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Exploring the Technical Expression of Academic Knowledge: The Science-in-CTE Pilot Study

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The Science-in-CTE pilot study tested a curriculum integration model that enhanced the science that occurs in CTE curricula. The study replicated the National Research Center for Career and Technical Education's (NRCCTE) Math-in-CTE experimental research design (Stone, Alfeld, & Pearson, 2008) with applied science in secondary agricultural education. The semester-length study was conducted in North Dakota with secondary agricultural educators who were randomly selected to participate in the experimental and control groups. The experimental treatment mirrored the Math-in-CTE model of extended professional development, partnering experimental CTE group teachers with science educators, and use of a 7-element pedagogic framework. Standardized measures of science achievement were administered to students to determine the impact of the treatment on their science knowledge and skills. The results of hierarchical linear modeling (HLM) analysis indicated that the intervention had a statistically significant positive impact on posttest science achievement for students in the 2nd, 3rd, and 4th quartiles on pretest science achievement. We interpreted the intervention's effects as small for participants in the 2nd quartile and as moderate for those in the 3rd and 4th quartiles. Relative to the control group, the intervention appeared to have no impact on students in the 1st quartile on pretest science achievement.

Keywords: curriculum integration; science achievement; secondary agricultural education students

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The Science-in-CTE pilot study tested a model of curriculum integration that enhances the instruction of science in career and technical education (CTE) curricula. The pilot replicated the experimental research design of the Math-in-CTE study conducted by the National Research Center for Career and Technical Education (NRCCTE) from 2004-2005 (Stone, Alfeld, Pearson, Lewis, & Jensen, 2006). Findings from the Math-in-CTE study provided evidence that enhancing the instruction of mathematics in CTE curricula could improve students' math skills. Students in experimental/treatment classrooms scored significantly higher on standardized tests of achievement in mathematics than did their counterparts in control classrooms. Furthermore, students' academic improvements came without loss of occupational knowledge and skills (Stone et al., 2008). The success of the Math-in-CTE study generated additional testable questions regarding other possibilities for academic integration. Specifically, NRCCTE researchers considered whether it would be possible to adapt the model to integrate science with CTE.

The decline of national science achievement scores added urgency to this question. Consistent with the trends in math achievement that led to the Math-in-CTE study, National Assessment of Educational Progress (NAEP, 2005) data on science achievement showed that student scores had not increased in spite of an increase of required science credits from 1.4 in the mid-1980s to 3.2 in 2004 (Silverberg, Warner, Fong, & Goodwin, 2004). In fact, NAEP data showed that at the Grade 12 level, the average score for science achievement had declined since 1996. In 2005, only 54% of students scored at or above the Basic level on the science exam (NAEP, 2005). Collectively, such data not only challenged the prevailing assumption that requiring more science credits would lead to increased knowledge and skills, but also suggested the need for a different approach to science education.

CTE and Academic Curriculum Integration

The content of career and technical education is driven by the needs of the workplace; therefore CTE instructors maintain a close connection with "real work." Examination of CTE curricula through mapping and other kinds of integration strategies has revealed a context rich with authentic opportunities for strengthening academic skills (Zirkle, 2004). The Math-in-CTE study, upon which the Science-in-CTE study described in this paper was designed, clearly demonstrated that CTE teachers can identify the significant amount of academic knowledge and skills that are embedded in the technical content, while providing their academic counterparts with real-life, problem-based activities through which students can apply academics in relevant ways (Stone et al., 2008).

When the Science-in-CTE study was first proposed, few studies were found that addressed the impact of CTE-science integration on student achievement, although the field of CTE has had a long-term priority focus on curriculum integration (Hoachlander, 1999). An earlier study conducted by Roegge and Russell (1990) utilized a quasi-experimental design to test the effect of incorporating biology principles into a unit of instruction in vocational agriculture on student achievement and attitudes. Roegge and Russell found the integrated approach superior to the traditional approach in producing higher overall achievement and higher applied biology achievement. They also reported that students had a more positive attitude toward the learning experience. Similarly, Conroy and Walker (2000) conducted interviews with teachers and students that revealed that students performed better in math and science classes as a result of what they learned in aquaculture. These early studies suggested the need and potential for further research on the integration of CTE and science.

The integration of academics into the CTE curriculum was a major policy objective of the Carl D. Perkins Career and Technical Education Improvement Act of 2006, also known as Perkins IV. The Perkins IV legislation explicitly linked professional development (PD) to improved teaching practices and student outcomes and required that PD in career and technical fields promote "the integration of coherent and rigorous academic content standards and career and technical education curricula, including … opportunities for the appropriate academic and career and technical education teachers to jointly develop and implement curricula and pedagogical standards." Furthermore, the PD was to be "high quality, sustained, and intensive" and was to increase academic knowledge (Carl D. Perkins Career and Technical Education Improvement Act of 2006, S. 250, Sec. 122 (c) (A), p. 36). Converging with the stagnation of science achievement and the proven success of mathematics integration, this legislative mandate provided further justification for testing a CTE-science integration model.

Science Instruction in Context

Concurrent with the Perkins IV legislative mandate was an emerging conversation among science professionals about traditional science teaching methods—specifically, the need to provide a relevant context through which to learn science concepts and principles. Gilbert (2006) summarized the discussion in this way:

(a) Because of high content loads, the science curricula are too often aggregations of isolated facts detached from their scientific origin;

(b) Students do not know *how* they should connect the aggregations of isolated facts that do not lend themselves to the

> formation of coherent mental schema and give no meaning to what they have learned;
> (c) Students fail to solve problems using the same concepts in other situations than those that closely mirror the ways in which they were taught.
> (d) Students do not feel a sense of *why* they learn the material required; it does not become relevant for them.
> (e) The traditional emphases of the science curriculum ("solid foundation," "correct explanation," and "scientific skill development") are increasingly seen as an inadequate basis for the more advanced study of science. (p. 958; emphasis in the original)

Bennett, Lubben, and Hogarth (2007) offered this definition of a *context-based approach* to science education:

> *Context-based approaches* are approaches adopted in science teaching where contexts and applications of science are used as the *starting point* for the development of scientific ideas. This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications. (p. 248; emphasis in the original)

These authors reported that context-based science courses motivate students and help them feel more positive about science by helping them see the importance of what they are studying. When students are more interested and motivated by the experiences they are having in their lessons, their increased engagement may result in improved learning (Bennet et al., 2007).

