Improvements in Student Achievement and Science Process Skills Using Environmental Health Science Problem-Based Learning Curricula

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Abstract

Project EXCITE, a seven-year federally funded teacher professional development program prepared middle grade teachers to design and implement integrative, problem-based, environmental health curricula with over 1600 students. This article examines how this program, through the developed and implemented curricula, impacted both state-based, proficiency test scores and process skills test scores. Analyses of proficiency and performance scores indicate positive effects for both measures, offering educators further support for the use of integrative problem-based environmental health science curricula.

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Introduction

The Environmental Health Science Context for Learning

In 1998 the State Education and Environmental Roundtable (SEER) report (Lieberman & Hoody, 1998) described how using the environment as a context for learning broadly impacts student achievement. Since then, others have described the same effect and advocated the expanded use of environmental topics in schools. A study by the National Environmental Education and Training Foundation (Glenn, 2000) reported that environmentally based education:

- Improved reading and math scores
- Improved performance in science and social studies
- Developed student abilities to transfer knowledge to new contexts
- Enabled students to "do science" rather than just "learn about science"
- Decreased classroom discipline problems and
- Provided all students with the opportunity to learn at a higher level.

Environmental *Health* Science (EHS) explicitly links environmental conditions to personal and public health. This emphasis can enhance student engagement and topic relevancy even beyond what can be achieved with ecologically linked environmental science. The indoor and residential environments in urban, rural, and suburban settings, provide near-at-hand opportunities for EHS explorations whereas these same settings may not have diverse and accessible outdoor environments to explore. In recognition of this, the National Institute of Environmental Health Science funded programs for the development of school-based environmental health instructional materials, teacher enhancement and development, and most recently, the Environmental Health Science as an Integrating Context (EHSIC) program aimed at combining effective EHS instructional materials with high quality professional development and classroom implementation.

Project EXCITE (**E**nvironmental health science e**X**plorations through **C**ross-disciplinary and **I**nvestigative **T**eam **E**xperiences) was one of the EHSIC grant programs. The EHSIC goals included: developing EHS curricula, deepening student learning outcomes and motivation to learn across the disciplines using EHS as an integrative context, facilitating teacher development of best practices, and fostering student awareness of EHS as both a viable career opportunity and as an essential understanding needed for socially responsible citizenship. One specific set of goals for students included: enhancement of critical thinking skills, increased competence in identifying problems, ability to assemble relevant data, improved solution building, development of inquiry process skills and better performance on standardized tests.

Project EXCITE met these program goals by working with three cohorts of teachers over a two year period (over 160 contact hours for each cohort member) to develop and implement multidisciplinary, problem-based learning (PBL) units addressing locally pertinent EHS issues in the middle grades (4th – 9th). These PBL units, called Odysseys, span topics such as:

- indoor air quality in schools
- a proposed natural gas electric generation facility in a rural village
- the safety of household chemicals
- community and environmental impacts of school construction projects
- pest management practices in a rural village
- the spread of communicable diseases in schools
- water quality and distribution in small and middle size cities and
- food health and safety in a school cafeteria.

The EXCITE-brand of PBL provides rich opportunities for students to develop critical thinking, problem solving, and service learning through a four phase Odyssey experience: *Meet the Problem, Inquiry and Investigation, Build Solutions, and Take Action* (see Figure 1). During the *Meet the Problem* phase, students are presented with a semi-structured and developmentally appropriate local problem to investigate. After the students have outlined what they currently know and what they need to know about the problem, they identify possible resources for learning and generate a beginning hypothesis (an inference regarding the nature of the problem). Students then devise a plan to guide them through the next learning phase, *Inquiry and Investigation*. In this phase, students design and conduct tests to find answers to research questions and use process skills (observation, inference, measuring, data collection and organization, data analysis, data presentation and discussion, among others). Students revisit the problem by sharing findings from others, revise their original ideas/hypotheses, and summarize what they now understand to be true. When students have unraveled the problem and have constructed deeper understandings of the related content they *Build Solutions*. They then use critical thinking skills to weigh the positive and negative outcomes associated with each possible solution in order to establish a best-fit solution. After students decide upon a best-fit solution, they develop a plan to *Take Action*, thus encouraging active citizenship and social responsibility. Action projects consist of creating informational products to communicate their newly constructed knowledge, designing and constructing models or prototypes, developing action-oriented projects, or organizing a program or event. During this final phase, service learning is actuated, as students apply newly acquired knowledge, skills and dispositions outside the classroom to better society. Student reflection is emphasized throughout the Odyssey as students are given frequent opportunities to respond to questions in a daily reflection log.

