicate that they use at least 2 new effective instructional strategies
100% of learning experiences demonstrate the effective use of instructional strategies as determined by the instructional strategies rubric	100% of the learning experiences (n=44) demonstrated effective use of instructional strategies
Statistically significant increase in the number of teachers reporting an increase in the amount of their class instruction in quadrant D	Statistically significant number of teacher participants (n=127) reported improvement in classroom instruction.
40% of the learning experiences will reach level D "adaptation" on the Rigor and Relevance Framework	56% of the participants (N=71) reached level D on the rigor and relevance framework.
Goal #3: Improve teachers' content knowledge of mathematics, science and / or technology.	
80% of Summer Institute Participants will report that they were satisfied with the quality of PD and reported that it improved their content knowledge	100% of teacher participants in 10 Summer Institute (n=128) indicated that they had improved content knowledge as a result of participating in the Institute.
80% of administrators report a positive impact on the school organization from the MST activities	All administrators (n=60) have indicated a positive impact of MST activities on their schools.
70% of participating teachers will show a statistically significant improvement in their pre- and post- test scores on content knowledge	93% or 128 of teachers who participated in summer institutes and completed pre/post testing (n=137) showed statistically significant ($P \leq 0.15$) improvement in their STEM content knowledge.
Goal #4: Develop more rigorous mathematics, science and/or technology curricula that are integrated and aligned with State and local academic content standards and with the standards expected for postsecondary study in engineering, mathematics, and science.	
90% of teachers observed demonstrated the application of the appropriate MST State Standards	90% of 71 teachers observed through the peer-review process demonstrated the application of MST State Standards. Of these 19% were Distinguished, 47% were Proficient, 24% were Emerging and 10% had units that did not meet expectations.
85% of the learning experiences/units demonstrate integration of MST State Standards	98% of 71 teachers observed integrated math science and technology into their units. Of these 28% were Distinguished, 53% were Proficient, 17% were emerging and 2% did not meet expectations.
80% of the participants will state that the peer review process helped them to integrate the MST State Standards	100% of the71 participants indicated that the peer review process assisted them in integrating the MST State Standards.
85% of the learning experiences/units published on website	70% of the learning experiences units (n=44) have been published on the STEM Partnership website with plans to publish more when edits are completed.

Specific Example – Energy Literacy Workshop

A summer institute related to energy has been taught twice through this STEM Partnership program. Some of the details of this institute are included here to provide examples of the content, delivery and outcomes. The goals and general approach used to meet and assess the goals are included in Table 6. Details of the institute are available at the STEM Partnership web site.[17]

Table 6: Goals for teachers attending the Energy Institute

Goal	Comments, Assessment
Participants increase their level of energy literacy (knowledge, attitudes, behavior).	Pre-post literacy survey developed previously was used to assess changes in literacy[18]
Participants experience many hands-on energy activities that can be adapted for their own classroom use	Short lectures to explain the science and mathematics were interspersed throughout the workshop with hands-on and inquiry based activities previously developed through our partnership programs.[19,25-27]
Participants develop a plan for integrating project-based, hands-on, and integrated STEM energy activities into their classrooms to improve the energy literacy of their students.	All participants expected to complete a Learning Experience plan for implementation in their classroom and peer-review. Equipment and Clarkson students for support in classroom offered.

The energy literacy institute was developed based on Clarkson faculty expertise in energy technologies, particularly wind power,[20-21] energy systems and their environmental impacts,[22-,23,24] and energy education and literacy.[25-26 27] These areas of expertise helped to define the scope of the institute. Four major areas were covered in the 5-day institute:

Unit 1: Introduction to energy science, sources, uses
Unit 2: Energy use in our homes and schools
Unit 3: Transportation systems – Fuels we use
Unit 4: Alternative energy sources – focus on wind and solar

Some examples of the hands-on activities used to support these units include graphing energy consumption and supply data, use of watt meters, making biodiesel and hydrogen, posters representing the environmental lifecycle of energy systems, and designing and testing blades for balsa wind turbines. The use of a relevant topic such as energy provided the opportunity for teaching many basic science and mathematics concepts to the teacher participants. Through the experience and assessment gained in the first offering of the institute, several areas were improved and emphasized in the second to strengthen teachers' basic skills and capabilities. These areas included utilizing MS Excel effectively, using a multimeter, converting units of energy, definitions and use of prefixes (mega, tera, etc), and definition and calculations for energy vs. power.

