

Successful Institutionalization of a K-12 - University STEM Partnership Program¹

Abstract

Clarkson University's outreach efforts were initiated in 2000 primarily with a GK-12 grant from the National Science Foundation, which provided the fundamental basis for almost all of our current outreach activities: a project-based approach that provides both rigor and relevance to enhance teacher and student learning, and retention and interest in STEM (science, technology, engineering and math) disciplines. In 2004, with the establishment of its Office of Educational Partnerships, Clarkson initiated a concerted effort to institutionalize its outreach efforts in a manner to increase the extent of these efforts, assess their impacts, and maintain the University's commitment to area school districts for an extended period of time. Through these institutionalization efforts, our regional educational STEM Partnership now includes teachers and classes from all school districts in the county and over 20 faculty members from STEM departments who are leading in-class or teacher development activities in subjects ranging from "Finding Nano" to robotics to ecology.

The development of an extensive partnership beyond Clarkson's campus has been a critically important aspect of the success and growth of our outreach programs. Partners include the county-wide Board of Cooperative Educational Services (BOCES) and other nearby Universities that provide synergistic expertise, including educational assessment. The partnership helps to provide an umbrella organization and common themes across all individual programs, which help to main continuity for all stakeholders as the specific funding sources come and go. The common elements that have been consistent across all individual programs and that have been shown to be critical to our success include: (1) hands-on, inquiry and project-based activities that emphasize academic rigor and cover relevant, cutting-edge topics; (2) integration of STEM disciplines and use of technology in the classroom; (3) training and workshops for K-12 teachers and college students and faculty involved in the programs; and, (4) communication and networking among all stakeholders involved.

Introduction – Regional programs and need

The need for Universities to be more involved in partnerships with K-12 educational systems has been stressed by industries, federal and state governments and such esteemed organizations as the NAS and the NAE. Universities themselves are also concerned with the quality of incoming students – many of whom are ill prepared for the rigorous class work and critical thinking required for engineering majors. The net result has been the development of programs at numerous campuses, many of which survive only for the duration of the initial funding source and then disappear. Like many schools, Clarkson University has traditionally had a few small and isolated K-12 outreach programs. However, in 2004 with the establishment of its Office of Educational Partnerships, it initiated a concerted effort to institutionalize its outreach efforts in a

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manner to increase the extent of these efforts, assess their impacts, and maintain the University's commitment to area school districts for an extended period of time. As with our integrated approach to STEM (science, technology, engineering and math) education, we also see the various programs as parts of an integrated whole with beneficial synergies among almost all the pieces. These synergies are critical for creating and sustaining a regional K-12 – University STEM Partnership. The primary players in this partnership currently include Clarkson University (STEM faculty and students), the St. Lawrence-Lewis Board of Cooperative Education Services (BOCES), SUNY Potsdam (educational assessment experts), administrators and teachers from all 17 St. Lawrence County school districts, and the nearby St. Regis Mohawk Tribe's Akwesasne Boys and Girls Club and student chapter of AISES (American Indian Science and Engineering Society).

Clarkson University's educational outreach activities have their primary origins in the NSF-funded GK-12 Project-based Learning Partnership Program and its companion Partners in Engineering program. The primary goal of these programs is to enhance both graduate student and K-12 education by bringing graduate (and some undergraduate) STEM students into local schools. The initial 3-year funding, which focused on environmental engineering and science applications, was followed in 2003 with a 5-year GK-12 Track 2 grant. The inclusion of more mathematics in the Track 2 grant was the seed for a growing emphasis on integrating curricular units across STEM disciplines within project or problem-based learning environments wherever possible.

The impact of the Clarkson's GK-12 program has been extended significantly with other specific outreach programs that include extensive teacher professional development (Table 1). The K-16, or even K-20+, professional development is important as many of the teachers are initially less familiar with the project-based approach, and with the interplay between the different discipline areas. The St. Lawrence County Mathematics Partnership was funded by NYS Education Department (NYSED) as a three year MSP (math science partnership) program to enhance both content knowledge and teaching skills of math teachers. Additional NYSED-MSP funding was received in June 2007 for the current STEM Partnership Program that will engage students and teachers in integrated STEM activities and professional development through 2010.

When assessing the educational needs as a "whole" in Northern New York's St. Lawrence County, there is an obvious contradiction in poverty and wealth. St. Lawrence County has some of the poorest and neediest rural K-12 schools in the state, while at the same time; it is a rich area in terms of colleges and universities. There is a wealth of diversity, leadership, academic rigor and excellence, and a vision for a global future within the county's four institutions of higher education. Over the last five years, all seventeen St. Lawrence County School Districts and BOCES have focused on building partnerships, creating consortiums and identifying and sharing resources to overcome the limitations of the economically disadvantaged school districts.

Families residing in the isolated, rural communities served by this Partnership are often severely disadvantaged both educationally and economically. Many are confined to generational welfare with five-year public assistance clocks expiring; are teen parents; are learning disabled; are without high school diplomas; are without marketable job skills; are lacking an understanding of effective parenting skills; are without transportation; and have little or no understanding of how

Table 1: STEM grants and projects integrated into the St. Lawrence Co. K-12 - University Partnership