All of the EXCITE Odysseys are interdisciplinary. They promote both deeper understandings of content and the acquisition of skills related to science, mathematics, language arts, social sciences and health. Because they are framed by real problems that face real people, they provide opportunities for students to examine, discuss, and clarify the ethical issues related to the problem at hand. Each EXCITE Odyssey is framed by national and state educational standards spanning across the curriculum.

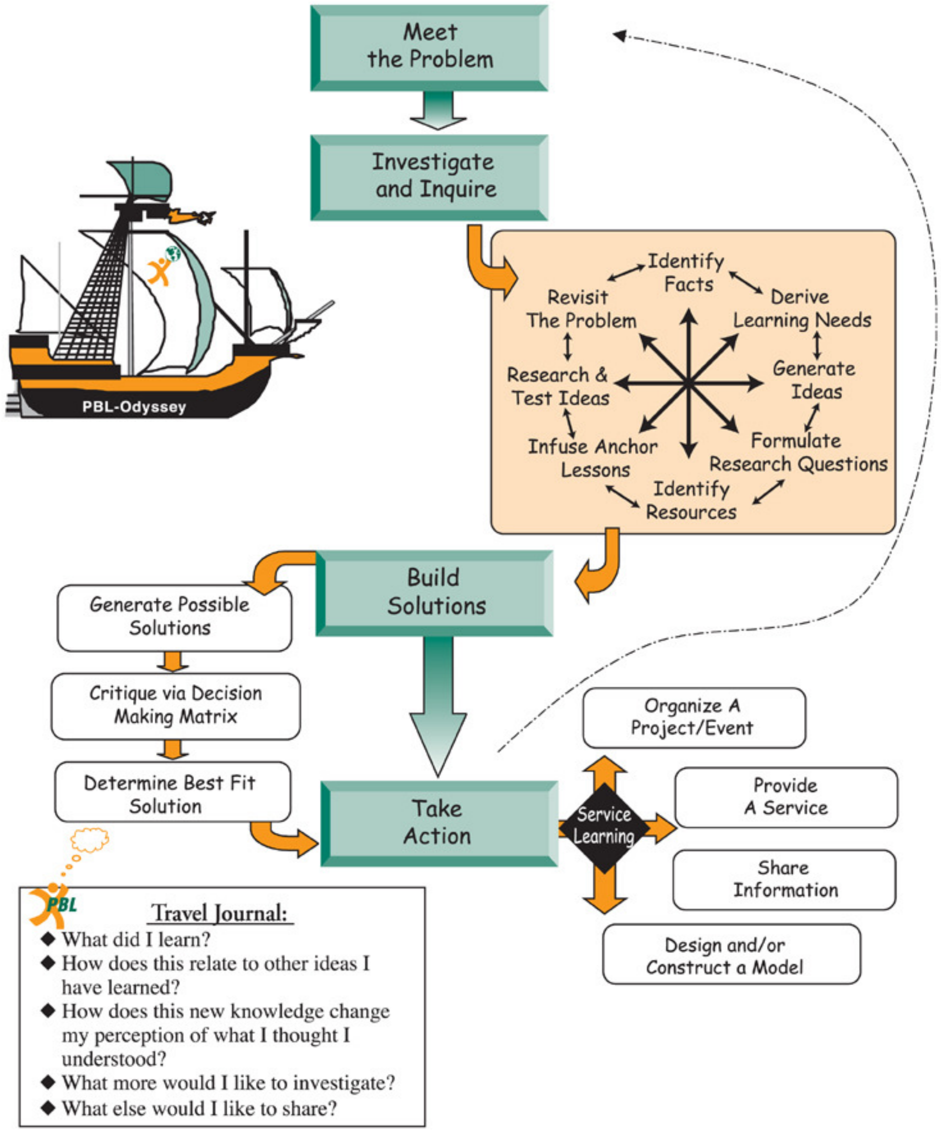

Figure 1. Project EXCITE PBL Odyssey Model

Science Process Skills

Science process skills are inseparable from the practice of science and play a key role in both formal and informal learning of science content. Padilla's (1990) essay defined these skills as "transferable abilities, appropriate to many science disciplines, and reflective of the behavior of scientists." He re-emphasized that science processing includes both basic and integrated skills. Basic processing involves: observing, inferring, measuring, communicating, classifying, and predicting. Integrated science process skills require controlling variables, defining terms operationally, formulating hypotheses, interpreting data, experimenting, and formulating models. Both basic and integrated skills are needed to be scientifically literate. Science process skills are not only important for those pursuing careers in science, but most jobs in this new millennium involve using these skills (Rillero, 1998). While an exhaustive knowledge of science content is impossible, mastery of science process skills enables students to understand, at a much deeper level, the content they do know and equips them for acquiring content knowledge in the future. Assessing process skills is not as common as assessing content knowledge, but it can be done (Harlen, 1999).