A total of seventeen teachers participated in the two sessions, representing a broad range of grade levels (4^{th} – 12^{th}) and subjects (science, math, technology, home economics). The anecdotal evidence from all teachers showed that their awareness about energy issues increased substantially. The energy literacy pre-post test[18] proved a reliable means of assessing real gains in the teachers' knowledge, behavior and attitudes about energy and its use (Table 7). Significant gains were made in the knowledge and attitude attributes of energy literacy (p <

0.05). As expected, real changes in individual's behavior scores did not change over the 5-day period (p=0.10). On average, the teacher participants coming into the institute would barely pass on basic energy knowledge. Their pre-test scores ranged from 28-86% correct. Not surprising, the high school science teachers performed much better on the pre-test than teachers from non-science subjects or lower grade levels. The improvement on the post-test was substantial, with scores ranging from 73-95% on the knowledge questions. To provide some perspective, preliminary results from the same survey administered to 228 high school students from across New York State had mean scores of 51, 77 and 66% on the knowledge, attitude and behavior scales.[27] The self-selected group of teachers had much higher average scores than HS students, even before the institute.

Table 7: Results of 2008 and 2009 combined Energy Institute content knowledge assessment (n=16 for pre test statistic, n=13 for post test, gain and t-test statistics)

	Energy Literacy Attribute**		
Statistic	KNOWLEDGE	ATTITUDE	BEHAVIOR
Average Pre-test score	69.7	88.1	81.0
Average Post-test score	85.9	95.0	86.7
Average Gain (paired)	14.1	7.0	3.5
p-value*	0.003	0.002	0.104

* one-tailed, paired t-test to test hypothesis that each participant increases their energy-related literacy over the intensive intervention period
** all on 100-point scales

The effectiveness of the Energy Institutes has also been assessed with documentation that the teachers are bringing energy related lessons and projects into their classrooms. At this point in time, there are eight energy-related learning experiences that have completed the peer review process and have been published on the STEM Partnership web site.[28] These range from 4th to 12th grade levels and cover topics as diverse as heat transfer in a house to biodiesel to climate change. Teachers from the 2009 Energy Institute are working on learning experiences related to solar PV systems, including electric circuits, the use and safe disposal of compact fluorescent light bulbs, and using watt meters to assess home appliance power and energy use. Other teachers who have not yet submitted learning experiences have challenged their students to stretch to quadrant D of the rigor and relevance framework through their participation in an energy science fair held annually in the region.

Conclusions

STEM Summer Institutes offered to teachers in the SLL-BOCES district in New York State have been developed to increase teacher content knowledge and capability to bring an increased level of STEM rigor and relevance into the learning experiences of students.. Numerous institutes have been held over the last two years. Most of these include integrated STEM applications and problem solving approaches that are the foundation of engineering approaches. Assessment of the teachers' content knowledge and learning experiences that they develop as an outcome of the institutes shows that this mode of teacher professional development does indeed meet its objectives.

Several key lessons have been learned through this experience that could help with the development of similar programs at other Universities. Some of the key issues that can applied broadly:

1. University STEM faculty need the support of an educational specialist to understand how to bring their expertise and ideas to the approriate level for K-12 students and teachers.
2. University STEM faculty need a network and support structure to help them find suitable opportunities on campus and in local school districts.
3. Teacher professional development, especially at the high school level, is a great place to integrate the quantitative skills that we expect in incoming freshmen – solving ill-defined word problems, basic unit conversions, use of MS Excel, etc.
4. The University needs to recognize and support outrreach activities that their faculty contribute to. This can be as simple as recognizing this as a valuable skill and experience for strengthening NSF proposals.
5. A well-run and intensive K-12 outreach program will reward the University in terms of regional public relations and increased interest in the region's children in applying for enrollment.

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References

[1] National Science Board, *Preparing Our Children: Math and Science Education in the National Interest,* Report NSB 99-31, Washington DC, 1999.

[2] Gonzales, P., Calsyn, C., Jocelyn, L., Mak, K., Kastberg, D., Arafeh, S., Williams, T., and Tsen, W., *Pursuing Excellence: Comparisons of International Eighth-Grade Mathematics and Science Achievement from a U.S. Perspective, 1995 and 1999*. (NCES 2001-028). National Center for Education Statistics, U.S. Government Printing Office, U.S. Department of Education. Washington, DC. 2000 (http://nces.ed.gov/timss/highlights.asp)

[3] Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S., *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context* (NCES 2009–001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC. 2001 (http://nces.ed.gov/pubs2009/2009001.pdf)

[4] McClure, C., Reeves, C., Rural teacher recruitment and retention: Review of the research and practice literature. *ERIC Digest.* ERIC Clearinghouse on Rural Education and Small Schools, Charleston, WV, 2004. (Eric Document Reproduction Service No. 484967)

[5] Collins, T., Attracting and retaining teachers in rural areas. *ERIC Digest,* ERIC Clearinghouse on Rural Education and Small Schools, Charleston, WV. 1999. (Eric Document Reproduction Service No. 438152)

[6] Chambers, L., Rural schools balance strengths and challenges. *Changing Schools*. Mid-Continent Research for education and Learning, Aurora, CO. 2000. (http://www.mcrel.org/topics/changingSchools.asp)

[7] Hilkirk, K., Chang, B., Oettinger, L.A., Saban, A., Villet, C., *Strengths and challenges of a rural professional development collaborative.* Ohio University. Athens, Ohio, 1997.