Title	Funding source	Dates	Funds Received (thousands)	~ numbers involved annually*	Comments
Partners in Engineering (PIE)	Engineering Information Foundation	06/99 – 06/00	\$20	1/4/1/15/1	Primarily to increase interest of middle school girls in STEM. Continued through '07 as part of PBLP.
	NSF - DUE	09/00 – 08/03	\$93	1/6/1/20/1	
K-12 Project-Based Learning Partnership Program (PBLP)	NSF-GK-12	09/99 – 03/04	\$987	1/12/4/470/7	Focus on training and utilizing graduate students in the classroom as STEM professionals.
	GE Foundation	03/02-03/05	\$315	(#'s part of above)	Included focus on increasing diversity
	NSF GK-12 Track 2	07/04 – 06/09	\$2,000	5/14/10/650/17	Extended to include St. Lawrence Univ.; Focus on institutionalization
	NSF-OPP Supplement to Dr. J. Dempsey's research grant.	09/06 –09/07	\$15	2/6/6/280/7	Preliminary lessons and electronic communication between classes and research team during '06 field work at McMurdo Station, Antarctica.
Technology Apps. to Enhance Mathematics Education (Franklin Essex BOCES)	NYSED – NCLB – Title IIB	07/04 – 06/06	\$250	2/4/8/200/16	Teacher professional development on using technology to enhance mathematics education
Math Partnership (in conjunction with SLL BOCES)	NYSED - MSP	01/05 – 06/07	\$1,700	4/10/17/5,092/288	Significant teacher professional development, including through institutes lead by college STEM faculty
Impetus (in conjunction with SLL BOCES)	NYSED – STEP	07/06 – 06/10	\$1,100	4/10/14/96/20	To increase the number of underrepresented and disadvantaged students prepared to enter college, and improve participation rates in STEM related fields
VEX Training Grant	NYSED	06/07 – 10/07	\$75	2/10/13/112/13	Teacher training in VEX robotics and student robotics competition. College student mentors.
STEM Partnership (in conjunction with SLL BOCES)	NYSED - MSP	07/07-06/10	\$2,400	20/30/18/6,400/200 (anticipated)	Extends math partnership program to include broader aspects of science and technology

* Faculty/college students/school districts/K-12 students/teachers (numbers not additive across programs since some individuals included within multiple grants)

to help their child academically and socially. Per-capita income is well below that of New York State in general. Recent figures put St. Lawrence County at an average income of \$27k in 2000 compared to the state average as a whole of \$40k. According to Socioeconomic Trends, the overall poverty rate is 17.7% as compared with 14% for all other rural counties in New York State, with 25% of children in St. Lawrence County living below the poverty level.ⁱ According to SUNY Potsdam's Rural Services Institute, in 2000 there were 4,680 persons (9%) over the age of 25 with less than a 9th grade education and another 9,897 persons (19%) with a 9th to 12th grade education, but no high school diploma. The children of these economically and educationally disadvantaged adults will remain trapped in this cycle without intensive, high quality educational intervention.

Collective Goals of the K-12 – University STEM Partnership

Regardless of the various funding sources over the last several years, each of which have slightly different secondary goals, the primary goals of the Partnership and its program components are to increase the competency and interest of students in STEM disciplines by increasing the quality of STEM education. The multi-pronged approach, which includes sub-goals for teachers' content knowledge and pedagogical approach, curricula improvements, and Partnership development, contributes to the overall student-centered goals of the Partnership. The overall Partnership-wide goals include:

Goal 1. Impact K-12 Student

- Increase student achievement and attitude in STEM disciplines by engaging K-12 students via active learning in classroom and extracurricular project-based learning experiences.

Goal 2: Impact Teachers and Teaching

- Enhance the STEM content knowledge of local teachers.
- Increase the development and implementation of effective instructional strategies, including targeted interventions to reach at-risk students.
- Increase the integration of STEM disciplines and relevant project-based experiences in their classrooms.

Goal 3: Impact STEM College Students

- Increase college students' communication and teaching skills and basic STEM knowledge.

Goal 4: Further development of a sustainable educational partnership

- Generate a culture among educational institutions in the region that utilizes the capabilities and contributions the Universities can provide to K-12 school districts while valuing and respecting the mission and needs of the school districts, their teachers, and their students.

- Develop and locally disseminate more rigorous STEM curricula that are integrated and aligned with State and local academic content standards and with the standards expected for postsecondary STEM disciplines.
- Expand the disciplinary diversity of University Faculty and their students who are involved in Partnership activities.
- Utilize the Partnership to provide networking links among all educational institutions and stakeholders at all levels
- Coordinate assessment efforts across specific programs to identify best practices and overall impacts

The specific assessment tools used to evaluate progress on these goals are described after both the common elements and some programmatic specifics are described in the sections below.

Example Program Components

Elements Common across Programs

The common elements that have been consistent across all individual programs and that have been shown to be critical to our success include: (1) hands-on, inquiry, and project-based activities that emphasize academic rigor and are relevant, cutting-edge topics; (2) integration across STEM disciplines and use of technology in the classroom; (3) training and workshops for K-12 teachers that includes contact with college students and faculty; and, (4) communication and networking among all stakeholders involved.

Inquiry and project-based learning approaches looks at the “big picture” to enhance STEM knowledge, critical thinking, and problem solving skills. These approaches require a depth of understanding and *application* in comparison with typical superficial coverage of technical topics in middle or high school curricula.ⁱⁱ Project-based approaches mirror techniques used by practicing engineers and scientists by requiring students to tackle and solve a real-world problem involving an understanding of the complex interaction among various technical, social, economic and ethical issues.ⁱⁱⁱ This application of learning is not only a worthy learning objective in itself, but also an effective route to greater retention of knowledge and depth of mastery. This is supported by Caine^{iv} who wrote, “Children learn best if they are immersed in complex experiences and are given the opportunity to actively process what they have learned.” Further, Stevenson and Stigler^v pointed out that only 16 percent of instruction in U.S. classrooms could be characterized as application.

Perhaps the most compelling research driving the need for application is that the majority of students learn best when instruction emphasizes application, as Conrath reported in *Our Other Youth*.^{vi} To assist students in achieving content mastery, teachers must create learning environments that present students with challenging problems so that they can demonstrate their knowledge through application.

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.^{vii} 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,"^{viii} whereas their perception of “relevance” in engineering coursework is a large factor in keeping women enrolled in engineering.^{ix} A holistic or project-based learning approach to engineering and science brings relevancy and connectivity to their coursework and to the outside world.

