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Science Literacy: Exploring Middle-Level Science Curriculum Structure and Student Achievement

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Science is built up of facts as a house is of stones, but a collection of facts is no more a science than a pile of stones is a house.
-- Henri Poincare, La Science et l'Hypothese (1908)

Abstract: Although national and state science curriculum standards are based on an integrated model, there is little quantitative data supporting integration. This study explored and described the relationship between middle-level science curriculum structure and student science literacy. Specifically, it compared Connecticut science curriculum specialists' characterizations of the degree to which their school districts' middle-level science curriculum was integrated with their school districts' mean scale-scores on the standardized Middle School Science CMT. An Internet-based survey was developed specifically for use in this study. Overall, participants reported a moderate level of science curriculum integration, as well as significant inconsistencies in the planning, design, implementation, and assessment processes of their integrated science curriculums. No significant relationship was found between the characterization of degree of integration and student science achievement as measured by the eighth-grade CMT.

Keywords: curriculum, middle-level, integrated, science achievement, science literacy

Context for Examining Middle-Level Science Curriculum Structure

Science education is in a state of crisis in the United States. Once the world leader in science, the United States is losing ground relative to other nations in science literacy (U.S. Department of Education [U.S. DOE], 2011). According to the *2009 National Assessment of Educational Progress* (NAEP; National Center for Education Statistics [NCES], 2009), only 72% of fourth-graders, 63% of eighth-graders, and 60% of twelfth-graders performed at or above the basic level in science in 2009. Worse, only 34% of fourth-graders, 30% of eighth-graders, and 21% of twelfth-graders scored at the proficient level in 2009, which is the nation's goal for science achievement. Five levels of achievement are defined for these standardized tests: Below Basic, Basic, Proficient, Goal, and Advanced (Connecticut Voices for Children, 2007). In *The Nation's Report Card* (NCES, 2006), comparative science achievement data showed that national science literacy has been declining since the early 1990s, with little or no improvement in closing the achievement gap. At the same time, many other countries, particularly in Asia, have been advancing their science literacy and consistently have outranked the United States in student science achievement over the past two decades (U.S. DOE, 2011). Such a decline is alarming, since a strong academic background in science has been identified as essential to national economic success (National Science Teachers Association [NSTA], 2005), as well as to addressing world issues such as global climate change, energy shortages, human population growth, and advances in medicine (Olson, 2009; NSTA, 2005; Wagner, 2008). Science education has never been as important as it is today.

Many authors have stated that, among the factors that influence national science literacy, the most essential underpinning for science education is a coherent, consistent, and logical science curriculum framework (BSCS, 2000; DeBoer, 1991; Duschl, Schweingruber, & Shouse, 2007; NSTA, 2005; Schmidt, Houang, & Cogan, 2002). Such a curriculum framework for any particular science discipline would consist of well-defined concept and content standards, scope, sequence, and pedagogical techniques (National Research Council [NRC], 1996). Common Core's (2009) report examining the characteristics of high-achieving countries identified a coherent, content-rich curriculum as the primary factor in science academic success.

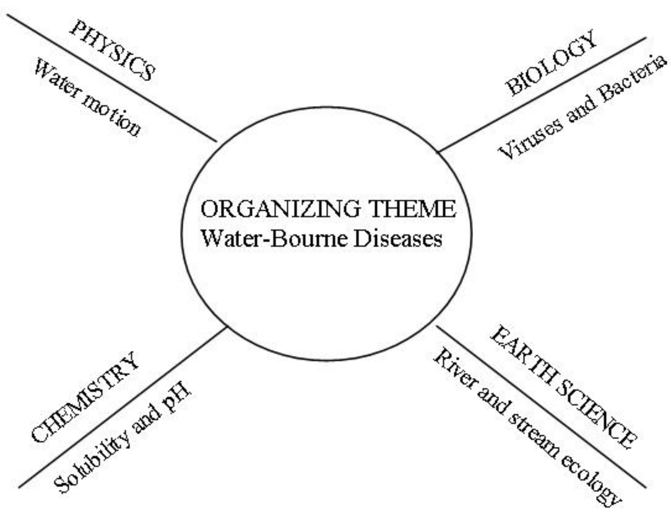
In contrast, the United States has had no single, clear, uniform national science curriculum with a defined content, scope, and sequence (Duschl et al., 2007; Common Core, 2009). Furthermore, the U.S. developed its national and state assessments before creating content standards (Common Core, 2009; U.S. DOE, 2011). Roseman and Koppal (2008) contended that this lack of uniform, national standards and the reverse order of development have been fundamental causes in the decline of U.S. science achievement.

