

Enhancing Teachers' Beliefs and Practices Through Problem-Based Learning Focused on Pertinent Issues of Environmental Health Science

Jodi J. Haney, Jing Wang, Chris Keil, and Jennifer Zoffel

ABSTRACT: The authors examined teachers' beliefs and classroom practices during a 2-year professional development program that required middle-school teachers to develop, implement, and revise problem-based, interdisciplinary curricula focusing on locally relevant environmental health issues. The results of the study indicate that over the course of the program, teachers' self-efficacy, beliefs about the classroom learning environment, and reported use of reform-based classroom practices increased significantly. The results also indicate that teachers' beliefs about the likelihood of support from the school environment declined significantly, and their outcome expectancy beliefs did not change significantly. The authors offer related data showing the impact of the program on other teacher and student outcomes and advocate for the use of problem-based learning curricula that use local environmental health science issues as an integrative context.

KEYWORDS: environmental health, integrated curricula, problem-based learning, teacher beliefs

The National Institute of Environmental Health Sciences (NIEHS), through its Division of Extramural Research, has funded science education projects since 1993. NIEHS's most recent programs (2000–2007), nine Environmental Health Science as an Integrative Context (EHSIC) projects, enabled investigators to examine the effects on teaching practices and student performances of using curricular materials that integrated environmental health science (EHS) into other academic disciplines.

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The results of a growing body of research on the effectiveness of an integrated, team-taught, environmental education (EE) approach to teaching and learning influenced the staff at NIEHS to develop and promote integrated EHS materials. Lieberman and Hoody (1998) reported that students immersed in integrated EE curricula performed as well or better on achievement tests than did students experiencing traditional separate-subject curricula. They also found that students using the integrated curricula had better attendance, fewer disciplinary problems, and enhanced motivation. The results of another study (Lewis & Shaha, 2003) indicated that an integrated curriculum was superior to other curricula in improving student achievement and attitudes about learning. Boyer and Bishop (2004) reported that interdisciplinary, multiyear teaming resulted in enhancing students' personal growth, including confidence, independence, tolerance, leadership, collaborative skills, and sense of belonging. Focusing on the effects on teachers, Warren and Payne (1997) found that an integrated teaming experience increased teacher efficacy and beliefs about the teaching environment. Vars (2001) concluded that several philosophical, sociological, and psychological benefits resulted from using an integrated curriculum. Bailey (2003) reported that through the use of integrated curricula, middle school students could meet academic standards without sacrificing academic quality. Despite these positive results about the use of an integrated EE curriculum, most teachers were unaware of EHS as a viable option for an EE curricular approach (Morrone, 2001).

Project EXCITE,¹ one of the nine new EHSIC projects funded by NIEHS, was a 2-year professional development program during which teams of middle school teachers examined, designed, developed, and field-tested interdisciplinary, problem-based learning curricula that focused on relevant local EHS issues, such as the indoor air quality of their school building, large-scale agricultural farming practices, the impact of urbanization on human health, pesticide spraying, or the safety of household cleaner use. EHS curricula explicitly linked environmental conditions to personal and public health. The EXCITE project team developed an EHS system that conceptualizes the intended EHS learning outcomes (see Figure 1). Six teams consisting of four or more classroom teachers from a variety of disciplines, university preservice teachers, and building administrators worked together for 2 years. Team members attended EXCITE summer institutes and monthly meetings during the academic year, in which they focused on developing EHS concepts and promoting the use of problem-based learning strategies, inquiry teaching, and other research-based best practices, including cooperative learning, performance-based assessment, teaching for critical thinking and conceptual understanding, and interdisciplinary learning. During the 2-year period, EXCITE teachers networked and actively collaborated with one another and with relevant community agencies, local scientists, and university environmental health and education faculty. For this work, each teacher received more than 160 hrs of professional development credit applied toward graduate study.

We investigated the changes in EXCITE teachers' beliefs (context, efficacy, and classroom learning environment) and the reported frequency of use of reform-based best practices during their participation in the project. Our research had one limitation: Because the EXCITE model encompassed many research-based best practices, we cannot attribute the effects of the project on teacher beliefs and practices to any single best practice but, rather, to the synergy created by the integrative context of the model.

