2006-262: IMPROVING SCIENCE LITERACY THROUGH PROJECT-BASED K-12 OUTREACH EFFORTS THAT USE ENERGY AND ENVIRONMENTAL THEMES

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Improving science literacy through project-based K-12 outreach efforts that use energy and environmental themes

Abstract

An educational outreach program uses project-based curricula with environmental themes as a means to engage students and increase their interest and competency in science, technology, engineering, and mathematics (STEM). Engineering and science students from Clarkson University work in partnership with area teachers to develop and teach modules that require students to learn and apply standards-based mathematics and science content and process skills as they work to solve a real-world problem that is relevant to their school or community. A combination of quantitative and qualitative assessment results demonstrate that the program successfully enhances student interest and confidence in STEM, and contributes to measured improvements in mathematics and science achievement scores.

Introduction

While today's science instructors struggle to meet the demands of increasingly complex learning standards [1-4] and mandatory high-stakes testing programs, the primary responsibility of any science education program remains: to improve *scientific literacy*. This is defined by James et al. as "familiarity with science in the wider context of human social affairs."[5] Students need to emerge from a science education program not only with a sound knowledge base of scientific concepts and phenomena, but also with good scientific process and thinking skills that will enable them to extend their knowledge as they encounter unfamiliar situations, and to critically analyze scientific information to make informed decisions that affect their lives.[6, 7] Science and technology are deeply imbedded in the lives of today's students, and impact political, technical, and social decisions on a global scale. Scientific and technical literacy will empower students to become responsible citizens in the rapidly changing world in which we live, and will prepare students for effective participation in the decisions and actions that take place in their homes, their communities, and their world.[7] Likewise, literacy within the environmental sciences will prepare students for interpreting and acting on issues related to energy and the environment.

Project based learning has been suggested to present the best case for teaching and learning science process skills and content.[8, 9] The technique has roots in the "learning by doing" approach to education promoted by John Dewey.[10] The curriculum is generally centered around the assignment of a problem or project – students learn, and then apply, science content and skills that are relevant to their project or problem solution. The technique improves student learning and retention of science concepts, largely because students learn more when they are interested and actively involved in what they are doing, and when they understand the relevance of the material to their own lives.[8, 11]

Recent developments in curriculum reform have also promoted the integration of science, technology, and mathematics in an effort to deviate from the traditional, compartmentalized subject structure and move toward learning situations that mimic the real world.[12-14] These reform movements promote the teaching and learning of science process skills, focusing on the "whole of science, upon student mind engagement, upon a reunion of science and technology."[15] The Science, Technology, and Society (STS) movement further endorses the immersion of integrated science, mathematics and technology content and process skills within a societal context.[5, 7, 14-20] The idea behind the STS approach to science teaching is to frame science topics within a societal context as a means of connecting the material to students' lives in an attempt to make science more personally meaningful to students.

Environmental and energy-related issues provide a convenient platform for problem or project assignments in an integrated math/science/technology project-based curriculum. Environmental topics are *tangible* and "real" for most students, regardless of gender or background. Energy issues are particularly *relevant* to today's students, and are readily positioned within a societal context; the limited supply of fossil fuels, combined with detrimental effects associated with energy conversion and use, are dictating dramatic changes in the way we harness and use energy. The study of energy encompasses a broad range of interconnected themes, providing ample opportunity to integrate not only math/science/technology subjects but also social, political, economic and environmental aspects. Integrating these themes in an engineering problem solving activity broadens students' awareness of the "holistic" nature of engineering in today's world.

Effective science and environmental education may be particularly important in light of evidence suggesting that American students – in fact, the U.S. public in general – are lacking in awareness of environmental and energy-related issues.[21-25] Education programs that promote scientific literacy will help prepare students to interpret scientific, environmental, and energy-related issues and make sound choices and actions as voters, consumers, and professionals. Effective education will enhance student competency in science, technology, engineering, and mathematics (STEM); improve critical thinking and problem solving skills; and positively impact student interest and attitudes toward learning STEM subjects.

The objective of this paper is to show the value of using project-based learning and real-world environmentally-related problems, such as energy, in middle school math, science and technology (MST) classes for enhancing student interest and competency in STEM concepts. Added value is gained by incorporating this method into outreach efforts that bring college science and engineering students into the classroom. The paper reports on project-based curricula designed at Clarkson University, Potsdam NY through our K-12 Project Based Learning Partnership program and presents results of six years of quantitative and qualitative assessment data used to evaluate this objective.