Driven by the pressure of performance on high-stakes testing, many science curricula unfortunately often over emphasize content knowledge. But just as a quality literacy program equips children with the basic tools of reading literacy: code breaking, text use, participation in the text and analysis of text, science literacy should also provide the tools required for all forms of scientific knowing (Colvill & Pattie, 2002). Moreover, it is believed that content knowledge is acquired more efficiently and understood at a deeper level when obtained via inquiry using the fundamental tools of science, the process skills (National Research Council, 1996). Not only do science process skills improve science content knowledge, but they also improve language arts and mathematics skills (Ostlund, 1998) (Lieberman & Hoody, 1998).

So a challenge exists. Students need improved science process skills for their long-term academic and personal success. At the same time, given the current policy climate, performance on high-stakes tests should not be jeopardized. Meeting this challenge is one goal of Project EXCITE. The EXCITE Odyssey four-phase PBL model provides frequent opportunities for students to develop both the basic and integrated process skills using environmental health as a context for learning. These same basic and integrated skills are found in middle grades science state and national science standards.

Research Questions

Our first research question was whether student participation in a time-intensive interdisciplinary curriculum such as Project EXCITE produces a measurable difference in state achievement (proficiency) test scores. This question was driven by both the goals of EHSIC and the perception among teachers and administrators that innovative curricula like Project EXCITE jeopardize student preparation for these standardized tests. Our hypothesis was that dedicating instructional time to EXCITE, which is not "test-driven" but is standards-aligned, would not negatively affect proficiency test scores when compared to similar, non-EXCITE schools and in fact might increase scores due to the interdisciplinary approaches of EXCITE resulting in better (deeper and transferable) subject learning.

Our second, research question was whether participation in Project EXCITE improved students' science process skills. This question was examined for differences among demographic variables including: gender, student performance level, and school. Our hypothesis was that the inquiry based EXCITE approach would indeed improve science process skills.

Methods

Treatment

Participating students were in classes taught by teachers that have undergone professional development though Project EXCITE. These teachers participate in Project EXCITE as a multidisciplinary team and undergo over 160 hours of professional development over a two-year period. This professional development includes two summer institutes and academic year meetings. Teachers are trained in: problem-based learning (PBL), the design and development of PBL units, core concepts and processes of environmental health science, approaches to inquiry learning, strategies to assess PBL, and classroom management techniques needed for conducting PBL units.

All EXCITE students first participate in the ZoOdyssey, an introduction to PBL and EHS in the form of a simulated investigation into an illness outbreak following a trip to the zoo. This Odyssey was developed by EXCITE faculty and staff and aims at teaching the process of PBL (described earlier) over three to five hours of instruction. Following ZoOdyssey, the students go through the Odyssey developed by their teachers focusing on a local EHS issue. The local Odysseys units were implemented over a period from one to four weeks (30 – 90 hours of instructional time). The mode of delivery varied based on instructional decisions about implementation made by the participating teachers. Some schools devoted multiple class periods a day to the unit over a period of one or two weeks. Other schools experienced their Odysseys a few class periods a week over a longer period of time. However all Odysseys incorporated strict adherence to the four-phase EXCITE model.

Participating Schools

Interdisciplinary teacher teams from twelve EXCITE schools have been through the complete two–year professional development and Odyssey implementation cycle of Project EXCITE. Six schools participated from 2001 – 2003 as “Cohort 1” and six schools participated from 2003 – 2005 as “Cohort 2”. All 12 of these schools represented separate school districts. The schools represented a wide diversity in demographics. Table I summarizes information about the EXCITE schools.

Two non-EXCITE middle schools, DON and GLN in the same district as an EXCITE school (FIN) were used as control groups for proficiency test analysis. Six non-EXCITE classrooms identified as MAU and SMS were used as control groups for science process skills testing. These classrooms were in the same school building as EXCITE teams, MGW and SRG respectively. But were used as controls in years subsequent to EXCITE being implemented in those schools and with teachers who had not participated in the EXCITE program. The demographics for the proficiency testing and process skill control groups are also included in Table I. Ethnic and economic data were obtained from state department of education reports. Economically disadvantaged status is based on eligibility for free or reduced cost lunches.