Method

Sample

Our sample comprised 18 sixth-, seventh-, and eighth-grade teachers (8 science teachers and 10 nonscience teachers) who were part of one of three teams organized in northwest Ohio during the 7-year project. Fourteen of the 18 teachers were women, and 4 were men; 8 teachers taught science, and 10 taught other subjects, including language arts, social studies, mathematics, health, and special education. Their teaching experience varied from 3 to 29 years. The teachers represented three

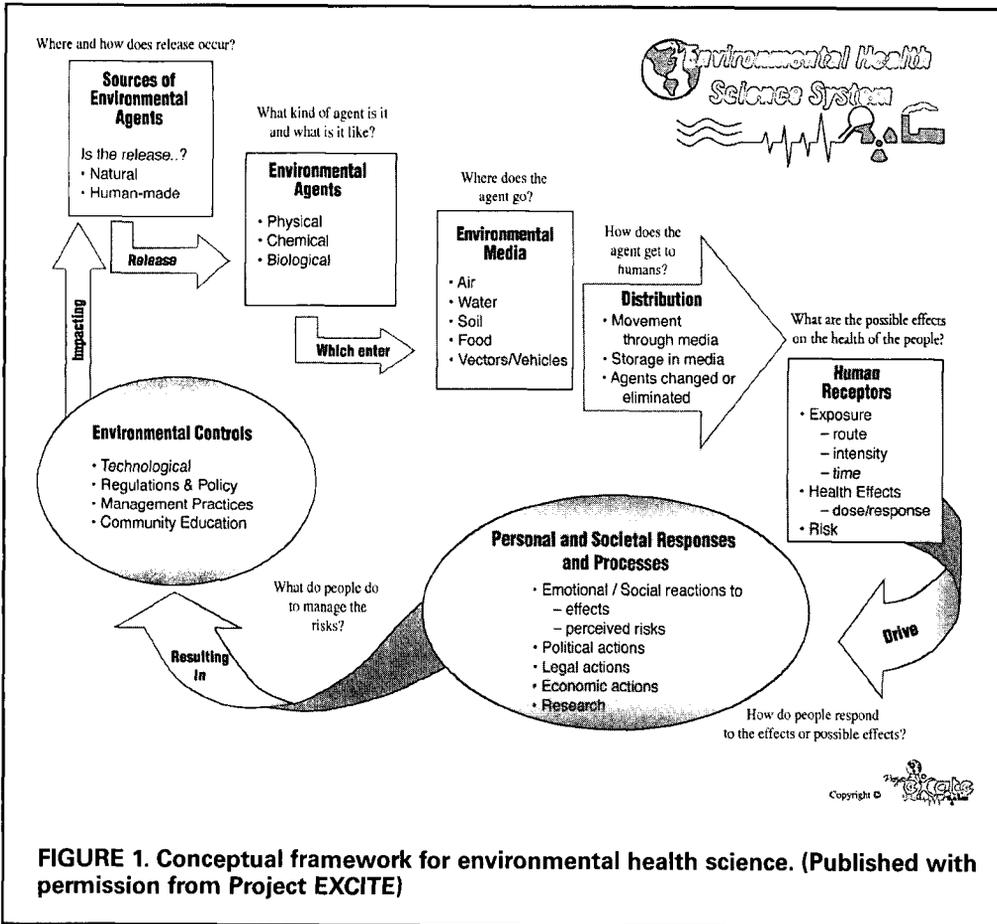


FIGURE 1. Conceptual framework for environmental health science. (Published with permission from Project EXCITE)

urban schools and three rural schools. One school was a parochial school, and the remaining five were public schools.

Measures

To measure context beliefs about the teaching environment, we used the Context Beliefs About Teaching Science Instrument (CBATS; Lumpe, Haney, & Czerniak, 2000), modified to focus on EHSIC rather than science teaching environment. CBATS consists of 26 contextual factors that measure *enable beliefs* (EB), teachers' beliefs about the degree to which identified factors would enable them to be an effective science teacher (the Likert-type responses ranged from 4 = *strongly agree* to 0 = *strongly disagree*), and *likelihood beliefs* (LB), teachers' beliefs in the likelihood that those factors will occur (the Likert-type responses ranged from 4 = *very likely* to 0 = *very unlikely*).