In 2005, Willard R. Daggett, Ed.D. of the International Center for Leadership in Education extended Bloom’s Taxonomy to add a second dimension (Figure 1),^x 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 more effective learning.

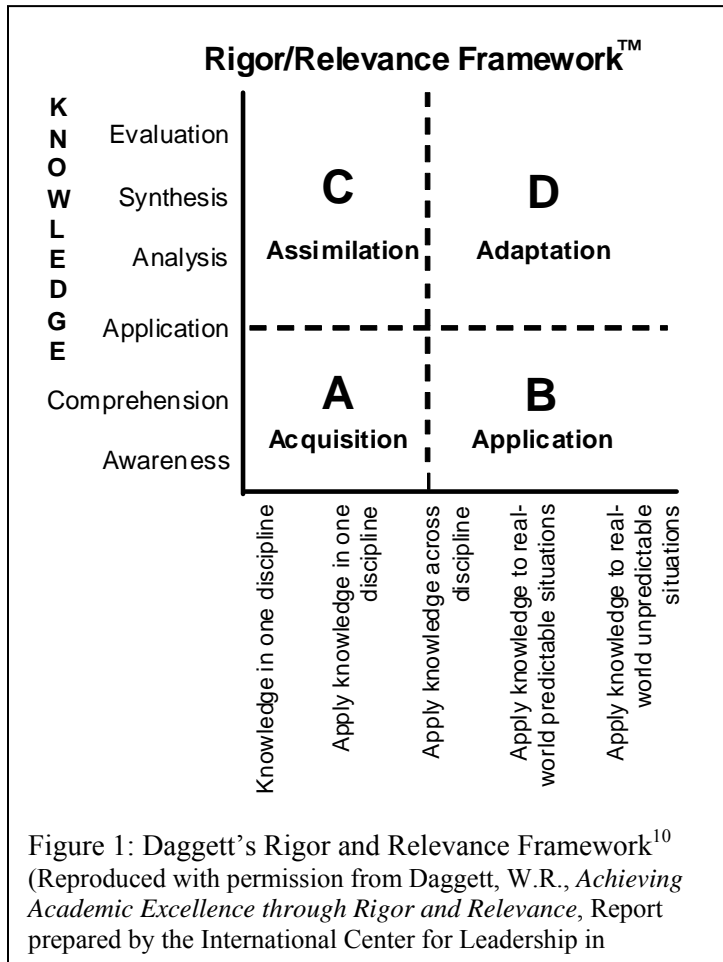


Figure 1: Daggett’s Rigor and Relevance Framework¹⁰ (Reproduced with permission from Daggett, W.R., *Achieving Academic Excellence through Rigor and Relevance*, Report prepared by the International Center for Leadership in

The rigor and relevance framework has become a centerpiece of our teacher, and University faculty and student training. Helping these instructors to understand this framework and place their own instructional activities within it can help them establish a benchmark for their current pedagogical approaches and strive to move into a higher quadrant.

Specific Program Components

There are numerous programs and program components within our Partnership. A few examples are described here to illustrate the breadth of both the approaches used and the STEM disciplines addressed.

Teacher Training through STEM Institutes

The optimal partnership involves teachers partnering with working scientists, mathematicians, and engineers, who have sophisticated equipment in laboratory work space, computing facilities and other resources of higher education. Well-designed 30-hour Summer Institutes provide a “hands-on”, project-based environment to improve teachers’ content knowledge through application, synthesis, and evaluation. Teachers attending the institutes working in TRIADs of

Table 2: STEM Institutes offered to St. Lawrence Co. Teachers

Integrated Math & Physics	Exploring Genetics & Evolution	Lego Robotics
Contest to Classroom	Cyber Civics	VEX Robotics
Computer Graphics	Health Sciences	CSI Potsdam
Finding Nano	Conservation Science	Energy Literacy

mathematics, science and technology teachers provide mutual support to continue progress toward mastery. The Institutes are supplemented by science-based research (SBR) workshops (Rigor and Relevance Framework and Understanding by Design) offered throughout each academic school year and MST Instructional Specialists working within the classroom to continue the embedded professional development and to ensure that new content knowledge and classroom practice gets to actual classrooms and students. Finally, the STEM cross-curricular learning units that the teachers develop as an outcome of the Institutes and workshops are peer-reviewed and posted on a web site. The sharing of these materials informs practice and changes instruction to benefit ALL students and to improve academic achievement.

The Clarkson University Summer Teacher Institutes share several common features. They all actively engage teachers in learning about new trends in science, technology, engineering, and mathematics that they can implement in their classrooms to energize their students' interest and enhance their understanding of current STEM disciplines. All topics (Table 2) integrate mathematics and technology with science and engineering concepts in project-based approaches that make meaningful connections with students' lives. The institutes also model best teaching practices of inquiry-based learning and will involve real-world problem solving and critical thinking skills.

There are several objectives that are common to many of these institutes and workshops and that are addressed in slightly different ways appropriate to the specific subject content:

- Improve teacher understanding of math and science topics, and of newer branches of science, engineering and technology to help them develop the innovators of tomorrow;
- Provide a deeper appreciation of how STEM disciplines work together, using appropriate technology to solve real problems and understand natural phenomena;
- Provide opportunities for teachers to develop curricular materials that include engaging hands-on activities integrating the key concepts and activities of the workshop;
- Empower teachers to use a scientific thought process to integrate STEM and broader disciplinary knowledge and skills; and,
- Create and share projects which will be class tested and peer-reviewed, assisted by mentoring from Clarkson University faculty and students.