[8] Nation Center for Education Statistics, *Teacher quality: A report on the preparation and qualifications of public school teachers.* National Center for Education Statistics, U.S. Department of Education. Washington, DC 1997.

[9] Dwyer, C. et al., *America's challenge: Effective teachers for at-risk schools and students*. National Comprehensive Center for Teacher Quality. Washington, DC, 2007.

[10] Powers, S.E., B. Brydges, P. Turner, G. Gotham, J.J. Carroll, D.G. Bohl "Successful Institutionalization of a K-12 - University STEM Partnership Program." In: Proceedings of the 115th Annual ASEE Conference & Exposition (Pittsburgh PA, June, 2008, on CD, Session # AC 2008-1652).

[11] Powers, S.E., J. DeWaters, "Creating Project-Based Experiences for University- K-12 Partnerships." In: *Proceedings* of the Frontiers in Education Conference, (Savannah GA November, 2004, on CD).

[12] Daggett, W.R., *Achieving Academic Excellence through Rigor and Relevance*, Report prepared by the International Center for Leadership in Education (http://www.leadered.com/pdf/Academic_Excellence.pdf), (Accessed September 2005).

[13] Pavelich, M.J., Moore, W.S., "Measuring the Effect of Experiential Education Using the Perry Model," *Journal of Engineering Education*, 85, 287-292, 1996.

[14] ---, "Chilly Climate for Women Engineers," *AIChE Extra*, August 1994.

[15] Henes, R., Bland, M.M., Darby, J., McDonald, K., "Improving the Academic Environment for Women Engineering Students Through Faculty Workshops," *Journal of Engineering Education*, 84, 59-67, 1995.

[16] NY State Academy of Teaching and Learning. Statewide Peer Review. http://www.emsc.nysed.gov/nysatl/booklet.pdf (p. 15) (accessed Dec. 2009)

[17] St. Lawrence County STEM Partnership. STEM Energy Institute. http://www.stlawcostempartnership.org/energyinstitute/ (accessed December 2009)

[18] DeWaters, J.E., S.E. Powers and M. Graham, "Developing an Energy Literacy Scale." In: Proceedings of the 114th Annual ASEE Conference & Exposition (Honolulu HI, June, 2007, session AC 2007-1069, on CD).

[19] Clarkson University Project Based Learning Partnership Program. Energy Systems and Solutions http://www.clarkson.edu/highschool/k12/project/energysystems.html (accessed December 2009)

[20] Brown, M. M., and Visser, K.D. "Optimum Blade Numbers and Solidities for Small HAWTs,", AIAA-2007-1370, 45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV., January 2007.

[21] Duquette, M.M, Swanson, J. and Visser, K.D.,"Solidity and Blade Number Effects on Small Horizontal-Axis Wind Turbines," *Wind Engineering*, 27(4), 299-316, 2003.

[22] Lavigne, A., S.E. Powers, "Valuing fuel ethanol feedstock options from multiple energy perspectives: corn and corn stover feedstocks." *Energy Policy*, 35, 5918–5930, 2007.

[23] Dominguez-Faus, R., S.E. Powers, J. Burken, P.J.J. Alvarez, "The Water Footprint of Biofuels: A Drink or Drive Issue?" *Env. Sci. Technol.* 43(9): 3005–3010, 2009 (feature) (DOI: 10.1021/es802162x)

[24] Kusiima, J.M., S.E. Powers, "Monetary Value of the Environmental and Health Externalities Associated with Production of Ethanol from Biomass Feedstocks." Energy Policy (accepted, December 2009)

[25] DeWaters, J., S.E. Powers. "WIP: A Pilot Study to Assess the Impact of a Special Topics Energy Module on Improving Energy Literacy of High School Youth." In: Proceedings of the 35th ASEE/IEEE Frontiers in Education Conference (San Diego CA, Oct 2006, on CD).

[26] DeWaters, J.E., and S.E. Powers, "Using a Real-world, Project-based Energy Module to Improve Energy Literacy among High School Youth." In: Proceedings of the 116th Annual ASEE Conference & Exposition, Austin, TX, June 14-17, 2009, paper number AC 2009-231.

[27] DeWaters, J.E., and S.E. Powers, "WIP: The Relationship Between Energy Education and Energy Literacy – the Potential Benefit of Reaching a High Level of Rigor and Relevance." In: Proceedings of the 39th ASEE/IEEE Frontiers in Education Conference, San Antonio, TX, October 18-21, 2009, paper number 1112.

[28] St. Lawrence County STEM Partnership. General web site http://stlawcostempartnership.org/ (accessed December 2009).