Munby, Taylor, Chin, and Hutchinson (2007) defined differences between school science and workplace science in terms of purpose, emphasizing that students in science-rich workplaces frequently do not make connections between their work tasks and the academic science taught in school. The authors suggested that this occurs in part because workplace science often masks the underlying science by transforming science-based procedures into routine sequences. Munby et al. (2007) further suggested that metacognitive instruction could be helpful for students to both (a) understand their work tasks more fully by understanding the underlying science and (b) simultaneously improve their fundamental knowledge of academic science.

The National Science Education Standards published by the National Committee on Science Education Standards and Assessment and the National Research Council (2007) provided a number of guidelines for improving K-12 science education. Among these methods were: (a) learning through inquiry, (b) "hands-on" learning, (c) "minds-on" learning, and (d) "science as process." (p. 2). These guidelines recommend that teachers begin with the problems that arise at work or in the community and introduce the scientific ideas needed to identify and test possible solutions to those problems as opposed to beginning with abstract principles of science and adding application as an afterthought.

An emerging model supporting knowledge integration was found among those in the science community who argued for "coherent science education" (Kali, Linn, & Roseman, 2008). In doing so, they promoted a movement beyond standards to a more systematic approach to science instruction that makes explicit the connections among scientific concepts and principles. The authors further promoted contextualized science learning through the use of real-world problems and inquiry-based projects. Specifically, the Center for Curriculum Materials in Science (CCMS) approach emphasized curricular coherence based on these characteristics: (a) "interconnectedness of core knowledge," (b) "connections between ideas of science and phenomena in the real world," (c) "connections between new ideas and prior knowledge," and (d) "connections between scientific ideas and the enterprise that produced them" (Roseman, Linn, & Koppal, 2008, pp. 16-25). The CCMS modeling, based on empirical research, closely paralleled the approach of the evidence-based contextualized approach of the Math-in-CTE model, which proved to increase students' math skills.

Theoretical Underpinnings

The theoretical underpinnings of a contextualized approach can be traced back to Dewey (1916), who proposed that students should be educated through occupations rather than for occupations. "Rather than conceptualizing narrow, specific job skills as the goal of occupational courses, Dewey argued that occupational contexts could provide a rich venue in which students could effectively learn important fundamental concepts in traditional subject matter" (NRCCTE Curriculum Integration Workgroup, 2010, p. 2).

Situated Cognition

As with the Math-in-CTE study, the Science-in-CTE pilot study drew heavily upon the theory of situated cognition (Lave & Wenger, 1991). Situated cognition is a complex interplay between physical and social context, authenticity of experience, and personal construction of knowledge (Darvin, 2006; Hendricks, 2001). Although it is sometimes difficult to fine-tune the terminology, most agree that it represents a "move away from the individual as an isolated unit into which knowledge may or may not be 'plugged'" (Moore, 1998, p. 170). As the NRCCTE Curriculum Integration Workgroup (2010) reported:

> Numerous theories exist as to how experiential learning works and for whom, educators generally agree on the value of relevance and application. The importance of relevance is prominent in the experiential learning theory of situated cognition, which promotes the context in which learning occurs as being central to understanding (Brown, Collins, & Duguid, 1989; Paige & Daley, 2009). Brown and colleagues (1989) suggested that situated cognition requires us to consider knowledge as a set of tools that can (a) be useful only when understood and (b) vary in purpose based on the situation at hand. Situated cognition emphasizes learning experiences in "authentic versus decontextualized contexts" (Choi & Hannafin, 1995, as cited in Merriam et al., 2007, p. 180). (p. 7)

The contextualized approach used in the Science-in-CTE model required that CTE teachers change their way of teaching to more actively engage students in learning science and in *thinking as scientists* (National Research Council, 2000). As with the Math-in-CTE model, the authentic context of CTE served to situate science in ways that helped students cognitively make sense of the academic content (Brown et al., 1989; Cognition and Technology Group at Vanderbilt, 1990; as cited in Stone et al., 2008).

Conceptual Framework

A major activity of the Science-in-CTE pilot study was to develop the conceptual framework that would guide the integration process. The research team, with input from a science education consultant, drafted a framework that was subsequently presented to an advisory group of science and CTE educators for feedback and further refinement.

The overall approach to the CTE and science integration reflected the Math-in-CTE model in which the CTE concepts within the curriculum dictated the selection and use of the academic content. Therefore, as a first step, the research team adopted the Math-in-CTE pedagogic (instructional) framework to ensure that the transfer of learning elements were retained in the development of the science-enhanced CTE lessons (Stone et al., 2008). These seven elements, as below, were used to guide teachers' development of the integrated lessons and their subsequent instruction:

1. Introduce the CTE lesson.
2. Assess students' science awareness as it relates to the CTE lesson.
3. Work through the science embedded in the CTE lesson.
4. Work through related, contextual science-in-CTE examples.
5. Work through explicit science examples.
6. Students demonstrate their understanding.
7. Formal assessment. (Adapted from the Math-in-CTE model, Stone et al., 2008)

This process of solving a real, relevant problem, practicing several similar examples, and then applying the concept to a more abstract problem (transfer of learning, Elements 3-5 of the seven-element model) was also congruent with the characteristics of connectedness called for in coherent science instruction (Kali et al., 2008).