K-12 Project-Based Learning Partnership Program

Clarkson University has worked in partnership with several schools in Northern New York State since 1999 to engage and excite middle and high school students in science, mathematics, and technology classes. The program has been funded by the National Science Foundation and the GE Foundation. Each project-based curriculum has been designed to engage students in STEM fundamentals, and science and engineering process skills, through the solution of problems related to the environment or community. College graduate and undergraduate engineering, science and mathematics majors in the K-12 Project-Based Learning Partnership Program work in consultation with their partner teachers to define suitable problem statements, develop activities and lessons, and then work two to three days per week throughout a semester to jointly teach the project unit to middle or high school students.

The lessons and materials we bring to the classroom uniquely value:

- the integration of math, science and technological content through hands-on activities in a holistic systems approach.
- the application of STEM principles to real-world problems by first providing a framework for problem solving and scientific inquiry, rather than just charging into math equations.
- the breadth and capacity of technology and engineering to solve problems that have social relevance.

Given the increasing pressures on teachers to cover STEM "content" on state exams, bringing project-based learning experiences into the classroom requires close integration of state or nationally defined learning standards. There is little opportunity to stray beyond these constraints. Thus, the development of curricular material for any University – K-12 partnership program must understand and integrate these standards as much as possible. State MST standards (e.g., [1]) are sometimes more stringent and detailed than the national counterparts.[2-4] Utilizing projects as a mechanism for learning contributes most extensively to meeting New York State (NYS) Standards 1, 2, 6, and 7, identified by NYS as "extended process skills:"

- Standard 1 - Analysis, Inquiry and Design. *Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.*
- Standard 2 - Information Systems. *Students will access, generate, process, and transfer information using appropriate technologies.*
- Standard 6 - Interconnectedness: Common Themes. *Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.*
- Standard 7 - Interdisciplinary Problem Solving. *Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.*

In contrast, New York State Standards 3, 4, and 5 correspond to mathematics, science and technology content:

- Standard 3 – Mathematics. *Students will understand mathematics and become mathematically confident by communicating and reasoning mathematically, by applying mathematics in real-world settings, and by solving problems through the integrated study of number systems, geometry, algebra, data analysis, probability, and trigonometry.*
- Standard 4 – Science. *Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.*

- Standard 5 – Technology. *Students will apply technological knowledge and skills to design, construct, use, and evaluate products and systems to satisfy human and environmental needs.*

These "content" standards are often the primary focus of many classes that are taught with more traditional pedagogical approaches. By focusing on the some of the process oriented standards, our partnership contributes substantially to the overall learning needs in the classroom. In NYS, progress of middle school students towards learning the key ideas embodied in these standards is currently accomplished through state-wide exams in mathematics and science at the end of 8th grade. Although students in New York State are required to complete a full year of technology education by the end of 8th grade, the state technology exam is optional.

Coupling the need to meet teacher and school district responsibility in covering state standards and the Partnership Programs' ideal of project based learning to improve student competency in and attitudes toward STEM disciplines requires careful consideration of curricular topics.[26] We have developed and taught project-based units that are based on a variety of environmental themes (Table 1), including solid waste reuse, water quality, and renewable energy systems. Variations of each curriculum have been taught at both middle school and high school levels.

Table 1. Summary of Project-based Curricular Themes

Theme	Years Taught†	Total Schools	Total Students
Solid Waste Re-use	AY01	3	248
	AY02	3	372
	AY03	4	445
	AY04	1	40
	AY05	6	270
	AY06‡	3	178
Renewable Energy Systems	AY04	4	196
	AY05	9	529
	AY06‡	2	142
Water Quality	AY06‡	4	121

†AY01 refers to academic year 2000-2001, etc.
‡AY06 data are for fall 2005 only.

The general outline for the ***Energy in Our Lives*** curriculum is outlined in Table 2. As described above, energy literacy is becoming increasingly important as our Nation faces priorities to reduce our dependence of foreign oil. National and NYS MST standards also include fundamental concepts of energy as well as an appreciation for the role of energy in our society.