Table I
Demographic Data for Participating Schools

School	Cohort	Public or Parochial	Participating Grade Level	School Grade Levels	School Population	% Non-White	% Economically Disadvantaged
BGR	1	Public	8	7-8	500	11.5	15.6
MGW	1	Public	7	6-8	700	9.0	N/A
SRG	1	Public	6,8	6-8	890	21.0	21.8
ATW	1	Public	7	7-8	590	3.4	N/A
RSF	1	Public	8	7-8	330	6.7	32.3
YNG	1	Public	4,5	K-5	760	44.5	80.7
ARC	2	Public	7	K-12	620	3.8	18.1
LBC	2	Public	6	5-8	400	5.0	18.4
NBL	2	Public	7,8	7,8	130	3.9	15.0
SPX	2	Parochial	5,6	K-8	240	N/A	N/A
FOS	2	Public	8	6-8	490	33.1	59.0
FIN	2	Public	6	6-8	490	16.2	27.7
DON	Prof-C	Public	6	6-8	460	6.5	27.1
GLN	Prof-C	Public	6	6-8	440	15.1	41.2
MAU	POPS-C	Public	7	6-8	670	10.5	13.3
SMS	POPS-C	Public	6,8	6-8	950	24.1	26.0

N/A: Not available
Prof-C: control group for proficiency test comparisons
POPS-C: control group for science process skills test comparisons

Proficiency Testing

In Ohio students are tested on their proficiency in reading, writing, math, citizenship and science. In each subject area student proficiency levels are classified as "advanced", "proficient", "basic" or "below basic". "Advanced" and "proficient" are considered passing levels. Obtaining student or even classroom specific proficiency test data was extremely difficult. Many schools were unable to access and provide the needed test data and information in the format needed. Privacy laws prevented the schools from providing student-level data without coding the information first and schools refused to allow us to code the data as needed. Some schools were able to provide partial information. Results for an entire grade level were available on the state department website for each school, but in most cases an entire grade level did not participate in Project EXCITE during the same year proficiency tests were given. However, in one EXCITE school (FIN) an entire 6th grade level participated in Project EXCITE before they took the proficiency test that year. This school was in a district with two other middle schools (DON and GLN) that had no exposure to Project EXCITE. The percentage of students passing the five subject areas and the percentage of students scoring "below basic" was compared for the year immediately prior to FIN beginning Project EXCITE (2003) and after their second year in the project (2005). Results from 2005 were considered because at that point FIN teachers had experienced the full professional development program and developed experience with both PBL and EHS.

Science Process Skills Evaluation Instrument

Students' scientific process skills were evaluated using the 21 question Performance of Process Skills test (POPS) (Mattheis & Nakayama, 1988). This is an instrument developed to evaluate integrated science process skills such as: experimental design, use of variables, and data presentation and interpretation. The POPS was previously tested for validity and had a total test reliability of 0.75 using the Kuder-Richardson formula 20 for this study.

EXCITE students took the POPS test before participating in the ZoOdyssey. Following the local Odyssey, EXCITE students took the POPS test again. Time between the pre- and post-test ranged from 3 to 29 weeks depending on when the ZoOdyssey and local Odysseys were implemented during the school year. Ten weeks was the median interval. Valid pre- and post-test scores were available for over 1600 students.

In the control groups the POPS test was given three times to look for changes in science process skills due to standard instruction and changes that might occur by simple maturation. The period between the first and second test was a period with "normal", non-EXCITE instruction that ended shortly before the winter holiday break. The interval between the second and third tests began before the winter holiday and concluded a few weeks after the winter holiday. This interval represented a period of time with more "limited" non-EXCITE instruction due to the wind down before break, the break itself, and the gearing up after break. This period was intended to see if maturation of the students over a period of weeks might account for any gains in science process skills seen in the treatment groups. The length of the non-EXCITE normal instruction interval, ranged from 4 to 6 weeks. The period of limited instruction, was 5 or 6 weeks. Overall the span of time between the initial and final POPS test administration for the control group ranged from 9 to 12 weeks which brackets the median pre/post test interval (10 weeks) for the treatment groups. Three valid and reliable tests were administered and data were collected for over 100 non-EXCITE students (see Figure 2).