We used the Science Teaching Efficacy Belief Instrument (STEBI-A; Riggs & Enochs, 1990) to measure self-efficacy. The instrument consists of 25 items including two dimensions of *self-efficacy* (SE), teachers' beliefs about their own ability to be an effective teacher, and *outcome expectancy* (OE), teachers' beliefs about whether students can learn if effective teaching takes place. We asked teachers to rate their level of agreement with the given statements by selecting one of five phrases ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Twelve of the 25 items measured outcome expectancy (OE); the remain-

ing 13 items measured self-efficacy (SE). Although the authors of STEBI-A developed the instrument using elementary school teachers, researchers have successfully used the instrument to examine the beliefs of middle school and secondary science teachers (Rubeck & Enochs, 1991).

We dropped 4 of the 25 STEBI-A items (items 10, 13, 20, and 25) because of the low reliability of the subscales for outcome efficacy. Our action was consistent with the results reported in previous studies (Bleicher, 2004; Riggs & Enochs, 1990).

We used the Constructivist Learning Environment Survey (CLES; Taylor, Fraser, & White, 1994) to measure teachers' beliefs about their constructivist teaching practices. The instrument consists of 35 items, with six items in each of the five subscales: personal relevance (meaningful learning), science uncertainty (the nature of science), critical voice (student reflection on or questioning of teaching and learning), shared control (student decision making about curriculum and assessment issues), and student negotiation (collaborative learning structures). We collapsed the subscales because of sample size constraints.

We used the Best Practices Survey (modified from Biological Sciences Curriculum Study, 1994) to measure the frequency with which teachers used traditional strategies (lectures, a text-driven curriculum, and isolated learning) and reform strategies (experiential learning, use of primary sources of data, and collaborative learning). Four of the 15 items measured traditional strategies (TS); the remaining 11 items measured reform strategies (RS).

Data Analysis

We created a composite score for each scale or subscale by adding the items. To control the overall experimentwise error rate, we first applied a multivariate Hotelling T^2 test. If we found that the null hypothesis was rejected in the multivariate approach, we used a series of repeated measure t tests to compare different subscales at Time 1 (pretest, given at the first meeting of the 2-year team) and Time 2 (posttest, given at the last meeting of the 2-year team). We also calculated effect size (Cohen's d) for each test. We conducted all statistical analyses in Statistical Analyses Software (SAS) 8.1.

Results

The result of multivariate analysis showed that at least one variable changed statistically from pretest to posttest, Hotelling's $T^2 = 50.01$, $p < .05$. Then, we applied a repeated measure t test for each variable ($\alpha = .05$, established a priori). In Table 1, we report the means, standard deviations, and reliabilities (Cronbach's alpha) for each subscale.

Scores for CBATS

The results of the t test showed that likelihood beliefs (LB) at pretest ($M = 51.11$, $SD = 14.58$) were significantly different from likelihood beliefs at posttest ($M = 42.06$, $SD = 12.33$), $t(17) = -2.47$, $p < .05$. The effect size of $-.58$ indicated a large effect (Cohen, 1988). The mean for enable beliefs (EB) had changed from 79.78 ($SD = 8.15$) at pretest to 77.11 ($SD = 8.62$) at posttest. This decrease, however, was not statistically different from 0, $t(17) = -1.39$, $p > .10$. All of the Cronbach's alphas for both subscales at pretest and posttest were higher than .85.

Scores for STEBI-A

The results showed that science teachers' personal self-efficacy (SE) improved significantly from pre- to posttest, $t(17) = 3.52$, $p < .001$. The average of change was 5.94 ($SD = 7.17$). The effect size of .83 indicated a large effect (Cohen, 1988). The change of outcome expectancy (OE) was not statistically different from 0, $t(17) = -.67$, $p = .56$. For both subscales, the Cronbach's alphas were higher at posttest (OE, $\alpha = .80$; SE, $\alpha = .89$) than at pretest when OE and SE were both .65.