For the purpose of the pilot study, and with input from an advisory committee, the research team used the term *explicit science* to express the embedded science as it might appear in a science classroom or on a standardized test. Drawing from the science education literature, the research team surmised that the science explicit in CTE curricula would represent any of three overlapping domains of science knowledge and skills (see Figure 1). These domains, from which teachers could draw to create integrated lessons, included science concepts and unifying principles, the nature of science (NOS), and scientific inquiry (Biological Sciences Curriculum Study [BSCS], 2006; Flick, 2006; Schwartz & Crawford, 2006; Scott, Asoko, & Leach, 2007).

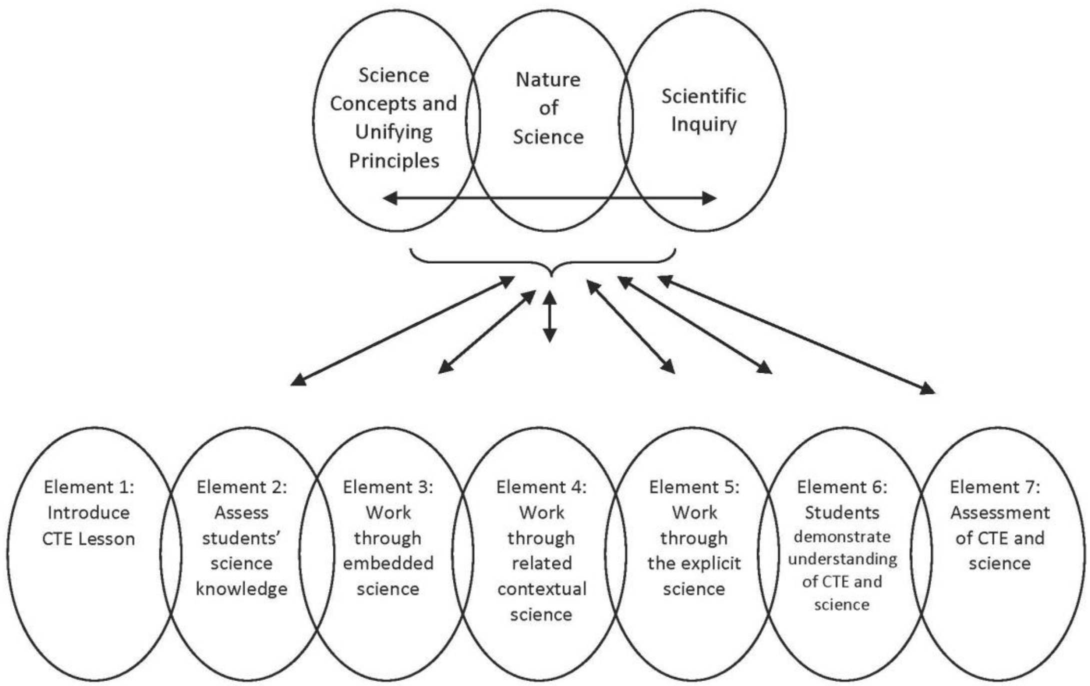

Figure 1. The relationship of science education perspectives to the pedagogic framework.

Notably, this conceptual model reflected a movement in the science education community away from the "process versus content" debate toward helping students understand science as it occurs in the natural world (BSCS, 2006). The research team hypothesized that the pedagogic framework developed for this pilot study would provide opportunities for students to learn science within the CTE context in ways that were complementary to these perspectives in the science education community. Guided by this framework, the CTE-science teacher teams participating in the pilot developed CTE lessons through which students not only learned the factual information of science, but also engaged in the more complex interactions of scientific concepts and principles and scientific inquiry (BSCS, 2006; Flick, 2006; Schwartz & Crawford, 2006; Scott et al., 2007).

Purpose and Research Question

The purpose of the Science-in-CTE pilot study was to test a model of curriculum integration that enhanced the science embedded in CTE curricula. The following research question guided the study: Is there a significant difference in the scores of students who received science-enhanced CTE instruction and those of students in control classrooms, as measured by a standardized test of scientific knowledge?

Methods and Procedures

The Science-in-CTE pilot study replicated the experimental design of the NRCCTE's Math-in-CTE study (Stone et al., 2008), as adapted to test integrated science instruction. The intervention consisted of a process of extended PD and a seven-element pedagogic framework that was used to develop and teach science-enhanced CTE lessons. Pre- and posttests were administered to students in the classrooms of participating teachers to determine the impact of the treatment on their science knowledge and skills.

Experimental Design

The semester-length pilot was conducted in Spring 2010 with CTE teachers in North Dakota. Replicating the research design used for the Math-in-CTE study, the research team utilized a group randomized trial (GRT; Jacob, Zhu, & Bloom, 2009; Murray, 1998). Twenty-nine agricultural education teachers who volunteered to participate were randomly assigned to either an experimental group (15 teachers) or a control group (14 teachers). Random assignment of teachers from a common pool of those who volunteered was used to distribute any unmeasured factors that might be related to outcome variables to the two conditions. Because analyses were conducted at the classroom level, a pretest of student science achievement was used to ensure that the random assignment of teachers yielded comparable classrooms (Fraenkel & Wallen, 2003).

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Intervention

The experimental group CTE teachers received six days of extended PD patterned after the model tested in the Math-in-CTE study. They were paired with science teacher partners and engaged with them in a community of practice to map curricula, develop science-enhanced lessons, and critique and refine lessons (see Table 1).