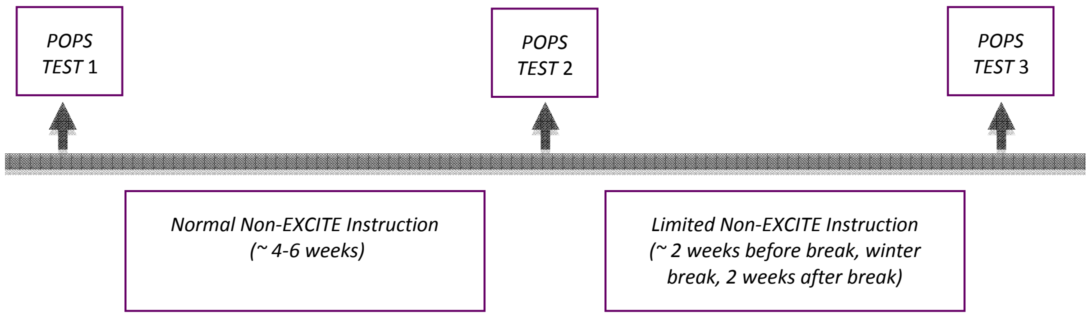

Figure 2. Control Group Testing Periods for POPS

POPS Data Analysis

Matched pair one-tailed t-tests were completed to test for an increase in POPS scores. Though data is interval (number correct), the range is wide enough (0-21) that if a normal distribution of scores is exhibited, parametric tests can be done.

Students with scores lower than 4 on either the pre or post-test were eliminated from the analysis (i.e. on several answer sheets there was evidence that there was not a genuine effort to complete the test and were described as non-efforts). These represented 3.1% (52 out of 1661) of the EXCITE students who completed both pre and posttests. No student scored less than 4 on both pre and posttest. The non-effort rates across the twelve schools were non-normally distributed. The pre test non-effort rate averaged 1.3% (range: 0% - 5.9%) with a median of 0.7% and a 95% confidence interval on the median of 0% - 4.8%. The post test non-effort rate averaged 1.5% (range: 0% - 5.6%) with a median of 0% and a 95% confidence interval on the median of 0% - 4.3%. The POPS control groups non-effort rates was not statistically different than the EXCITE group.

The comparisons were completed for various groupings of students. These groupings were:

- All EXCITE students
- All EXCITE students by gender
- Each school
- By pretest performance level (quartiles)

Results and Discussion

Proficiency scores

The proficiency test performance analysis is for the one EXCITE school (FIN) in which an entire grade level (6^{th} grade) of students participated in Project EXCITE during a year the proficiency test was given. This school also completed their EXCITE Odyssey prior to taking the proficiency test. Proficiency test scores for two schools in the same district were used for comparisons. This was to see whether the school that dedicated the time to the EXCITE curriculum did at least as well as the non-EXCITE schools and did not suffer from their participation.

The changes in pass rates from the year immediately before Project EXCITE to the results after two years of Project EXCITE are presented in Table II. Also presented is the standard deviation of the pass rates in each subject area for the 5 years prior to EXCITE. Though the sample size, 5 years, is too small to make full use of parametric statistics, the standard deviation is presented as a measure of typical year-to-year variability.

Table II
Change in Pass Rates from 2003 – 2005

	Subject Area (change, standard deviation)				
School	Reading	Writing	Math	Citizenship	Science
FIN	+10.5 (5.5)	+3.8 (3.3)	+13.3 (6.1)	+10.4 (4.4)	+2.2 (5.1)
DON	-2.8 (8.0)	-3.5 (4.8)	+12.5 (6.3)	+2.8 (3.6)	+1.5 (8.4)
GLN	+19.3 (6.2)	-3.2 (8.3)	+4.1 (13.9)	+11.1 (6.6)	+9.9 (12.4)

After the two years in which FIN participated in EXCITE, pass rates were higher in all subject areas than the year immediately prior to beginning EXCITE. For reading, writing, math and citizenship (four of the five subject areas), the increase was greater than the annual variability for the preceding five years as measured by the standard deviation.

Over the same period DON had decreased pass rates in two subjects and increased pass rates in three subjects. Only the increase in the math pass rate was larger than the annual variation as measure by the standard deviation (one of five subject areas). GLN had pass rate increases in reading, math, citizenship and science. The increase in pass rates in reading and citizenship were greater than the measure of annual variability (two of five subject areas).

Qualitative observations as well as the science process performance results presented later in this paper suggest that "lower performing" students may benefit more from participation in Project EXCITE. This may be due to the non-traditional problem-based approach to learning or the use of "real-world" environmental health contexts, or a combination of both. For this reason we looked for changes in the number of students in the "below proficient" results category. Table III presents the change in the percentage of students scoring "below proficient" along with the standard deviation in the percentage of students in that category in the previous five years. A negative value indicates a decrease in the number of "below proficient" students, the desired result.