The *Energy* curriculum was initially taught in AY04 (2003-2004) and has been adapted and changed based on our program assessment and teacher needs. Variations in the manner in which we've covered this content range from a three-week shortened version in 8th grade technology class to an entire semester with various aspects taught in 8th grade science, mathematics and technology classes. As with all our curricula, regardless of which components are taught, the emphasis is on understanding and solving a problem, including communication of findings. The specific projects or problems that the students have tackled within the *Energy* curriculum have included selecting a power source for an off grid house, reducing grid-supplied power consumed by an average home by 50%, and quantifying the benefits of replacing incandescent light bulbs with compact fluorescent bulbs (CFB).

Table 2. Example Content included in *Energy in Our Lives* curriculum
Unit 1: Energy Choices – Understanding the Problem 1. "Energy Choices" board game 2. Renew-a-bean activity (renewable vs. non-renewable resources) 3. Introduction energy, work, power - Human power activity 4. Broader global perspective **Unit 2: Exploring Solutions to Energy Problems** 5. Summarize the "problem," define problem solving approach and semester project 6. Conservation a. Home energy audit activity b. Light bulb activity (heat and light from CFB vs. incandescent) 7. Alternative energy systems a. Introduce energy sources / conversions (fossil fuel demo) b. Energy forms and states (puzzle activity, household item activity) c. Energy systems (internet research, flow chart diagramming activity) d. Efficiency of Conversions (Lego motor activity, including calculations) **Unit 3: Physical Models of Energy Systems** 8. Exploring/improving efficiency of energy systems (wind, hydro, solar Lego kits) **Unit 4: Proposing solutions** 9. Presentation of group projects 10. Discussion/debate – which solutions would work best to improve our energy future?

Assessment Methods

For the middle and high school student audience, the program aims to improve science literacy by "*engaging K-12 students via active, project-based learning as a means to enhance their interest and competency in STEM concepts*." The assessment program follows a mixed-methods quantitative/qualitative design that uses a variety of written and verbal instruments (Table 3). Competency levels have been monitored by collecting and analyzing student achievement scores on the New York State science and mathematics assessments for 8th grade, and also by measuring students' pre/post performance on our own Math and Science Content/Skills Assessment. This assessment, created in the fall of 2004 as part of our program, was developed based on relevant questions from the New York State 8th grade mathematics and science exams, and focuses primarily on measuring process skills such as data analysis, problem solving, and critical thinking skills, as well as some key math/science concepts in areas that are relevant to our program. The assessment has been administered pre/post during two program years; it was slightly modified following the 2004/05 program year, but the basic areas and topics remain consistent (Table 4). The test is comprised of 13 multiple-choice questions with one correct answer, and one free-response graphing question containing four parts.

Student interest and attitudes toward STEM subjects have been evaluated with both written and verbal instruments administered to students, teachers, and parents. Students complete brief questionnaires pre/post program, whereby they are asked to respond to a series of questions related to their affinity for mathematics, science, and technology (our "I Like Math" survey). Questions are based on the attitude portion of the 1999 TIMSS (Third International Mathematics and Science Study),[27] and have suitable benchmarks for comparison. Students respond to the following questions, using a 4-point Likert scale (4=strongly agree…1=strongly disagree): I like (math/science/technology); I am good in (math/science/technology); (math/science/technology) is important in everyday life; I would like a job using (math/science/technology). Students, parents, and teachers have also completed post-program surveys containing a combination of Likert-scale type and free-response questions about their perceptions of the program. Additionally, teachers participate annually in post-program focus group discussions with trained personnel. The written free-response questions and focus group discussions are designed to supplement quantitative survey data and provide a deeper understanding of the program's impacts.

Table 3. Summary of Assessment Instruments, by method and subject

		Students	Teachers	Parents	Quantitative	Qualitative
Competency*	**New York State 8th grade exam scores** (mathematics available from pre-program; science available from AY02)	x			x	
Competency*	**Math/Science Content Assessment** (started AY05)	x			x	
Interest/Attitude	**"I Like Math" Survey** (started AY04)	x			x	
Interest/Attitude	**Post-program questionnaire** (all program years)	x		x	x	x
Interest/Attitude	**Focus group discussions*** (all program years)		x			x

*Teacher comments in focus group discussions have also provided information concerning the impact of the program on student competency levels.