TABLE 1. Means, Standard Deviations, Reliabilities, Results of *t* Tests, and Effect Sizes (*N* = 18)

Measures	Pretest			Posttest			Change from pre- to posttest				
	<i>M</i>	<i>SD</i>	α	<i>M</i>	<i>SD</i>	α	<i>M</i>	<i>SD</i>	<i>t</i> ^a	<i>p</i>	Effect size
CBAT											
EB	79.78	8.15	.87	77.11	8.62	.87	-2.67	8.13	-1.39	.182	-.33
LB*	51.11	14.58	.91	42.06	12.33	.87	-9.06	15.55	-2.47	.024	-.58
STEBI											
OE	18.72	3.37	.65	17.83	4.54	.80	-0.89	5.67	-0.67	.257	-.16
SE*	28.11	3.63	.65	34.06	7.34	.89	5.94	7.17	3.52	<.001	.83
CLES											
CLE*	131.56	18.21	.96	138.89	17.78	.94	7.33	15.76	1.97	.032	.47
Best Practices											
TS*	11.11	2.19	.48	10.17	2.20	.57	-0.94	1.73	-2.31	.017	-.56
RS*	27.33	4.60	.66	30.28	5.04	.80	2.94	5.59	2.24	.020	.53

Note. CBAT = Context Beliefs About Teaching Science Instrument. EB = enable beliefs. LB = likelihood beliefs. STEBI = Science Teaching Efficacy Belief Instrument. OE = outcome expectancy beliefs. SE = self-efficacy beliefs. CLES = Constructivist Learning Environment Survey. CLE = classroom learning environment beliefs. Best Practices = Best Practices Survey. TS = use of traditional strategies; RS = use of reform strategies.
^a*df* = 17 for all *t* tests.
**p* < .05.

Scores for CLES

The results showed that teacher beliefs about their constructivist teaching practices improved significantly from pre- to posttest, $t(17) = 1.97, p < .05$. The average of change was 7.33 ($SD = 15.76$). The effect size of .47 indicated a small to moderate effect (Cohen, 1988). The Cronbach's alphas were higher than .90 for both time occasions.

Scores for Best Practices

The results showed that teachers used traditional strategies less frequently at posttest compared with use at pretest, $t(17) = -2.31, p < .05$. The mean change was $-0.94 (SD = 1.73)$, with a moderate effect size of $d = -.56$. Teachers used reform strategies more frequently at posttest, $t(17) = 2.24, p < .05$. The mean change was 2.94 ($SD = 5.59$), with a medium effect size of .53. For both subscales, the Cronbach's alphas were higher at posttest (TS, $\alpha = .57$; RS, $\alpha = .80$) than they were at pretest (TS, $\alpha = .66$; RS, $\alpha = .80$).

Discussion

In this study, we applied a multivariate approach followed by univariate *t* tests to control the overall experimentwise error. Hummel and Sligo (1971) studied the experimentwise error rate for univariate *t* tests following rejection of null hypothesis by the T^2 test (Rencher, 2002). They found that using a significance level of .05 ($\alpha = .05$) for each individual test yielded an overall α acceptably close to the nominal .05. However, they also found that the overall α was too high if they performed the univariate tests without a prior T^2 test.

The data presented in Table 1 show that teachers' beliefs were enhanced over the course of the 2-year EXCITE project. Specifically, when using EHS in an integrative context, teachers became

more confident about their ability to be effective teachers (SE), and their beliefs about the classroom learning environment (CLES) were significantly enhanced. Moreover, after participating in Project EXCITE, teachers reported significantly more frequent use of reform-based best practices (interdisciplinary, inquiry-based, hands-on, cooperative, problem-based, teaching for depth of student understanding, assessing performance-based tasks, and contextualized learning). Cohen (1988) considered that effect scores above .8 were large effects; small effect sizes were below .5. Therefore, teachers' enhanced self-efficacy beliefs were a large effect associated with Project EXCITE. Teachers' significant changes in likelihood beliefs (LB), classroom learning environment beliefs (CLE), and use of reform-based strategies (RS) were moderate effects.