College Students in the Classroom

A second key mechanism for improving the quality of STEM education is to work directly with the K-12 students in their classrooms. College students are trained^{xi} through the Partnership to work with students both in-class settings and after-school extra curricular activities (Table 3). The college students' duties range from leading specific hands-on activities to being the primary instructor for an entire project-based curriculum. The particular topics covered by the college students includes both standard curricula that have been developed through the years of this Partnership^{xii} and very specialized topics that relate to the college students' own research areas.

In-Class Units	Extra-curricular / On-campus
Solid waste reuse (concrete, composting)	Math Counts
Rehabilitation engineering	Science Olympiad
Energy in our lives	Energy Science Fair
Roller coaster design	Project Green Teams
Transportation fuels of the future	Roller coaster design
Atmospheric science	Lego and VEX robotics
Water quality	Boys & Girls clubs
Biomedical engineering	AISES student chapter
Computer networking and home automation	
VEX robotics	
Antarctica	
Cyber-civics	

Anecdotal evidence from the teachers has indicated that the college students are also critically important as role models. Many of the students in this rural and economically struggling area have had no other connection to college students or college graduates.

Example - Robotics Applications

Based on the demand by local teachers, an overall effort of the Partnership to include more engineering principles at an earlier age, Clarkson's experience of involving high school students in successful First Robotics competition teams,^{xiii} and the wide success of other universities,^{xiv,xv} we recently expanded our Partnership to include significant robotics components. These efforts are described here briefly because they have infiltrated into all components of our partnership.

In the summer of 2007, STEM teachers participated in Lego (12) and VEX robotics (12) summer institutes at Clarkson University. These institutes taught the teachers the basics of robotics, programming, engineering design and the basic skills necessary for the First Lego League and VEX competitions. College students worked with after-school teams of 5-6th grade (Lego) and 7-9th grade (VEX) students at 14 school districts, 2 private schools and 1 BOCES Tech Center during the fall semester. A weekend of competition events brought 269 students to the Clarkson campus to show off their newly-gained robotics prowess. The efforts are continuing in the Spring semester 2008 to include robotics in technology classes for all 8th grade students at 2 schools. College students are currently working with the technology teachers to best identify the learning concepts that can be taught with the robotics to more actively engage ALL students in the excitement of the robotics. Content assessments of both teachers and students and student self efficacy surveys in STEM disciplines have been collected and analysis on-going. Two Clarkson faculty members and approximately 20 college students have been involved with the robotics components of the Partnership.

Example - Roller Coaster Design

The Partnership has also been able to leverage and use a successful roller coaster design project in many of its components. This particular topic was initially developed by teachers in the Franklin-Essex Co. NYSED grant in 2004. It was successfully expanded to attract NYSED STEP funding to increase the number of historically underrepresented and disadvantaged students prepared to enter college, and improve their participation rate in STEM related fields, and has been integrated into NSF GK-12, Math Partnership, and STEM Partnership grants. Four

faculty members and approximately 12 graduate students are currently involved with roller coaster design components of our Partnership.

The roller coaster design topic focuses on the integration of the mathematics, physics, and computing involved in designing a roller coaster. The roller coaster theme is used to motivate interest and excitement among the participants. Activities include physics experiments utilizing data collection equipment such as sensors, mathematical modeling of scientific phenomena, and analysis of data using computer technology as well as “paper and pencil” math techniques. The roller coaster equipment includes photogate sensor strips, a 5-m track, test vehicles, computer, and a data acquisition system. The roller coaster design activities have been included in a wide range of our overall Partnership components, including:

- A one- week summer Roller Coaster Camp for NYSED STEP students and their teachers where all participate in laboratory-based activities geared towards learning how to use data gathering equipment to measure the friction associated with a toy car and make predictions for its performance, and to use a software package to design their own roller coaster. The week includes a field trip to the Six Flags Great Escape amusement park for practical experience on roller coasters and scientific data collection.
- A five-day summer institute for teachers in which teachers are introduced to the Roller Coaster Project theme, trained in the use of data and data gathering equipment, and provided with practical applications of the use of computer technology in the classroom. Instructional equipment, including a miniature roller coaster setup, laptop computers, data acquisition apparatus and software, is supplied to the schools.
- In-class roller coaster design units taught by college students in 8th grade technology and HS physics classes where all students benefit from the data acquisition, mathematical modeling and design experience.
- Extra-curricular programs for disadvantaged youth that include activities based on the roller coaster project and sessions to provided students and parents with information on college and career preparation in STEM fields and the financial aid and the college admission process.
- Additional events to get NYS STEP students on campus, including a career fair; a celebration of π Day (March 14th); a “Chemistry Magic Show”; and, opportunities to play with a virtual roller coaster that allows students to design their own thrilling roller coaster, test its design for safety and then actually ride it, all while on campus.

Approaches used for Institutionalization and Assessment

Building trust, value, and establishing common goals

The evolution of our Partnership has progressed as Clarkson has built its reputation in the region for high quality outreach activities that bring academic rigor to the STEM disciplines while remaining cognizant of the constraints inherent in middle and high school classrooms. The acceptance of our early interventions in a couple of middle school science and technology classrooms helped to provide credibility for the approaches we could bring to the educational

environment. Over time, the programs have grown to the point where the superintendents of the county's school districts now attend regular meetings at Clarkson to stay abreast of the programs and assessment findings. At a 2006 meeting, St. Lawrence County teachers and administrators indicated that they want and need to:

- Expand teacher content knowledge in mathematics and science
- Use technology as an instructional tool
- Integrate mathematics, science and technology into learning units
- Integrate higher level thinking skills and authentic learning into coursework
- Investigate and question our world through mathematics, science and technology
- Providing regular meetings with superintendents

All of these aspects have been integrated into our most current NYSED STEM Partnership funding. The consistency of many of these specific points with the project-based educational approach indicates that the stakeholders in the program now understand and value the rigor and relevance components we have increasingly been emphasizing over the years. A STEM Advisory board was established in 2007 to continue to help define direction for the partnership and maintain open lines of communication. With these administrative efforts, the Partnership can be sustained even as individual funding sources come and go.