Assessment Results

Student Competency in STEM. Participant scores on the 8th Grade New York State Mathematics and Science Exams are shown in Figure 1, together with corresponding scores from comparison schools assigned by the New York State Department of Education. These data represent averaged values from the three schools that began our program in AY01 (2000-2001); comparison schools are also shown as combined averages. Student scores on the science test, which was first administered in 2002, are consistently high and fairly stable for both participants and comparison schools, although the comparison schools show a slight decline in performance during years 2003 and 2004 that is not matched by the participant schools. Performance on the Mathematics exam is more differentiated between the participants and the comparison schools: participants score consistently higher than their comparison schools. Moreover, the performance of participating students has improved almost every year since the partnership program began (AY01), although the same can be said – to a lesser extent – for the comparison schools. Thus, while it is promising that student performance is improving from year to year, it is not clear how much – if any – of that improvement can be attributed to our program. This uncertainty exemplifies the limited value of a single assessment tool for these types of programs, emphasizing the importance of a multifaceted approach to enable a more thorough investigation into the program's impacts.

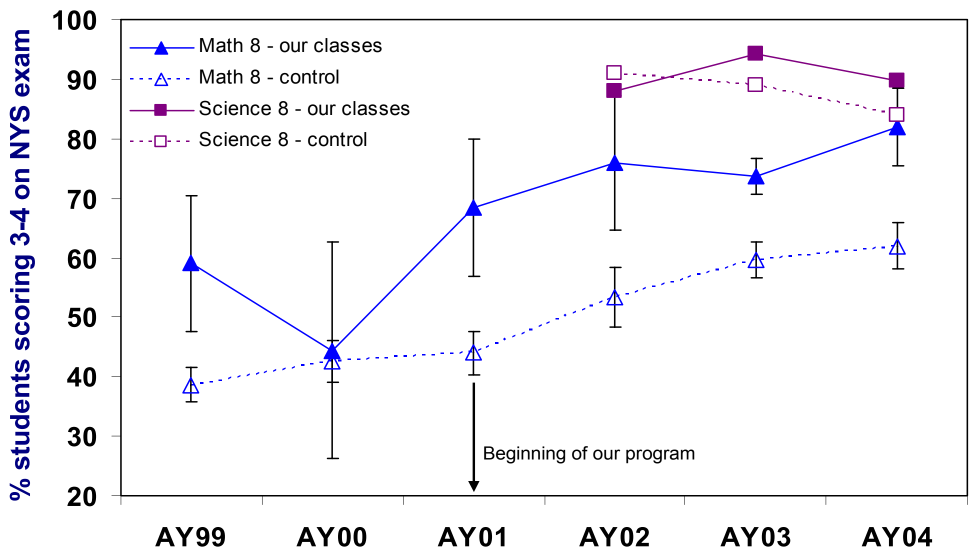

Figure 1. New York State 8th Grade Assessment Scores, Science and Mathematics. Control schools specific for our participating schools are assigned by the New York State Department of Education. Error bars represent +/- one standard deviation.

Student performance on the *Math/Science Content and Skills Assessment* provides another frame of reference for assessing impact on student achievement, perhaps more specific to our program's influence (Table 4). Students tested during two separate program years (AY05 and AY06) all exhibited slight improvement in their average (overall) test scores on the multiple choice test section after completing the program; improvement in AY05 (one school, 7th grade) was significant, while AY06 improvement (two schools, 8th grade) was not significant. Average scores on the free-response graphing question improved, pre-post, in two of the groups tested, and declined for the third group. Changes in performance on the graphing question were not significant at any school. In general, there is no appreciable difference in overall performance between the 7th grade group (AY05) and the two 8th grade groups (AY06), and the spread of the scores is quite large.

Performance on individual questions can provide information concerning student understanding of specific topics in science and mathematics that are of particular importance to our program. Values in Table 4 represent the percentage of students who correctly answered each question on the post-test; the symbols (+) and (-) indicate an increase or decrease, respectively, in correct answers of at least 5%, pre-post. Overall, students seem to improve in their understanding of science content included in our program that is appropriate for their grade level (life science for 7th grade; physical science and energy for 8th grade). A slight decline (3%, not indicated in table; post values still relatively high) in the number of 8th grade students who correctly responded to a question regarding energy conversion comes as a surprise, since this concept plays a key role in the *Energy* curriculum. All three groups improved in their ability to extrapolate a graph. Both 8th grade groups improved in their algebra performance (order of operations), and all three groups performed well on basic statistics questions (mean, median calculations). All of these improvements are encouraging, because these topics are all covered quite extensively in our curricula.