It is interesting that, over the course of the project, teachers did not strengthen their belief that good teaching could overcome student factors associated with learning (for example, student motivation or lack of the needed background knowledge), as noted by the declining, but statistically insignificant, outcome expectancy (OE) beliefs. Similarly, by the end of the project, teachers were no more likely to believe that school support factors (such as having more planning time, administrative support, or EHSIC resources) would enable them to become better EHSIC teachers. Moreover, as noted by the LB data in Table 1, teachers at the end of the project were less likely (a statistically significant decrease) to believe that these school support factors would be available to them. These downward trends in context beliefs suggest that teachers have less confidence in the school environment (the school and student-level enablers and barriers associated with teaching) than they have in their own ability to be effective teachers.

The increased use of reform strategies reported in our study supports the belief-to-action relationship hypotheses of Ajzen (1985) and Bandura (1986). Bandura also suggested that self-efficacy was the primary determinant of motivation to enact a given behavior. As we described earlier, self-efficacy comprises both teacher efficacy (confidence in the knowledge, skills, and abilities needed to teach effectively) and outcome expectancy (belief that teacher knowledge, skills, and abilities can indeed overcome obstacles to student learning). The results of Project EXCITE resulted in documentation of large statistical effects on enhanced teacher efficacy beliefs.

Bandura (1986) advocated fostering efficacy beliefs in the following ways: direct experiences of success, vicarious success (modeling), persuasion, and emotional arousal. Project EXCITE used those strategies directly, and the designers of the project used a research-based professional development model framed by Bandura's work to design the project (Haney & Lumpe, 1995). Instructors in the summer institutes used inquiry and problem-based interdisciplinary teaching strategies to enable teachers to experience success firsthand. The EXCITE colloquium, at which students presented the results of their research and demonstrated their understanding of the newly learned EHS concepts, was another opportunity for teachers to experience success. At the meetings during the academic year, teachers could share classroom success stories through small-group discussions about effective classroom lessons and events. At the meetings, teachers also viewed videos of lessons, which they critiqued and modified on the basis of group discussions about the effectiveness of the video lesson. Modeling effective teaching by means of the video lessons was another opportunity for vicarious learning. Participation in Project EXCITE persuaded teachers that inquiry and problem-based interdisciplinary teaching was at the core of effective science teaching. These teachers heard other teachers, scientists, university science educators, master teachers, school administrators, and community agency team members passionately espouse inquiry and problem-based interdisciplinary practices. The leaders of Project EXCITE tried to promote highs associated with success and buffer any lows that teachers might experience in attempting to design and implement new strategies.

We found other statistically significant moderate size effects that fostered positive teacher beliefs about the classroom learning environment (personal relevance, scientific uncertainty, shared control,

critical voice, student negotiation, and a reported increase in the use of reform-based classroom practices). Perhaps these factors are more resistant to change than self-efficacy beliefs, which had a large effect size, or perhaps changes to self-efficacy beliefs precede changes to these beliefs and practices. We believe that researchers should further investigate the relationships among self-efficacy beliefs, classroom learning environment beliefs, and the development of subsequent classroom practices.

Project EXCITE's explicit use of problem-based curricula, contextualized with locally relevant EHS issues, is probably responsible for the enhanced teacher beliefs related to the classroom learning environment. It would be difficult for teachers to participate actively in EXCITE and not increase their belief in classroom practices related to personal relevance (contextualized learning), scientific uncertainty (teaching the nature of science) and shared control (allowing students to make curricular and assessment decisions). The reported significant increase in the use of reform-based best practices suggests that the teachers directly implemented their beliefs about constructivist learning environment factors, such as personal relevance, scientific uncertainty, shared control, critical voice, and student negotiation.