The Science-in-CTE model was not designed as a team-teaching model; rather, the agricultural education teachers taught the enhanced CTE lessons on their own. They received ongoing support from their science teacher partners at their schools and participated in two days of additional PD at a midpoint in the pilot treatment period. During the PD sessions, each CTE-science teacher team created one science-enhanced lesson for a total of 15 for the group. Each of the lessons was presented before the full group; feedback was solicited and refinements were made. Each CTE teacher prepared an implementation calendar and committed to teach all 15 of the science-enhanced lessons during the treatment period.

The agricultural education teachers randomly assigned to the control groups were asked to conduct business-as-usual and to refrain from changing their instruction or curriculum during the treatment period. At the conclusion of the treatment period, the experimental teacher teams reconvened for a one-day session that included debriefing and focus groups; control teachers were invited to attend a one-day workshop at which they were debriefed and received training in the model and all instructional materials developed by the experimental teachers.

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Table 1

Pilot Study Research Design and Activities by Semester

Fall Semester 2009 Design and Activities		Spring Semester 2010 Design and Activities		
Teacher groups randomly assigned in the GRT	Initial PD	Student Pretest and Survey	Pilot Intervention Activities	Student Posttest
Experimental group: 15 agricultural education teachers with science teacher partners	4 days	Yes	Agricultural teachers teach science-enhanced lessons Agriculture-science teacher teams meet before each lesson 2 days of PD at mid-semester	Yes
Control group: 14 agricultural education teachers	No PD	Yes	Conduct business-as-usual; No change to curriculum or instruction	Yes

Student Pretesting and Posttesting

Students in classrooms of participating agricultural education experimental and control group teachers were pre- and posttested using standardized measures of science achievement. The selection of McGraw-Hill Terra Nova test batteries as appropriate instruments for this purpose was made by a science education specialist in conjunction with NRCCTE researchers. This selection was confirmed by a panel of experts who were convened at the beginning of the study to advise on the adaptation of the Math-in-CTE data collection instruments and pedagogic framework for use with science curricula. The science section of the Terra Nova Third Edition CAT Survey Level 21/22 Form C was used as the achievement pretest. The science section of the TerraNova, Third Edition, Complete Battery, Level 21/22 was utilized as the achievement posttest.

Fidelity of Treatment Measures

The research team employed multiple fidelity of treatment measures (a) to ensure that the enhanced lessons were implemented as planned and (b) to ascertain the extent to which they were instructed. These measures included: (a) monitoring of lesson calendars, (b) pre-teaching meeting reports submitted by the science teachers, (c) post-teaching reports submitted by CTE teachers, (d) collection of student work, and (e) debriefing of teachers in the focus groups.

Analyses

In this study, data for 376 secondary students were available for analysis. Due to coding errors, we could not determine classroom membership for 13 participants and removed these cases. We handled all other missing data using the expectation maximization (EM) algorithm, which is available in the IBM SPSS 19 software package. The percentage of data missing for the variables ranged from 6.1% to 19.0%, with an average of 8.4%. A test of the assumption that the data were not missing completely at random (MCAR) yielded a non-significant result, suggesting that the imputation method was appropriate (Little, 1988; Little & Schenker, 1995).

Following these procedures, data for 363 participants and 29 classrooms were available for analysis, with an average of 13 students per classroom. Table 2 displays demographic information for the cases before and after missing data were imputed. Due to the small number of ethnic minority students in the sample, we collapsed these participants into one minority group category. This group of 32 participants was comprised of 15 American Indian or Alaska Natives, 6 Asians, 1 Native Hawaiian or other Pacific Islander, and 9 participants who identified themselves as of more than one ethnicity.

Table 2

Sample Demographics

	Before Imputation		After Imputation	
	N	Percent	*N*	Percent
Condition				
Control	164	54.7	192	52.9
Treatment	136	45.3	171	47.1
Sex				
Male	227	69.4	263	72.5
Female	100	30.6	100	27.5
Ethnicity				
White	290	90.1	331	91.2
Nonwhite	32	9.9	32	8.8
Grade Level				
9^{th} grade	104	31.8	104	28.7
10^{th} grade	69	21.1	102	28.1
11^{th} grade	68	20.8	71	19.5
12^{th} grade	86	26.3	86	23.7

Hierarchical Linear Modeling

We used hierarchical linear modeling (HLM) to test the effects of the intervention on science achievement, specifying a two-level model that incorporated both student- and classroom-level predictors into a single analysis. We chose HLM for three reasons. First, our testing data were from students nested in classrooms, and this methodology has been successfully used in the treatment of such data, where Type I error rates may be inflated by the similarity among members of a cluster (Raudenbush & Bryk, 2002). Second, HLM allowed us to treat the intervention as a characteristic of classrooms and test its effects at Level 2, a more accurate statistical representation of our procedure. Finally, this statistical methodology allowed us to control for the possibility that the classrooms differed on pretest science achievement by entering mean classroom pretest achievement as a Level 2 predictor of the outcome. We carried out the HLM analyses using full maximum likelihood estimation and the HLM 6 software. See Table 3 for the predictors used in our analysis and see Table 4 for coding, centering, and equations.

Table 3

Descriptive Statistics for Level 1 and 2 Variables

	N	Mean	*SD*	Min	Max
			Level 1 Variables		
Posttest Number Correct	363	12.02	6.49	6.00	39.00
Age	363	16.04	1.36	12.00	20.00
Science Courses	363	2.17	1.47	0.00	9.00
Sex	363	0.69	0.44	0.00	1.00
Grade Level	363	1.40	1.13	0.00	3.00
Pretest Quartile	363	1.45	1.12	0.00	3.00
Minority	363	.10	.28	0.00	1.00
			Level 2 Variables		
Class Mean Pretest	29	14.33	1.99	9.20	17.50
Group	29	.52	.51	0.00	1.00

Results

For the null model, we observed that mean posttest scores for all models were statistically significantly different from zero (*ps* $< .001$). We also observed an intra-class correlation of .13 for the null model, indicating that 13% of the variance in science achievement was between classrooms. Finally, we observed significant between-group variance in the intercept for the null model ($p < .001$). We interpreted these results as suggesting that it was appropriate to use HLM.