Table 4. Student Performance on Math/Science Content and Skills Assessment

Area	Topic	Post-test % Correct		
		04-05†	05-06‡	05-06‡
Science	Density	35(+)	25.0(+)	21.2
	Dependent/Independent Variables	15(+)	12.5	12.1(-)
	Reading a Graduated Cylinder	8(-)	31.3(+)	15.2(-)
	Read/interpret Graph	96	87.5	78.8(-)
	Energy Sources	--	90.6(+)	75.8(+)
	Energy Conversion	77(+)	87.5	78.8
	Producers and Consumers	83(+)	--	--
	Tropic Levels	44(+)	--	--
Mathematics	Percent Calculations	52	50.0	39.4(+)
	Fractions	69(-)	65.6(-)	66.7(+)
	Algebra, Order of Operations	77	93.8(+)	75.8(+)
	Algebra, Word Problems	67(+)	62.5	42.4(-)
	Mean, Median	75	84.4(-)	75.8
	Extrapolate	92(+)	96.9(+)	93.9(+)
Comparing Class Average Scores, Pre-post*				
Questions 1-13	Post-test % correct	61.9 ± 16.3	67.2 ± 17.4	59.4 ± 18.2
	Overall Improvement, multiple choice questions 1-13	improvement (P=0.0006)	slight improvement (P=0.20)	slight improvement (P=0.50)
Free-response graphing	Post-test, points out of 10	4.19 ± 2.87	6.53 ± 2.21	4.65 ± 3.34
	Create hypothesis, Graph, Interpret Results (multiple part)	slight improvement (P=0.37)	slight improvement (P=0.25)	slight decline (P=0.21)

†Data from one school (7th grade) analyzed in AY05.
‡Data from two schools (8th grade) analyzed in AY06.
--Topics not addressed.
(+) Topic where percent students correct increased, pre-post, by at least 5%.
(-) Topic where percent students correct decreased, pre-post, by at least 5%.
* Post-test class average reported as mean ± standard deviation.

Improved competency in other science and mathematics topics seem sparse and scattered, and the percent students answering questions correctly on some of these topics is quite low. For example, two groups improved, while one declined, in their ability to calculate density, with percent correct on the post-test still at 35% or below. In one 8th grade class students improved in their ability to read a graduated cylinder, although the number of correct responses was only 31% on the post-test (still higher than the performance of the other two groups, which both declined). Similarly, students improved at one school in their ability to calculate percent, yet their final performance was only 39.4% correct, much lower than the post-test performance of the other two groups. This information is valuable because these specific details identify potentially weak areas in our curricula, which helps us to focus our efforts to improve.

The largest overall increase in performance among the various topics is seen in the 7th grade group (AY05), where students improved in all but two topics. The two 8th grade groups improved in fewer topics, and in fact at one school the number of improvements is nearly matched by an equal number of topics where performance declined. It seems counter-intuitive that students would decline, to the extent shown, in their understanding of particular topics as they progress through the school year. As with any type of student survey, questionnaire, or quiz, the value of the information provided is constrained by the willingness of the students to fully participate and acknowledge the seriousness of their response. The decline in performance for this one group of students suggests that these students may not have been putting forth their best efforts when taking the post-test. Thus, while this specific question-by-question analysis of the Content/Skills Assessment does indeed provide an additional lense through which to assess our program's impact on program effectiveness and student learning, this disparity in student performance on the pre/post test signals us to use caution when interpreting the test results at this level of detail.

That said, general improvements in the overall class average performance measured pre/post program indicate that student competency in mathematics and science process skills appears to increase as they progress through the project. Again, if we limit our analysis to this one test, the degree to which our program is responsible for this increase is unclear, since no adequate control measures have been identified or applied.

Student interest in STEM. The relationship between student achievement and student attitude is well documented.[28-31] Likewise, student attitudes toward a subject will be reflected by their interest levels in the classroom. If we are to believe that students learn more when they are interested in the material, then a measure of student attitude should provide insight into the potential for enhancing student achievement or competency.