County-Wide Assessment Components

The assessment components for the overall STEM Partnership have grown in their research base and consistency across the various particular programs. An operational logic model was developed to match the Partnership goals with specific assessment tools and quantifiable goals. The database of assessment results for over 17 thousand students and 300 teachers provides quantitative evidence of the preliminary Partnership successes. The extensive database was built for the NYSED Math Partnership grant and is currently being extended to the STEM Partnership. Assessment efforts from other grants have provided supplemental and benchmark data with more modest numbers of participants.

The development and implementation of the county-wide data base relies heavily upon the BOCES staff awareness of teacher participants and matching of their database codes with those of their students. Anonymity throughout the process and clarity in how the assessment results would be used were key components required for IRB, teacher union and school district approval and buy-in to this overall process. Unique identifying codes are generated by each of the teachers on their initial self-reporting attitude survey to preserve their anonymity. Because the BOCES staff have the confidence of the district unions and the reputation for NOT being or NOT being seen to be teacher evaluators, the teachers understood that this assessment activity was for the programs themselves and would not be misused for teacher promotion or tenure evaluation.

Implementation of the database requires the submission of several reports by the school districts to the central BOCES office where they are compiled into a secure and encrypted database. Each school is given a random single letter identification code and all names are removed, leaving only the encrypted student and school code as identifiers. This initial database development was

undertaken under extremely secure conditions in order to protect the anonymity of both teacher and student participants. The separate reports submitted from each school to the central BOCES office that are compiled into the database include:

- Student Lite report, which includes a database with all students currently enrolled in the school, student id codes, birthdates, gender, and ethnicity.
- Program Services Report, which includes a list of student id numbers corresponding with codes for such programs as free and reduced lunch, poverty, and mental and physical disabilities.
- Individual Class List Report, which allows the determination as to which students belong to the intervention grouping through their participating teachers.
- NYSED student achievement data on State standardized tests in Mathematics and Science.
- Self reported survey data from an eighty-four question teacher survey that asks participants to indicate attitudes on: use of instructional activities in science, technology and mathematics; practices in assessment in science technology and mathematics; dynamics that influence instructional practices; overall attitudes towards the instruction of science, technology and mathematics; and efficacy of participants in teaching science, technology and mathematics.
- School and grade cohort data from an on-line student attitude survey adapted from the Third International Math and Science Study (TIMSS, 1999)

Basic statistical assessments are performed on all groups by grade, school and teacher. Matches between students and teachers participating in the STEM Partnership, which are subsequently broken into intervention and comparison groupings, allows for further disaggregation and multivariate analysis.

Both quantitative and qualitative tools are being used for teacher assessment. The teacher database tracks the number of teachers involved in the various Partnership components, their hours and nature of professional development, comments from teacher observations and peer review, and triad quarterly reports. Teachers participating in institutes complete pre and post content knowledge assessments. Data has been collected on comparison teachers about subjects, certification, “highly qualified” status and information on advanced degrees. Class lists of all teachers in the math grant were collected. The teachers were classified as math, science, AIS, technology, special education or other. Adding this information to the database allowed for the matching of each student to one or more teachers participating in the grant as well as the classification of students that did not have a participating teacher.

At the University level, the numbers and disciplinary diversity of students and faculty involved in the Partnership are tracked, as are traditional measures of academic success (e.g., research grants, dissemination of results, etc.).

Assessment Results

While the current Partnership is striving to integrate assessments across most of the partnership activities, some of the preliminary results available are related to specific grants and programs.

These results are shown here to highlight some of the progress that has been made within the Partnership over the recent past. The goals related to our impact on students and the institutionalization of the Partnership are included below.

Goal 1: Impact on Students

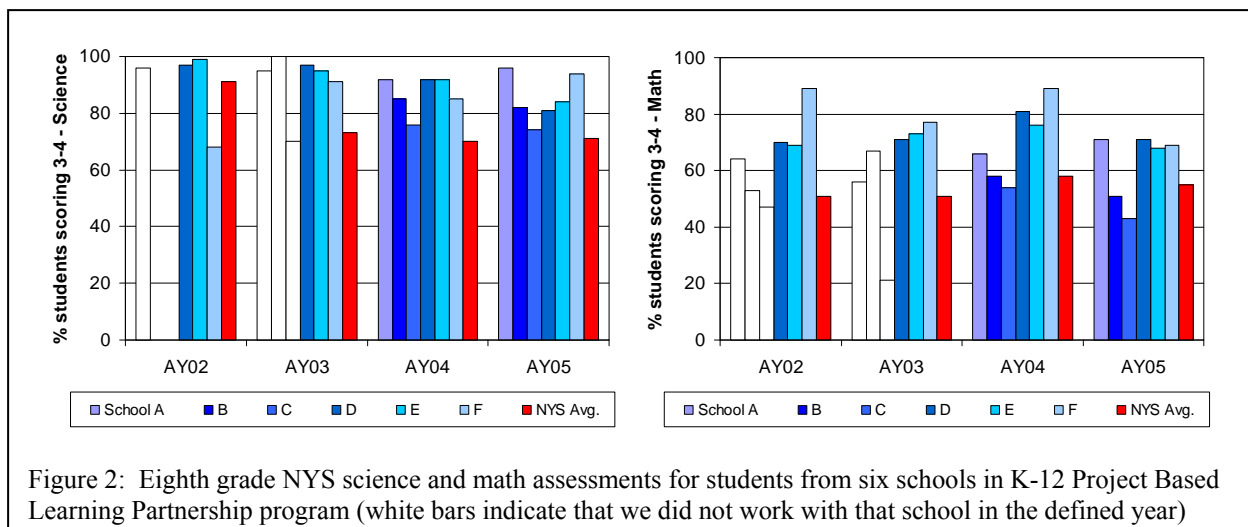
The goal of the Math Partnership was to positively impact the NYS exam scores of the students in St. Lawrence County. One metric for comparison is the percent of students defined as proficient in their NYS Math Assessments (scores 3-4). The data base of 3,748 total students in grades 6-8, included a comparison group (2,383 students who did not have a math teacher enrolled in the grant) and the treatment group of 1,365 whose math teachers received 60-90 hours of professional development. The students with a participating math teacher (treatment group = 67.94% proficient) outperformed students without a participating math teacher (comparison group=66.24 % proficient) in the grant. At certain grade levels the students of participating math teachers significantly benefited from their math teacher involvement in the grant. Students in the treatment group in grades five, six, seven, and eight especially benefited.