Table 4

Model Characteristics

Predictor	Description	Coding (if needed)
Student level predictors:		
Age[a]	Chronological age	
Science courses taken[a]	Total number of science courses taken	
Sex	Biological sex	0 = female and 1 = male
Grade level	Student academic level	0 = freshman, 1 = sophomore, 2 = junior, and 3 = senior
Pretest quartile	Quartile on pretest science achievement for each student	0 = 1st quartile , 1 = 2nd quartile, 2 = 3rd quartile, and 3 = 4th quartile
Minority	Reported ethnic background collapsed into Caucasian and minority	0 = Caucasian and 1 = minority
Classroom level predictors:		
Group	Treatment condition for each classroom	0 = control group and 1 = treatment group
Class mean pretest score[a]	Mean pretest science score for each classroom	

Equations:

The Level 1 model, including the within class variables listed above:

$$\text{Posttest science achievement}_{ij} = \beta_{0j} + \beta_{1j}\,\textit{age}_{ij} + \beta_{2j}\,\textit{science courses}_{ij} + \beta_{3j}\,\textit{sex}_{ij} + \beta_{4j}\,\textit{grade level}_{ij} + \beta_{5j}\,\textit{pretest quartile}_{ij} + \beta_{6j}\,\textit{minority}_{ij} + r_{ij}$$

The Level 2 model, including the between class variables listed above:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\,\textit{group}_j + \gamma_{02}\,\textit{class mean pretest score}_j + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{2j} = \gamma_{20} + u_{2j}$$
$$\beta_{3j} = \gamma_{30} + u_{3j}$$
$$\beta_{4j} = \gamma_{40} + u_{4j}$$
$$\beta_{5j} = \gamma_{50} + \gamma_{51}\,\textit{group}_j + \gamma_{52}\,\textit{class mean pretest score}_j + u_{5j}$$
$$\beta_{6j} = \gamma_{60} + u_{6j}$$

Note. [a] Predictors were grand mean centered.

HLM Level 1 Model

We specified and tested a Level 1 model to assess the degree to which student characteristics explained the variance in mean posttest science achievement (see Table 5 for parameter estimates). Initially, we estimated random effects for all predictors. In the Level 1 model, we entered age, number of science courses taken, sex, grade level, pretest quartile, and minority as Level 1 predictors of mean posttest science achievement. We observed statistically significant overall effects of sex, pretest quartile, and minority on mean posttest science achievement ($ps < .01$). Additionally, we observed that mean posttest science achievement for female White students in the lowest quartile on pretest science achievement was 13.77. Controlling for the effects of all other predictors, every unit increase in quartile on pretest science achievement corresponded to a 3.97 unit increase in mean posttest science achievement, being male was associated with a 1.67 unit increase in mean posttest science achievement, and minority status was associated with a 1.50 unit increase in mean posttest science achievement.

Table 5

Student and Classroom Level Predictors of Mean Posttest Science Achievement

Parameter	Null Model	Level 1 Model	Level 2 Model	Cohen's *d*
Student level predictors of mean science achievement:				
Intercept (γ_{00})	21.99(.54)***	13.77(.86)***	14.77(1.11)***	
Age (γ_{10})	-	-.55(.34)	-.64(.37)	
Science Courses (γ_{20})	-	.25(.39)	.30(.48)	
Sex (γ_{30})	-	1.69(.49)**	1.34(.60)*	.21
Grade Level (γ_{40})	-	.77(.47)	.72(.56)	
Pretest Quartile (γ_{50})	-	3.97(.25)***	3.50(.28)***	.54
Minority (γ_{60})	-	1.50(.68)*	2.31(.77)**	.36
Classroom level predictors of mean science achievement (i.e., γ_{00}):				
Class mean pretest (γ_{01})	-	-	.70(.25)**	.11
Group (γ_{02})	-	-	-.92(.84)	
Classroom level predictors of pretest quartile slope (i.e., γ_{50}):				
Class mean pretest (γ_{51})	-	-	-.032(.14)*	-.005
Group (γ_{52})	-	-	.97(.50)*	.15
Variance Components:				
Var. in intercept (τ_{00})	5.46(2.34)***	1.66(1.29)	-	
Age (τ_{11})	-	.38(.62)	-	
Higher Science (τ_{22})	-	2.08(1.44)	-	
Sex (τ_{33})	-	1.30(1.14)	-	
Grade Level (τ_{44})		.57(.75)	-	
Pretest Quartile (τ_{55})	-	.68(.82)	-	
Minority (τ_{66})	-	2.91(1.71)	-	
σ^2	36.37(6.03)	16.44(4.05)	-	

Note. Standard errors for parameters are in parentheses. Standard deviations for variance components are in parentheses. *p < .05; **p < .01 ***; p < .001.

The Level 1 model fit the data substantially better than the null model, as evidenced by substantially lower Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values (see Table 6). The AIC and BIC are indices commonly used to assess the relative degree to which statistical models, particularly nested models, fit the data (Kline, 2010; Raudenbush & Bryk, 2002). Reductions in BIC values greater than 10 have been suggested as very strong evidence of superior model fit (Raftery, 1995). In addition, there was a statistically significant reduction in deviance (p < .001). Deviance is another statistic that is commonly used to compare the fit of nested models in HLM and can be tested for statistical significance (Raudenbush & Bryk, 2002). The Level 1 model explained a substantial amount of the between groups (i.e., 30%) and within groups (i.e., 45%) variance in the null model (see Table 6). The variance component for the Level 1 model intercept was not statistically significant, suggesting that between groups there was insubstantial variance remaining in mean posttest science achievement. Though the between groups variance in the outcome had been explained, we tested for Level 2 effects to assess the effects of the intervention.