Table III
Change in Percentage of Students Scoring "Below Proficient"

	Subject Area (change, standard deviation)				
School	Reading	Writing	Math	Citizenship	Science
FIN	-10.2 (3.2)	-2.0 (1.8)	-10.4 (5.2)	-12.4 (4.9)	-1.9 (2.9)
DON	+0.4 (2.9)	+5.6 (3.9)	-5.6 (4.9)	-0.3 (4.0)	+1 (5.2)
GLN	-6.7 (4.7)	+1.7 (6.6)	+0.0 (11.2)	-7.7 (5.9)	-4.7 (10.9)

After two years of EXCITE participation, a smaller percentage of FIN students performed at a "below proficient" level in all subjects compared to the year immediately prior EXCITE. For reading, writing, math and citizenship the change was greater than the standard deviation of the percentage of students at that level over the preceding five years.

Over the same period, DON had a smaller percentage "below proficient" students in math and citizenship. This difference was greater than the measure of annual variability for math. DON had a larger percentage of "below proficient" students in reading, writing, and science. The difference was greater than the measure of annual variability for writing. GLN had a smaller percentage "below proficient" students in reading, citizenship and science. This difference was greater than the measure of annual variability for both reading and citizenship. GLN had a larger percentage of "below proficient" students in writing and no change in math.

To summarize, the EXCITE school (FIN) had increases in pass rates greater than the standard deviation in four out of the five subject areas while GLN showed similar increases in only two areas and DON in one. Similarly FIN had students move above the "below proficient" category at rates greater than the standard deviation in four out of the five subject areas while GLN showed improvements greater than the standard deviation in only two areas and DON in one.

State proficiency performance appears to be enhanced during the periods of EXCITE implementation. Though the sample size (only 5 years of data before EXCITE) precludes formal statistical testing, this data suggests that participation in Project EXCITE did not negatively affect standardized test pass rates and may in fact have improved pass rates and decreased the percentage of students at a "below proficient" level. Notably, the only sustained teacher professional development across the district during these years was Project EXCITE in the FIN school. Therefore, it is plausible to attribute this success to the EXCITE program and not some other professional development program or district initiative.

A primary goal of the NIEHS EHSIC program was to enhance student achievement in all subject areas using EHS as an integrative context for learning. Although additional data was not available to make greater use of inferential statistics (requiring teacher and/or student level data), the overall evidence suggests that for the FIN EXCITE students, proficiency performance during the years of EXCITE was improved across subject areas compared to years prior to EXCITE.

Keeping in mind that the average Odyssey implementation period was roughly 2 weeks (or 60 total hours of instructional time across disciplines), these gains become even more notable. Ironically, when interviewed and/or surveyed, many EXCITE teachers felt that although the EXCITE Odyssey experience was motivational for students and evoked deep understanding of local EHS problems, they felt uncomfortable spending so much time on a unit not perceived to be directly supporting test preparation. The majority of EXCITE teachers conveyed that they would continue to use EXCITE Odysseys/PBL in the future, but would need to limit the amount of time spent on the unit to leave time for test preparation. Furthermore, many teachers worried that although they believed students were developing critical thinking and higher order skills, and although they knew first hand that these curricular materials were standards-aligned, they were concerned that the Odyssey experience may not foster student achievement on the state tests.

It should also be noted that the science proficiency test scores did not notably improve in the FIN EXCITE school. At the time of testing, only a small fraction of this test measured process skills (under a broader category of the nature of science). Since then, a new achievement test is in place in Ohio aimed at increasing the emphasis on assessing scientific processing skills. For this very reason, the POPS test was also administered, as a more direct and valid measure of the impact of the primary goals of Project EXCITE.

Scientific Process Skills

Scientific process skills improvement was assessed using the POPS test. Table IV summarizes the changes in POPS test scores for all students that had valid pre and post tests. Significance of change was determined by matched pair t-test. These data were further analyzed based on their pre-test performance (quartile) and by gender. The sample size was smaller for the gender specific analysis because gender data was not provided for some of the students. A one-way ANOVA analysis shows that the gains were not different based on gender (p = 0.11).