An analysis of students in grades 3-8 showed that, overall, all students performed statistically better on their NYS math assessments in '06-'07 than they did in '05-'06 ($p < 0.05$, Table 4), regardless if their teacher participated in the Math Partnership. However, when broken down by subgroups, students identified with poverty or with a learning disability ONLY did statistically better in the second year IF they had a teacher who participated in this Partnership. Thus, the Math Partnership met its fundamental goals, especially as related to the critical need for the impoverished population in St. Lawrence County.

NYS math and science assessments have also been tracked for 8th grade students with college

Overall Gr 3-8	Average Score 05-06	Average Score 06-07	P Value**
Group 1 (874*)	658.618	665.749	2.20E-16
Group 2 (1741)	664.947	668.233	2.26E-09
Group 3 (1185)	664.726	670.401	1.02E-10
Group 4 (3198)	664.771	668.403	3.63E-03
Poverty Gr 3-8	Average Score 05-06	Average Score 06-07	P Value
Group 1 (322)	647.006	653.441	9.62E-07
Group 2 (508)	655.645	658.508	6.64E-03
Group 3 (429)	655.296	662.324	6.07E-04
Group 4 (1271)	656.065	660.290	6.26E-02
Disability Gr 3-8	Average Score 05-06	Average Score 06-07	P Value
Group 1 (133)	637.167	645.767	7.10E-08
Group 2 (126)	640.333	646.564	1.48E-02
Group 3 (118)	635.075	638.559	2.46E-01
Group 4 (471)	627.727	632.538	8.20E-02

Group 1: had a participating math teacher in 05-06 and 06-07
 Group 2: had a participating math teacher in 05-06 and not in 06-07
 Group 3: had a participating math teacher in 06-07 and not in 05-06
 Group 4: has never had a participating math teacher
 * number in group
 **Significance at the $\alpha=0.05$ significance level is highlighted



STEM students in their classroom through the K-12 Project Based Learning Partnership Program. While the numbers of students included in this evaluation are fewer, and the direct correlation between the partnership and resulting test scores harder to confirm, it appears that these students are also doing better than NYS students overall (Figure 2), despite the increased poverty levels and low school budgets in this region. The PBLP program generally targets science and technology classes at this level and, indeed, the proficiency rates for science were higher for all schools we worked with than for NYS. The math scores for four of the six schools were also consistently higher than NYS.

The Third International Mathematics and Science Study (TIMSS) provides a benchmark to compare the attitudes and self-efficacy of our students. Based on the assumption that students with high self-perception of capabilities display high motivation and attain high achievement,^{xvi-xx} data are being collected from students of teachers in the STEM partnership grant and a comparable group of students. Some of the TIMSS self-efficacy questions (“I like Math, I am good at math”, etc) have also been asked of students in the K-12 PBLP program for several years and preliminary data are available for the students who just completed the extracurricular VEX robotics competition. Figure 3 illustrates the responses of our Partnership students in comparison with the 1999 national averages.^{xxi} It is clear that the students who completed the VEX competition have higher self-efficacy in science, but not necessarily in math. Overall, the VEX students like science significantly better than other students in the county who have benefited from the Partnership programs. A key difference here is the comparison of students who elected to participate in the extracurricular robotics activities to the entire class evaluated through the K-12 PBLP program. These types of results highlight the need to continue extracurricular activities to retain the students who like science in STEM fields, yet also suggest the need to balance these extra-curricular activities with in-class exposure to engaging STEM activities to try to raise the efficacy of all students in STEM fields.

The STEM Partnership is also cognizant of the empirical research that TIMSS has generated regarding the “false sense of self efficacy” that has been uncovered when actual achievement versus self-perception between countries has been compared. Shen and Pedulla^{xxii} discovered that “in countries where students’ achievements are relatively high on the TIMSS tests, the students tend to rate their competence lower than do students in countries performing less well.