Table 6

Proportions of the Variance Explained and Model Fit

Parameter	Null Model	Level 1 Model	Level 2 Model
Between group variance explained in intercept	-	30%	-
Within groups variance explained in intercept	-	45%	-
Deviance	2362.85[3]	2088.17[36]***	1574.13[15]
AIC (n = 363)	2368.85	2160.17	1604.13
BIC (n = 363)	2380.53	2300.37	1662.55

Note. Numbers of parameters are in brackets. *p < .05 **; p < .01 ***; p < .001.

HLM Level 2 Model

We specified and tested a model that included Level 2 predictors to assess the degree to which characteristics of classrooms explained the variance in mean posttest science achievement. In this model, we controlled for the student level predictors so that we could assess the effects of the intervention on the outcome, over and above the effects of the student level predictors. Because the variance components were observed to be non-significant for the Level 1 model, in the Level 2 model we fixed the effects for all of the Level 1 predictors. As noted, this suggested that between groups there was insubstantial variance remaining for these predictors. We entered two Level 2 variables (i.e., class mean pretest score and treatment group) as predictors of both mean posttest science achievement and the effect of pretest quartile on mean posttest science achievement to assess the effects of our intervention. We theorized that the effect of these variables on the outcome might vary across levels of student pretest science achievement: That is, pretest achievement might moderate the effects of mean classroom achievement and also the treatment on posttest science achievement.

The pretest quartile had a statistically significant effect on mean posttest science achievement (p < .001) as in the Level 1 model. Controlling for all other predictors, each unit increase above the lowest quartile on pretest science achievement corresponded to a 3.50 unit increase in mean posttest science achievement. The class mean pretest score was observed to have a statistically significant effect on mean posttest science achievement (p < .01; controlling for all other predictors). Holding all other predictors constant, treatment group membership was observed to have a statistically significant effect on the pretest quartile slope (p < .05).

For participants in the treatment group classrooms, controlling for all other predictors, each unit increase above the first pretest quartile corresponded to a .97 unit increase in the effect of pretest quartile on mean posttest science achievement (p < .05). Thus, the effects of the treatment were incongruent across levels of pretest science achievement (i.e., pretest achievement moderated the treatment effect). We observed that treatment group membership appeared to have no effect on mean posttest science achievement for those in the first quartile on pretest science achievement, but a substantial positive effect for those in the second, third, and fourth quartiles. The magnitude of this effect increased for each quartile increase in pretest science achievement. See Table 7 for predicted scores tabled by condition and pretest science achievement quartile, and see Figure 2 for a graphical display of these scores.

Compared with the Level 1 model, we observed that the Level 2 model BIC was more than 80 units smaller and interpreted this as very strong evidence of superior fit (Raftery, 1995). We also observed a substantial decrease in the AIC. Despite the superior AIC and BIC values, the deviance value was not observed to change with statistical significance. Based on comparison of the AIC, BIC, and deviance values for the Level 1 and 2 models, we concluded that the Level 2 model appeared to fit the data substantially better than the Level 1 model.

Table 7

Predicted Posttest Mean Science Achievement by Quartile and Experimental Condition

Pretest Quartile	Control Group	Treatment Group
1	14.77	14.77
2	18.27	19.24
3	21.77	23.71
4	25.27	28.18

Note. Controlling for age, science courses taken, sex, grade level, and pretest quartile at the student level. Controlling for class pretest mean at the classroom level.

HLM 6 produces unstandardized estimates of effect size in the metric of the outcome measure, in this case the TerraNova science test. Because researchers often want to interpret the relative size of effects based on standardized estimates, we computed Cohen's *d*, an estimate of effect size in units of standard deviations (Valentine & Cooper, 2003). A *d* value of .40 is generally considered to be a moderate effect size in the social sciences, while .80 is considered to be a large effect (Cohen, 1988). According to Cohen (1988), these effects may be considered larger in the field of educational research, where effects are often small. The magnitude of the intervention's effects may also be assessed through observation of the predicted posttest means for prototypical participants, and the percent improvements in the students' mean posttest scores. These statistics are reported by quartile and treatment condition in Tables 7 and 8, respectively.

Table 8

Percentage Change in Number Correct at Posttest (Compared to Controls)

Pretest Quartile	Treatment
1	+0.0%
2	+2.5%
3	+4.9%
4	+7.3%

Conclusions and Discussion

The results of our HLM model analyses indicated that the intervention had a statistically significant positive impact on posttest science achievement for students in the second, third, and fourth quartiles on pretest science achievement (see Figure 2). Cohen's *d* was observed at .15 for those in the second quartile, .30 for those in the third quartile, and .45 for those in the fourth quartile. We interpreted the intervention's effects as small for participants in the second quartile and as moderate for those in the third and fourth quartiles. As Cohen (1988) noted, standardized effects are often smaller in education compared to those observed in other fields. Given the educational nature of this study, we judged a *d* of .30 to be of moderate size, although this would be considered small in other fields of research. Relative to the control group, the intervention appeared to have no impact on students in the lowest quartile on pretest science achievement. The negligible result for students in the first quartile seemed counterintuitive in relation to the upward trend in the higher quartiles, but could not be explained using the data available for analysis.