Attempts to quantify improvements in student attitudes toward STEM by analyzing the pre/post program "I Like Math" attitude surveys have been marginally successful. The data have provided sporadic results which largely consist of a smattering of positive and negative findings, none of which represent any real or consistent trend. In fact, looking at the bigger picture, we have seen that for any given year some schools tend to show more generally positive trends while others are more generally negative, and at any particular school this general trend may change from year to year. Taken as a whole the number of positive and negative changes have been fairly well balanced out over all pre/post measurement periods. As with the Math/Science Content and Skills Assessment, the variability in student responses exemplifies the difficulty in quantifying middle school student attitudes solely using this type of quantitative self-assessment procedure. Students react to a variety of inseparable factors as they complete their paper surveys, including classroom climate, teacher personality traits, student-to-student interactions, and even the day of the week or the time of year that students complete the assessment. Many of these complicating external factors may be playing a much greater role than our program in influencing student attitude, which confounds the application of a straightforward quantitative data analysis.

Post-program attitude scores from our participating schools can be compared with each other and with the results of the TIMSS study to provide a benchmark indicator of how our students' attitudes measure up to their peers, both locally and across the country (Figures 2 and 3). Data shown include the average post-program values from four questions in our "I Like Math" survey, collected at the three schools which began our program in AY01 (three years of data at one school; two years at two schools). National data represent the average values from 1300 8th grade students surveyed as part of the 1999 TIMSS.[28]

Participating students' affinity for and confidence in science (Figure 2) are highly variable, not only between schools but also within any particular school from year to year. Science results are scattered in both directions of the national average values (both higher and lower) but are all within +/- one standard deviation of the averages. Mathematics results (Figure 3) are less variable. Participants all responded at averaged levels lower than the national averages, but again all values are within +/- one standard deviation of each other and of the National averages. Interestingly, unlike the Science scores, which showed a mixture of student affinity relative to student confidence levels, Figure 3 shows that at every school – as well as the national average data – students responded more positively to questions regarding their confidence in mathematics than to questions concerning how much they like the subject.

Given that quantitative survey response methods fall short of adequately assessing our program's impact on student attitudes or feelings of self-efficacy, other than to show that our students' attitudes are in line with the National averages, we've used post-program questionnaire responses and reflective essays to provide additional qualitative information that helps improve our understanding of the students' general feelings toward the program itself, including their reactions to the subject matter, the project-based teaching methods and the presence of the Clarkson students in their classrooms. Although the students are not asked to respond to questions that specifically address their attitudes toward STEM, we would expect these attitudes to flavor their responses to these program-related questions.

Results (Table 5) indicate that, by and large, students have enjoyed their experiences with the program (86% responded favorably, 14% unfavorably, to questions concerning the overall rating of the program). Student interest in the subject matter has also been generally positive, although not to the same extent. Most students (57.5%) reported that they found the *energy* topic to be interesting or relevant, while the remaining students were split almost equally, responding as either not interested (20%) or unsure (22.5%) about their interest. Similarly, 61 percent of students surveyed indicated that they were interested in the *solid waste* topic, while 22 percent did not like the topic and 17 percent were unsure.

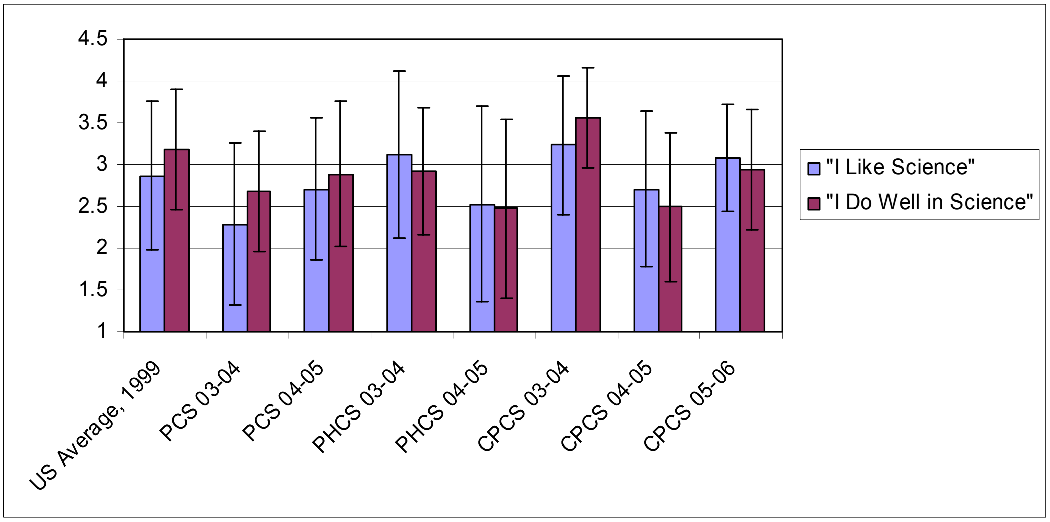

Figure 2. Average post-program responses to "I Like Math" student survey to questions regarding science attitudes, compared to TIMSS data (4=strongly agree; 1=strongly disagree). Error bars represent +/- one standard deviation.