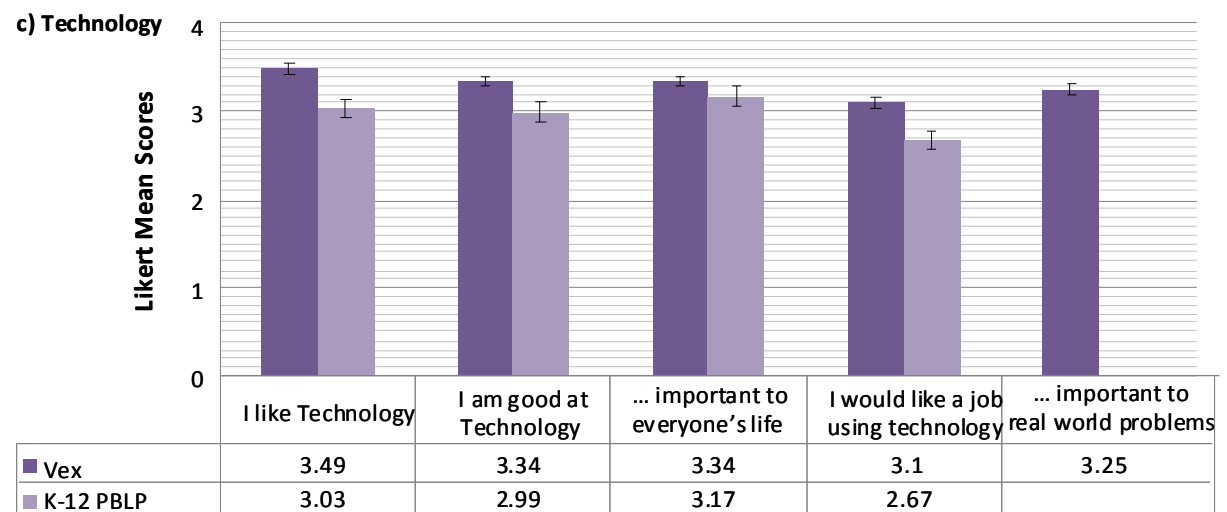
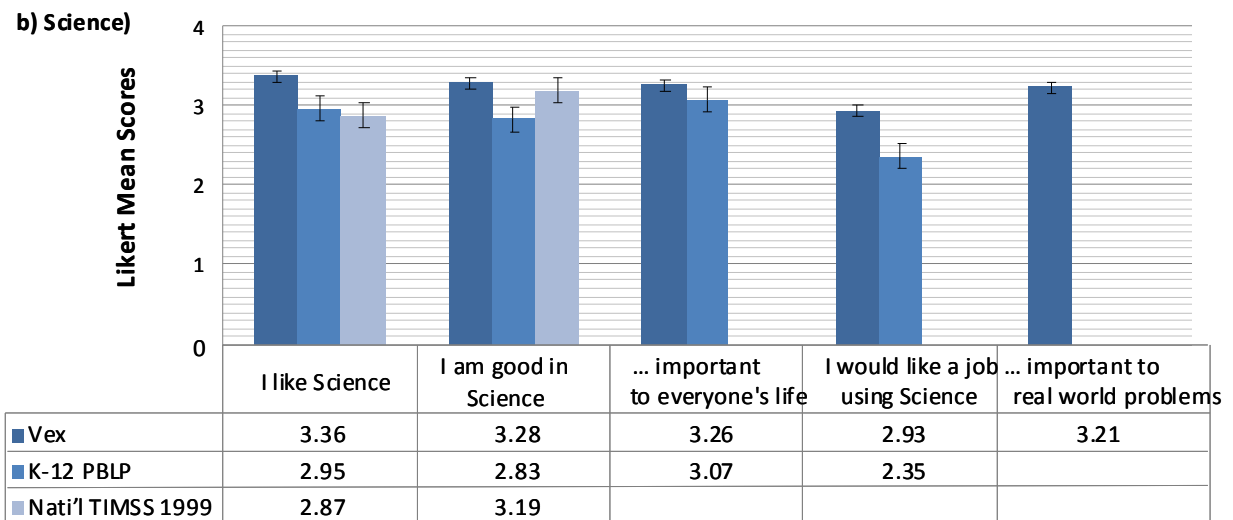
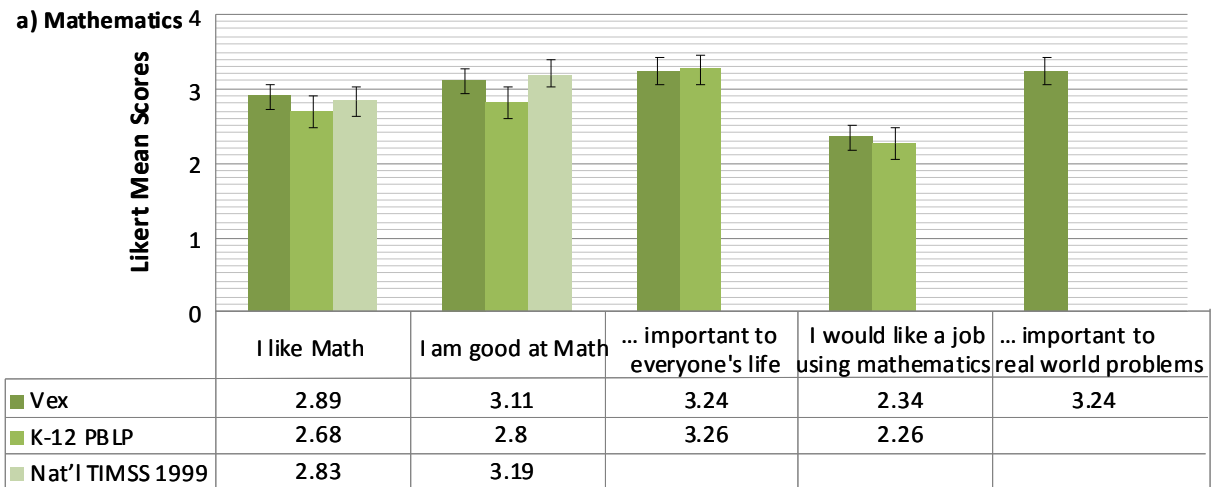