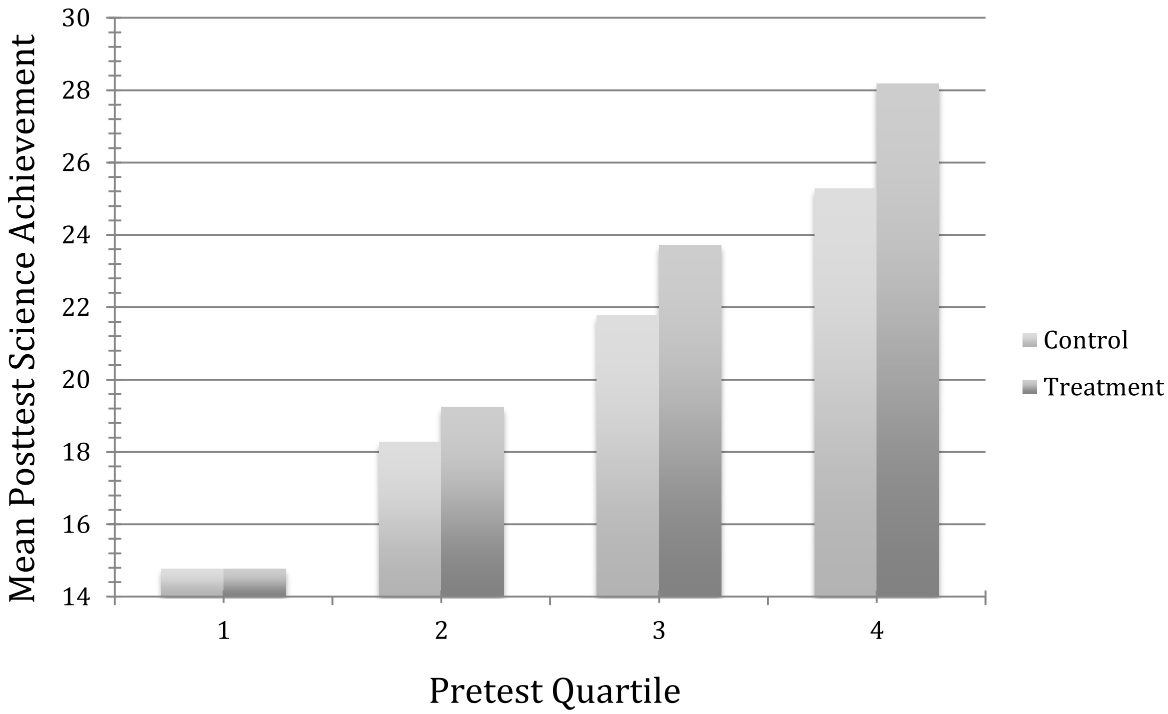

Figure 2. Predicted posttest mean science achievement by pretest quartile and condition.

One possible explanation for this result may lie in unknown variables associated with the difference in classrooms between the treatment and control groups. It could be the case that students' attitudes toward science in their CTE classes contributed to this result; in the focus groups, teachers did report variability in responses from their students.

Fidelity of treatment data revealed a rate of implementation higher than anticipated, given the limits of the semester-length implementation. Fourteen of the fifteen agricultural teachers taught all 15 lessons; 97% (219 of 225) of the scheduled lessons were implemented as scheduled. In the post-study focus groups, however, some teachers reported challenges in moving from Element 4 to Element 5 within the lessons, suggesting that the transfer of knowledge steps embedded in the pedagogic framework may not have fully been articulated in some of the lessons. It is possible this impacted the achievement of students performing in the lower quartile who may have struggled with abstractions or found it more challenging to make conceptual connections on their own.

Overall, the findings presented in this study support a contextualized learning approach. The findings are consistent with those of earlier studies conducted by Roegge and Russell (1990) and Conroy and Walker (2000). As in the Math-in-CTE study (Stone et al., 2008), the Science-in-CTE model reflects theoretical work in the areas of situated cognition and experiential learning (Brown et al., 1989; Lave & Wenger, 1991; Paige & Daley, 2009). Specifically, the seven-element pedagogical framework is congruent with the work of Kali et al. (2008) supporting the use of metacognitive approaches in science education.

Additional research should be conducted with revisions to the pedagogical model to include the increased use of inquiry which is consistent with contemporary science teaching methods and is an integral part of the national science educational standards (National Research Council, 2000). The infusion of inquiry into the overall model would be consistent with the "crucial ingredients" recommended by Bybee (2000, p. 30) for the successful implementation of inquiry in the science classroom.

A similar study should be carried out with other CTE occupational areas so that generalizations across different content areas may be drawn. Teachers who participated in this investigation volunteered to participate and were randomly assigned to groups; therefore, an element of self-selection existed. Further, teachers also received monetary compensation for their participation. Would results differ for instructors who represented a wider array of teaching abilities, levels of motivation, and CTE contexts?

The results of our analyses indicate that, relative to the control group, the intervention had a statistically significant positive impact on posttest science achievement for students in the second, third, and fourth quartiles on pretest science achievement. This supports further investigation of the integration of science in CTE classrooms. Future studies may seek to increase the amount of inquiry in the pedagogical model and apply the model to other CTE areas. The pilot Science-in-CTE study also supports continued investigation of a contextualized approach to infuse science in CTE classrooms as a means of furthering the mandate of Perkins IV to integrate CTE and academic subjects.

References

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education, 91*, 347-370.

Biological Sciences Curriculum Study. (2006). *Why does inquiry matter? Because that's what science is all about!* Colorado Springs, CO: Kendall/Hunt Publishing.

Brown, J. S., Collins, A, & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42. Retrieved from http://www.exploratorium.edu/ifi/resources/museumeducation/situated.html

Bybee, R. W. (2000). Teaching science as inquiry. In J. Minstrell & E. H. Van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 37-38). Washington, DC: American Association for the Advancement of Science.

Carl D. Perkins Career and Technical Education Improvement Act of 2006. Pub L. No. 109-270. (2006).

Choi, J., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational Technology Research and Design, 43*(2), 53-69.

Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19*(6), 2-10.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Conroy, C. A., & Walker, N. J. (2000). An examination of integration of academic and vocational subject matter in the aquaculture classroom. *Journal of Agricultural Education, 41*(2), 54-64. doi:10.5032/jae.2000.02054

Darvin, J. (2006). "Real-world cognition doesn't end when the bell rings": Literacy instruction strategies derived from situated cognition research. *Journal of Adolescent and Adult Literacy, 49*(5), 398-407. doi:10.1598/JAAL.49.5.4

Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*. New York, NY: Macmillan.

Flick, L. B. (2006). *Developing understanding of scientific inquiry in secondary students.* In L. B. Flick & N. G. Ledereman (Eds.), Scientific inquiry and the nature of science (pp. 157-172). Dordrecht, The Netherlands: Springer.

Fraenkel, J. R., & Wallen, N. E. (2003). *How to design and evaluate research in education* (5^{th} ed.). Boston, MA: McGraw-Hill.

Gilbert, J. K. (2006). On the nature of context in chemical education. *International Journal of Science Education, 28*, 957-976.

Hendricks, C., (2001). Teaching causal reasoning through cognitive apprenticeship: What are results from situated learning? *The Journal of Educational Research, 94,* 302-311. doi:10.1080/00220670109598766

Hoachlander, G. (1999). *Integrating academic and vocational curriculum: Why is theory so hard to practice?* Berkeley, CA: National Center for Research in Vocational Education, University of California.

Jacob, R., Zhu, P., & Bloom, H. D. (2009). *New empirical evidence for the design of group randomized trials in education*. New York, NY: MDRC.

Kali, Y., Linn, M. C., & Roseman, J. (Eds.). (2008). *Designing coherent science education: Implications for curriculum, instruction, and policy*. New York, NY: Teachers College Press.

Kline, R. B. (2010). *Principles and practice of structural equation modeling* (3rd ed.). New York: Guilford Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation. (Learning in doing: Social, cognitive and computational perspectives).* Cambridge, United Kingdom: Cambridge University Press.

Little, R. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association, 83,* 404.

Little, R., & Schenker, N. (1995). *Missing data.* In G. Arminger, C. C. Clogg, & M. E. Sobel (Eds.), *Handbook of statistical modeling for the social and behavioral sciences* (pp. 39-76). New York, NY: Plenum Press.

Merriam, S., Caffarella, R., & Baumgartner, L. (2007). *Learning in adulthood: A comprehensive guide* (3^{rd} ed.). San Francisco, CA: Wiley.

Moore, B. (1998). Situated cognition versus traditional cognitive theories of learning. *Education, 119*(1), 161-171. Retrieved from http://vnweb.hwwilsonweb.com/hww/results/ results_single_fulltext.jhtml;hwwilsonid=HWYHTIIZGCI4PQA3DIOSFGGADUNGIIV0

Munby, H., Taylor, J., Chin, P., & Hutchinson, N. L. (2007). Co-op students' access to shared knowledge in science-rich workplaces. *Science Education, 91*(1), 115-132.

Murray, D. M. (1998). *Design and analysis of group randomized trials*. New York, NY: Oxford University Press.

National Assessment of Educational Progress. (2005). *The nation's report card: Executive summary of science results for grades 4, 8, and 12.* Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://nationsreportcard.gov/science_2005/s0101.asp

National Committee on Science Education Standards and Assessment & National Research Council. (2007). *National science education standards*. Washington, DC: National Academy Press.

National Research Center for Career and Technical Education Curriculum Integration Workgroup. (2010, March). *Capitalizing on context: Curriculum integration in career and technical education.* Louisville, KY: National Research Center for Career and Technical Education, University of Louisville.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington, DC: National Academy Press.

Paige, J., & Daley, B. (2009). Situated cognition: A learning framework to support and guide high-fidelity simulation. *Clinical Simulation in Nursing, 5*(3), 97-103. doi:10.1016/j.ecns.2009.03.120

Raftery, A. E. (1995). Bayesian model selection in social research (with Discussion). *Sociological Methodology, 25*, 111-196.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2^{nd} ed.). Newbury Park, CA: Sage.

Roegge, C. A., & Russell, E. B. (1990). Teaching applied biology in secondary agriculture: Effects on student achievement and attitudes. *Journal of Agricultural Education 31*(1), 27-31. doi:10.5032/jae.1990.01027

Roseman, J., Linn, M. C., & Koppal, M. (2008). Characterizing curriculum coherence. In Kali, Y., Linn, M. C., & Roseman, J. (Eds.). (2008). *Designing coherent science education: Implications for curriculum, instruction, and policy* (pp. 16-25). New York, NY: Teachers College Press.

Schwartz, R. S., & Crawford, B. A (2006). *Developing understanding of scientific inquiry in secondary students.* In L. B. Flick & N. G. Ledereman (Eds.), *Scientific inquiry and the nature of science* (pp. 331-355). Dordrecht, The Netherlands: Springer.

Scott, P., Asoko, H., & Leach, J. (2007). Student conceptions and conceptual learning in science. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 31-56). Mahwah, NJ: Lawrence Erlbaum Associates.

Silverberg, M., Warner, E., Fong, M., & Goodwin, D. (2004). *National Assessment of Vocational Education: Final report to Congress.* Washington, DC: U.S. Department of Education, Office of the Under-Secretary, Policy and Program Studies Service.

Stone, J. R. III, Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Testing a model of enhanced math learning in career and technical education. *American Educational Research Journal, 45*(3), 767-795.

Valentine, J. C., & Cooper, H. (2003). *Effect size substantive interpretation guidelines: Issues in the interpretation of effect sizes.* Washington, DC: What Works Clearinghouse.

Zirkle, C. (2004). Integrating academic and occupational skills across the curriculum. *Techniques, 79*(6). Retrieved from http://www.acteonline.org/content.aspx?id=5790#integrating.

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