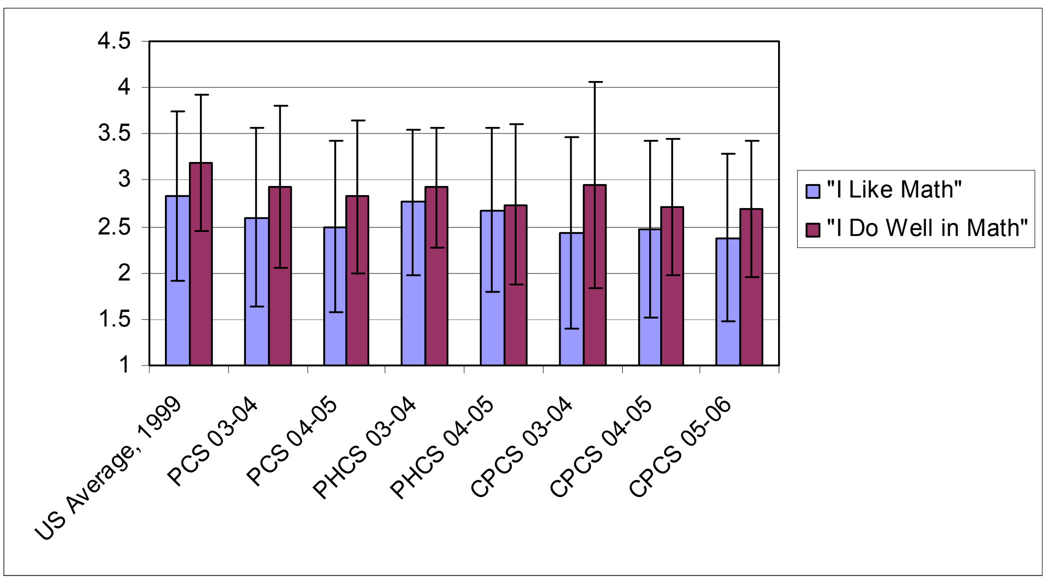

Figure 3. Average post-program responses to "I Like Math" student survey to questions regarding mathematics attitudes, compared to TIMSS data (4=strongly agree; 1=strongly disagree). Error bars represent +/- one standard deviation.

Free-response questions concerning student opinions toward specific aspects of the program revealed a few common threads that tend to persist throughout all student participants, regardless of school or program year. Students consistently reported that they favor the hands-on projects and activities, the field trips to Clarkson (where these were made available), and interacting with the Clarkson students in the classroom. Students have also commented that they enjoyed "learning how to save energy," and appreciated the fact that the Clarkson students were "actually studying [energy topics] in the field." Another clear thread that emerges is a general dislike among participants for aspects of the program that align with more traditional pedagogical approaches, including paperwork, homework, desk work and report writing, listening to lectures and taking notes. Several students also reported a specific dislike for incorporating mathematics into science and technology, which may well reflect a discomfort that comes from limited exposure to integrated subjects at these grade levels.

<table>
<tr><th colspan="4">Table 5. Summary of Post-program Student Questionnaire Response</th></tr>
<tr><td></td><td>Good to Excellent</td><td colspan="2">Fair to Poor</td></tr>
<tr><td>Overall Rating of “experience with the program”</td><td>545</td><td colspan="2">85</td></tr>
<tr><td></td><td>Agree</td><td>Unsure</td><td>Disagree</td></tr>
<tr><td>Found energy topic interesting or relevant</td><td>153</td><td>60</td><td>54</td></tr>
<tr><td>Found solid waste topic interesting or relevant</td><td>25</td><td>7</td><td>9</td></tr>
<tr><td colspan="4">Common Threads: Specific free-response reactions to program</td></tr>
<tr><td rowspan="3">Positive (total 249)</td><td colspan="2">Hands-on projects and activities</td><td>197</td></tr>
<tr><td colspan="2">Field trips to Clarkson University</td><td>131</td></tr>
<tr><td colspan="2">Clarkson students in the classroom</td><td>19</td></tr>
<tr><td rowspan="3">Negative (total 227)</td><td colspan="2">Paperwork, homework, desk work and report writing</td><td>89</td></tr>
<tr><td colspan="2">Listening to lectures and taking notes</td><td>27</td></tr>
<tr><td colspan="2">Incorporating math into science and technology</td><td>21</td></tr>
</table>