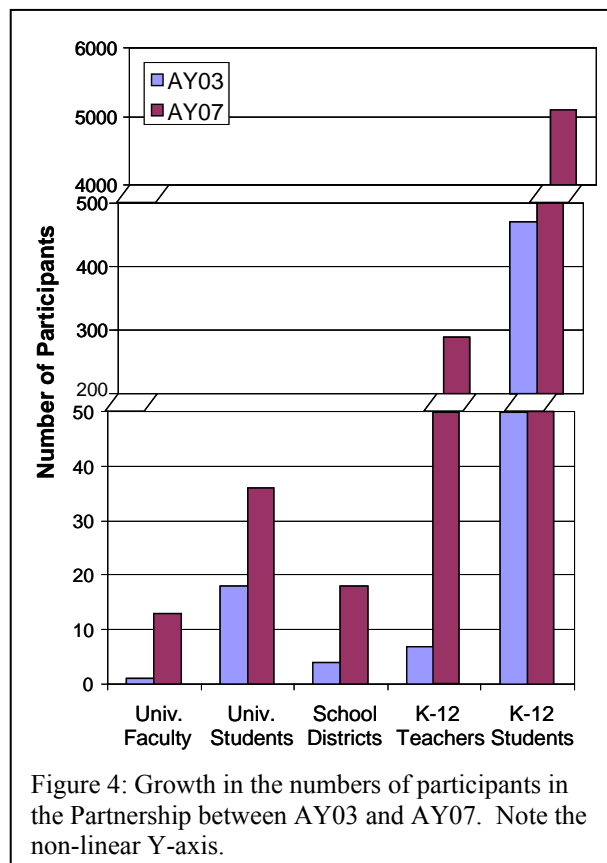
Figure 3: TIMSS-type math (a), science (b) and technology (c) attitude assessment for students in extracurricular VEX robotics program (grades 7-9) and in-class K-12 PBLP program (grades 7-8) compared to 1999 TIMSS national averages. The scale ranges from 4=strongly agree to 1=strongly disagree (Vex: n=222, PBLP: n=661)

Conversely, in countries where students’ actual achievements are relatively low, the students tend to rate their competence higher than students in countries performing better.” Since their findings are consistent with other studies,^{xxiii-xxv} they conclude that “a student’s self-evaluation of his or her competence is mainly affected by the standard established or conveyed by the curriculum and assessment system of the school, district or country.”^{xxii} Thus the Partnership has placed high emphasis on the importance of teachers developing highly rigorous and challenging units of curriculum that integrate mathematics, science and technology. Similarly, House,^{xxvi-xxvii} who found that adolescent students in Japan tended to achieve well on mathematics tests, reported that their teachers more frequently incorporated the use of active learning strategies (e.g. using things from everyday life when solving problems) during mathematics lessons. The STEM Partnership is aware of this variable and has placed emphasis on teachers developing integrated lesson units that reflect the highest standard of relevance. The rubric used to assess teaching units has specific criteria for rigor and relevance with descriptive qualitative indicators of a high standard target. Students are also being asked to rate their own sense of how important STEM subjects are to solving problems (Figure 3). The high scores show that the students recognize the importance of STEM disciplines in solving real world problems.

Goal 4: Further development of a sustainable educational partnership

From the University’s perspective, the institutionalization and sustainability of outreach partnership programs requires an organized administrative unit to coordinate such activities, sufficient numbers of participants so that the partnership does not depend on an individual champion, and a consistent message from the administration that time spent on educational outreach activities is an appropriate use of the faculty time. Clarkson University has made significant progress on all of these accounts.

The 2004 establishment of the Office of Educational Partnerships (OEP) and the subsequent strong alignment of that office with the county-wide BOCES have been the most significant factors contributing to the growth and sustainability of the Partnership. Clarkson’s OEP provides continuity among the various programs, training and support services for faculty and college students, and coordination of programs with various school districts and teachers. The BOCES office provides a direct and well respected link and communication access with administrators in school districts across the county. As shown in Figure 4, participation in the Partnership has grown substantially since the establishment of the OEP and development of strong ties with the BOCES.



Faculty access to the support services in the OEP has had a direct impact on the number of successful grants that have included outreach components. One example is the NSF supplement from the Office of Polar programs that helped to coordinate in-class room activities and electronic communication between an Antarctica field research team and seven local classrooms. Three other faculty members who have received NSF CAREER awards have also included K-12 outreach components. The OEP has provided the principle investigators of these grants with the expertise and connections necessary to gain leverage from existing programs so that the CAREER winning PIs can provide effective outreach related to their areas of research. Current K-12 PBLP units on atmospheric science, biomedical sensing devices, water quality, bone structure, and the environmental impacts of transportation fuels directly reflects the research that is being undertaken by Clarkson's faculty members.

Increasing the openness and visibility of Clarkson University to the K-12 school community has been a key element of the growth and sustainability of the program. Ten years ago, there was virtually no contact between the two levels of education institutions (other than hockey camps), and very little understanding of the value that the education and research activities at Clarkson could bring to the region. In contrast, current partnership activities on our campus, several of which have included the University President or Provost among the speakers, include:

- An annual meetings of K-12 administrators and teachers with posters and displays of partnership activities
- Hosting of the 2007 First Lego and VEX league robotics competitions for 269 5-9th grade students
- Hosting of the 2008 local teacher conference for middle and high school STEM teachers
- Numerous field trips to campus to break concrete, work on robotics, participate in competition events, or see University engineering design projects
- Summer "roller coaster design camp" for students and teachers in Impetus program
- Week-long teacher institutes in a variety of STEM disciplines

Summary – Sustaining the Partnership

Grants go away, partnerships do not! A very strong partnership has been developed with Clarkson University that involves all St. Lawrence County school districts and BOCES. This partnership is now being led by a STEM Advisory Board made up of Clarkson professors, school district superintendents, BOCES administrators, teachers and parents. This Advisory Board is committed to education PreK-20+ and will work to make sure that the wonderful opportunities that are afforded through this grant will continue. We have shown success in the past but this initiative will give us the time, funding and evaluation necessary to prove that these partnerships make a difference for teachers and students in K-12 schools as well as higher education. In a true partnership everyone wins and with this level of commitment we can make that happen.

ⁱ Annie E. Casey Foundation, KIDS COUNT Data Book: State Profiles of Child Well-being (<http://www.kidscount.org/datacenter/databook.jsp>), 2007.

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