Table IV
Change in POPS Test Performance for EXCITE Students

Group	Pre-test Quartile	Pre-test average	Post-test average	Average gain	p	n
All students	All	13.1	13.9	0.6	<0.001	1609
	1st	7.2	9.2	2.0	<0.001	367
	2nd	11.6	13.0	1.4	<0.001	445
	3rd	15.1	15.7	0.6	<0.001	392
	4th	18.3	16.4	-1.9	<0.001	405
Males	All	13.6	14.2	0.6	<0.001	588
	1st	6.4	9.2	2.8	<0.001	123
	2nd	10.4	12.0	1.6	<0.001	170
	3rd	14.0	15.1	1.1	<0.001	129
	4th	17.7	16.9	-0.8	0.002	166
Females	All	13.4	14.2	1.0	<0.001	612
	1st	7.7	9.6	1.9	<0.001	154
	2nd	12.0	13.2	1.2	<0.001	134
	3rd	15.2	15.6	0.4	0.041	165
	4th	18.3	17.9	-0.4	0.048	159

Table IV presents aggregate data for all EXCITE students in both cohorts. The same pattern of greater improvement in lower quartiles can also be seen when considered by cohort, year and school.

When analyzed by cohort, the Cohort 2 (2003 – 2005) students exhibited a greater average gain in POPS test scores, +1.1 compared to Cohort 1 (2001 – 2003) students who had an average gain of +0.5. ANOVA revealed that this difference was statistically significant (p <0.001). This may be due to the overall maturation of the EXCITE program. The project staff initially assumed that participating teachers did not need us to overemphasize how to do inquiry. During the first cohort training period, we spent more time deepening teacher EHS content knowledge and helping teachers with teaming structures and interdisciplinary planning. However, the POPS scores posted by Cohort 1 students and feedback from the teachers provided us with valuable information that we used as we refined our program. During teacher professional development, we subsequently spent a significant amount of time having EXCITE teachers participate as learners in designing and enacting controlled investigations and other inquiry and research methodologies. We also created anchor lessons that teachers could use with their students aimed at developing needed process-oriented inquiry skills such as graphing, controlling variables, planning research and communicating findings.

Within each cohort there was no statistical difference in the gain in POPS tests scores between students participating in the first year and students participating during the second year. In general, there was no statistical difference in the magnitude of the increase in POPS tests scores between the EXCITE schools. The average increase at SPX, however, (+1.7) was statistically greater than the increases in other schools in that cohort, BGR (+0.4), SRG (+0.4), ATW (+0.5) and FOS (+0.5).

The magnitude of the increase in average scores and the degree of statistical significance is highest for students that performed in the lowest (first) quartile on the pretest. The difference in scores by quartile is statistically significance for all quartiles. The statistically significant decrease in the scores for students performing in the top quartile on the pre-test is likely due to a ceiling effect of a 21 question test instrument.

The question remained whether the increase in POPS scores could have been: a) a result of simple maturation of the students or b) achieved with typical, non-EHS non-PBL instruction. In order to claim an “EXCITE effect”, we aimed to rule out these alternative explanations to the increased scores. We looked at the first question using an internal control group and at both questions using an external control group.

At one EXCITE school (NBL) some of the students who participated in EXCITE as 7th graders also had the same teachers in 8th grade and participated in EXCITE a second year. These students had demonstrated a statistically significant increase in POPS tests scores administered before and after EXCITE during the school year. The next year they took the POPS test again as a pre-test for their 8th grade participation. If maturation, the time over summer break, affected student’s scientific process skills, improved POPS scores at the beginning of 8th grade might be expected. There was no statistically significant increase in their POPS scores. This suggests that simple maturation does not contribute to improved science process skills as measured by the POPS test.

We also recruited six non-EXCITE classrooms from two schools to explore these alternative explanations of increased process skills test scores. Non-EXCITE control group classrooms took a POPS pre-test and then two follow-up tests, one after a period of normal instruction and then again after a holiday period with limited instruction, but also large periods of vacation. Table V presents data on significant changes in test scores between administrations of the POPS test to the control groups. There is little significant positive change in average POPS test scores in the control group. Notably, the lowest quartile of pre-test performers showed no significant change at all. This same group in the EXCITE schools exhibited the greatest gains in POPS test scores. The significant increase from test 1 to test 3 that was observed in MAU was driven by the performance of one quartile. Further analysis showed that it was the performance of the second quartile students from a single classroom driving the significance of the increase.

Table V
Change in Average POPS Test Score for Control Group Students.