In addition to the students' self-assessment data, focus group discussions and free- response questionnaires administered to teachers and parents provide a wealth of qualitative information that facilitates both specific and general interpretation of the program's impacts on student interest and perceived competence in STEM. Parental responses on post-program questionnaires have been overwhelmingly positive:

- 80% (208 out of 260 respondents) reported that their son/daughter was enthusiastic about their interactions with the program.
- 67% (26 out of 39 respondents) reported that their son/daughter was enthusiastic about the energy topic.
- 72% (151 out of 211 respondents) reported that their son/daughter was enthusiastic about the solid waste topic.
- 97% (255 out of 263 respondents) indicated that they would like the program to continue at their school.

- 71% (149 out of 209 respondents) indicated that their son/daughter appeared to be more interested in science/technology classes since the program began.

The vast majority of parents surveyed have shown support for the program and the impact on their child's learning experience, with comments that their child "talks more about science" at home (1 comment) and is "more interested" because of the active, hands-on learning (6 comments); and further, they value the interdisciplinary and team-based approach (7 comments) and the benefits of their child's interaction with college students (4 comments).

Written evaluation comments from teachers have indicated that they value the way the project-based curricula connect "real life" to the standards-based content material, and the way that the projects bring forth the mathematical foundation behind science concepts. Teachers have indicated in focus group discussions that they are delighted with the program's impact on their students. They believe that students are *motivated* by the program, are more *engaged* as a result of the project-based learning, and feel that they can understand the "big picture" of science processes better than ever before. One teacher stated and another agreed that on the middle school level, the students may not be specifically improving their understanding of math/science/technology, but are more excited about it. Most consistently indicate that the students love the hands-on approach to learning, and note that the program helps students become more comfortable operating in the science lab and using laboratory equipment. Several teachers have noted an improvement in students' ability to integrate various subject material, noting that many of them have opened up to math/science/technology in a way they were not doing previous to the program: students see the "interconnectedness of science and math," and benefit from an "integrated process" that provides "integration of topics and techniques." Teachers have also noted observed gains in students' confidence in their own skills, interest in hands-on problem solving, an increased sense of relevance for the students in science and math, and simple enjoyment of the project based learning. Also prominent in teacher remarks are strong positive feelings toward the presence of the Clarkson students in the classroom, for example: "The Clarkson [Fellows] provide an indispensable resource. The experiences that my students gain from working with well-educated, prepared, professional engineering [and science] students can not be duplicated or obtained in any other way."

In summary. Quantitative data indicate that, in general, students in schools that participate in our project-based learning partnership program are excelling in mathematics relative to comparison schools. Moreover, students have shown improvement on content-based math/science assessments administered pre/post program. While these are encouraging results, the extent to which exposure to the project-based learning program has influenced student improvement is unclear, simply due to the nature of student growth, maturation, and learning over the course of their participation.

Qualitative data and anecdotal evidence suggest that students have responded positively to their experiences with the program, in terms of engaging students in the classroom during project based learning activities, increasing their interest levels in STEM subjects, and – according to teacher comments – improving their self confidence and ability to see the whole of science and the connections between science, mathematics and technology.

Conclusions

The assessment results to date show that the use of project-based learning and real-world problems can be an effective means for engaging students in middle and high school classrooms. Students respond well to the active, hands-on problem solving curricula, the connections drawn to their own lives, and the integration of science, mathematics and technology subjects as applied to the solution of a real-world problem. The topics of environment and energy are particularly valuable, because they connect to a wide variety of educational themes and are particularly relevant to the students' everyday experiences. Although results are difficult to quantify, evidence suggests that the experience described in this report has enhanced student interest and confidence in STEM subjects, and has potential for improving student competency levels.

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