Other data indicate that Project EXCITE had a positive effect on additional teacher outcomes (EHS content knowledge, integrated thinking and planning, teaming abilities) and on student achievement outcomes (EHS content, scientific process skills, and Ohio proficiency testing; Haney, Keil, & Zoffel, 2006; George, 2005). We tested students' science process skills (experimental design, identifying and controlling variables, and data presentation and interpretation) by administering the Performance of Process Skills (POPS) test (Mattheis & Nakayama, 1988) before and after their teachers' participation in Project EXCITE. We tested the change in scores from pre- to posttest for statistical significance ($\alpha = .05$). The pretest mean for the entire group of students was 11.4 and the posttest mean was 12.6, a change of 1.2 that we found was statistically significant ($p < .001$). We disaggregated the data into quartiles and tested the change in mean scores. We found an increase in mean scores in all quartiles except Quartile 4 (highest quartile); these increases were all significant ($p < .001$). Students with the lowest pretest scores showed greatest improvement. A small, not statistically significant decrease in the mean score for Quartile 4 occurred after the treatment. Overall, students enhanced their inquiry skills after exposure to the project, with greater gains made by lower-achieving students (George, 2005).

In addition, we found that across three subject areas (writing, mathematics, and citizenship), proficiency test scores for Ohio students had significantly improved when compared with those of their non-EXCITE peers. In one school in which students participated in EXCITE, the pass rates on the sixth grade proficiency test, at the close of the 2-year period, were higher in all subject areas (reading, writing, mathematics, science, and social studies) than they had been the year immediately before beginning EXCITE. In the two non-EXCITE comparison schools in the same district, pass rates were higher in only three or four of the five subject areas. Similarly, after 2 years of participating in EXCITE, a smaller percentage of the students in the sample school performed at a "below proficient" level in all five subjects compared with the percentage at that level in the year immediately before EXCITE. Over the same period, the two non-EXCITE schools reported smaller percentages of "below proficient" students in only two or three subject areas (Haney et al., 2006).

EXCITE students also broadened and deepened their conceptual understanding of environmental health science and were more motivated and engaged when compared with their attitude toward other non-EXCITE units of study (George, 2005). Our research suggests that Project EXCITE was an effective program in helping teachers of middle school students reach current educational goals. Our data provide evidence that using inquiry and problem-based environmental science in an integrative context fosters positive teacher and student outcomes. Because the EXCITE model encompasses many research-based best practices, these reported effects on teachers' beliefs and practices are not attributable to any one practice but, rather, to the totality of the EXCITE approach.

Implications

Our findings are consistent with the body of research that indicates positive effects from employing integrated curricula (Bailey, 2003; Boyer & Bishop, 2004; Lewis & Shaha, 2003; Lieberman & Hoody, 1998; Morrone, 2001; Vars, 2001; Warren & Payne, 1997). Partly because of this emerging research, a surge in the use of integrated curricula and interdisciplinary teaching practices occurred from the late 1970s through the late 1980s (Drake & Burns, 2004; Palmer, 1998). Today, the integrated curriculum faces new challenges because beginning in the early 1990s the pendulum began again to swing toward standards-driven, discipline-based curricula (Drake & Burns, p. 141). Significant cuts in education budgets at the national, state, and local levels often dictate that school organization structures must be fiscally "lean." In our region, many schools are increasing class size, laying off teachers, and abolishing interdisciplinary structures, such as shared planning time, teaming, and flexible schedules. Of the 18 EXCITE schools, several have discontinued teaming structures because of reported budget constraints. Although a single teacher can teach an integrated curriculum in a single classroom, barriers such as those identified above impede the movement toward integration. Moreover, current national and state education standards spell out discrete knowledge and skills for students to master in each subject area. Many teachers and school administrators, knowing that integration provides a mechanism for coordinating these standards into meaningful instructional events, struggle to find ways to integrate these subject-specific standards into interdisciplinary units.

Although Project EXCITE is complex and multifaceted, and the integrative nature of the project makes it hard to isolate individual factors, we believe our findings can help make the case for an integrated curriculum framed by EHS issues. We therefore advocate for additional resources to support curriculum development, professional development, and subsequent research on the use of problem-based, interdisciplinary environmental education curricula.

NOTE

1. EXCITE = Environmental health science eXperiences through Cross-disciplinary and Investigative Team Experiences.

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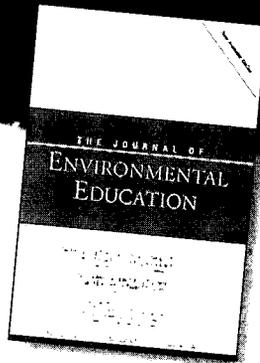
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