	1	2	3	Δ 1 - 2	Δ 2 - 3	Δ 1 - 3	n
All	15.4	15.9	15.7	+0.5*	-0.2	+0.3	102
1st	9.8	10.2	10.2	+0.4	+0.0	+0.4	22
2nd	13.6	14.6	14.6	+1.0	+0.0	+1.0	28
3rd	17.8	18.2	18.0	+0.4	-0.2	+0.2	29
4th	20.0	20.0	19.4	+0.0	-0.6*	-0.6*	23

*: significant at $\alpha = 0.05$

Student science process skills, as measured by the POPS test, appear to be enhanced through participation in Project EXCITE Odysseys. As shown in Table IV, the EXCITE schools made regular improvements in process skills scores. These improvements are most notable at the lowest quartile students, yet are statistically significant for the entire group. Moreover, improvements were found in both male and female students. Table V shows that in non-EXCITE schools process skills do not appear to be developed by "normal" instruction (test 1 – test 2 timeframe) or maturation alone as examined during "limited" instruction (test 2 – 3 timeframe). POPS scores for the control groups remained stable (or sometimes decreased) at periods of time with normal instruction, limited instruction and/or extended breaks from instruction.

It is makes sense that Project EXCITE Odysseys promote student attainment of these process skills. The EXCITE PBL model infuses inquiry-based instruction throughout the Odyssey experience. When students first meet the problem, they are required to access and organize available information as they identify relevant facts, derive related learning needs and make initial hypotheses and assumptions. They use process skills throughout the inquiry and investigation phase of the Odyssey experience, as they use the inquiry process to gather additional information and data needed to better understand the problem. During the solution-building phase, students again use process skills to analyze solutions in light of the strengths and weaknesses of each solution and ultimately generate a best-fit solution based on their analysis. Finally, students synthesize the newly constructed knowledge to both plan and enact a community-based action project to improve upon the problem. Again, the entire Odyssey experience averages two weeks or 60 total instructional hours, yet even in this limited time period, science process skill improvement was possible.

Implications

This study examined two research questions: whether participation in a time intensive interdisciplinary curriculum such as Project EXCITE produces measurable differences in state achievement (proficiency) test scores and whether participation in Project EXCITE improved students' science process skills. Data indicate that both were enhanced during the EXCITE Odyssey experience.

We believe this data offers further justification for using PBL and EHS as an integrative context for learning. Proficiency gains were noted across subject areas. As such, we believe that the inquiry skills infused throughout the PBL Odyssey experience enhanced the EXCITE learners' data organization, data analysis, and written communication skills and these skills were measured by the state proficiency tests in mathematics and writing. Similarly, EXCITE learners repeatedly designed procedures, controlled variables, and organized and interpreted data, as documented by the increase on the POPS test that measures these skills. However, only modest gains on the state proficiency test appear for science. This implies that state science proficiency improvement may not correlate well with science process skills performance. This appears to be the case for FIN students who made similar significant gains as other EXCITE students on the POPS test, but posted only modest gains in science proficiency test scores during the EXCITE experience.

Teachers perceive that the state science proficiency test is content-oriented and are concerned that spending time on the EXCITE Odyssey experience would not be justifiable. Considering that students improved their process skills performances, but only showed modest gains in their science proficiency test scores, there may be some truth to this thinking for science proficiency testing at least. It is our hope that the newly revised Ohio state achievement tests will more equally balance science content and science processes, so that students who are gaining process skills will also post similar improvements on the state science achievement tests. Given that process skills were not effectively assessed on the Ohio 6th grade state proficiency test, we were unable to document improvements in middle grade students' overall scientific literacy. In relationship to the evaluation of innovative curriculum, such as Project EXCITE Odysseys, state achievement test scores often only measure a fraction of the knowledge gained by the students as a result of the curricula. We believe this is one very good justification for the use multiple assessments when examining the impact of an inquiry-based professional development project on student achievement.

Given the positive impacts found in this study, we advocate that a problem-based interdisciplinary EHS curriculum lasting longer than 2 weeks or 60 contact hours would further develop student achievement and scientific process skills. Additional investigation regarding the relationship between length of implementation and impact on student learning is therefore warranted. We believe that as more data are available documenting the positive and significant impact of integrative and problem-based learning, it is imperative that we clearly and swiftly communicate this relationship within educational communities so that teachers will know that these innovative ways of teaching and learning can help them succeed and survive in an accountability driven era. More data-driven studies examining student performance on both state achievement tests and other valid and reliable assessment measures, like the POPS test, are needed to help make the case for a problem-based, EHS curriculum. We hope this investigation provides significant contributions in doing so.

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