Need for the Study

For the last five decades, the science education community has had an ongoing debate about the relative effectiveness of integrated vs. topical science curriculum structure for student science achievement. Curriculum integration in science is the deliberate connection and fusion of different disciplines (e.g., biology, chemistry) into a single curriculum, by means of the scope and sequence of learning units that enable students to construct increasingly deeper and more complex understandings of science concepts and content (BSCS, 2000; Harrell, 2010). For example, an integrated science learning unit for grade seven about water-borne diseases might include the study of bacteria and viruses (biology), water pH and solubility (chemistry), the motion of water (physics), and stream behavior (earth science). In a subsequent unit or year, these concepts and content would be reinforced and revisited in another context, such as the study of disease in the human body, or the impacts of weather events on disease transmission. In this way, the degree of structural integration in a curriculum equates to the degree of conceptual integration in a curriculum. Integrated curriculum sometimes also is called *spiral* curriculum, *interdisciplinary* curriculum, or *multidisciplinary* curriculum (BSCS, 2000), as well as *student-centered* curriculum, *core* curriculum, or *theme-based* curriculum (Drake, 2005). Under an integrated curriculum, students are expected to construct increasingly advanced knowledge every year on many science topics, as well as to make conceptual connections among the topics. Integrated curriculum typically is organized around a theme, problem, or event, so that there is a clear organizing center for teaching and learning (Drake & Burns, 2004). See Figure 1.

In contrast, a traditional, *topical* curriculum structure calls for students to study only one or two primary science disciplines each year in middle-level schools, often with a repetition of disciplines at a deeper level several years later. For example, the biological study of cells might be studied in both sixth and tenth grades. Topical curriculum structures have been acclaimed to provide students with considerable depth and retention of understanding, one topic at a time (DeBoer, 1991), but are not oriented toward encouraging students to make content and concept connections across science disciplines. Topical curriculum structure sometimes also is called *traditional* curriculum, *sequential* curriculum, *subject-based* curriculum, *discrete* curriculum, or *siloed* curriculum (Beane, 1993; DeBoer, 1991; NRC, 2012). See Figure 1.

Integrated Curriculum Model



Topical Curriculum Model

Chemistry of Matter
Atoms and Bonding
- What is chemical bonding?
- Ionic bonds
- Covalent Bonds
- Metallic Bonds
- Predicting Types of Bonds

Chemical Reactions
- Nature of Chemical Reactions
- Chemical Equations
- Types of Chemical Reactions
- Energy of Chemical Reactions
- Rates of Chemical Reactions

Families of Chemical Compounds
- Solution Chemistry

Acids and Bases
- Acids and Bases in Solution: Salts
- Carbon and Its Compounds
- Hydrocarbons
- Substituted Hydrocarbons

Figure 1. Contrasting an Integrated Curriculum Model with a Topical Curriculum Model. Integrated diagram adapted from *Interdisciplinary Curriculum: Design and Implementation*, by H. H. Jacobs, p. 57. Copyright 1989 by the Association for Supervision and Curriculum Development. Topical list taken from the Table of Contents in *Chemistry of Matter*, by A. Maton. Copyright 1994 by Prentice-Hall.

The literature is populated with many theories about the advantages of an integrated curriculum structure, including claims of improved conceptual understanding, enhanced retention of learned content, and expanded interest in the field of science (Beane, 1993; Drake & Burns, 2004; Etim, 2005; NRC, 1996; NRC, 2011). Evidence from a limited number of published case studies seemed to suggest that student engagement in science improves under integrated curriculum structures (Krajcik, McNeil, & Reiser, 2007; Nathan, Tran, Atwood, Prevost, & Phelps, 2010). However, there was a general lack of empirical evidence pointing to a relationship between curriculum structure and student achievement or literacy in science. Specifically, there seemed to be no peer-reviewed, quantitative, published studies using standardized testing data establishing a relationship between integrated curriculum structure and student science achievement. The dearth of empirical data supporting integrated science curriculum was identified by many science curriculum experts as a substantial weakness in national curriculum development (Duschl et al., 2007; George & Alexander, 2003; Krajcik et al., 2007; Pang & Good, 2000; Wineburg & Grossman, 2000), and many called for studies to examine the learning outcomes of integrated curriculum.

At the same time, several studies argued against changing from a traditional curriculum structure to an integrated structure. A number of critical articles focused on integrated curriculum's scope, sequence, and pedagogy, and how there was little or no evidence linking these teaching elements to improved student content and concept acquisition and retention (National Science Foundation [NSF], 2010). One of the strongest arguments against changing curriculum has been that the integrated structure is based upon decades-old psychological research into how students learn, without any data—especially recent data—about how students learn science (BSCS, 2000; Ellis, 2003; Harrell, 2010). In addition, a small number of case and qualitative studies identified the high cost of converting to an integrated curriculum as an impediment. These included a lack of teacher training, preparation, and coordination (Enyedy & Goldberg, 2004; Harrell, 2010; Lee, 2007; Leung, 2006), and as a mismatch between teacher certification requirements and the knowledge and skills needed to implement an integrated curriculum structure (Duschl et al., 2007).

It should be noted that both the *National Science Education Standards* (NRC, 1996), Connecticut's *Core Science Curriculum Framework* (Connecticut State Department of Education [CSDE], 2004), and draft national *Next Generation Science Standards* ([NGSS], Achieve, 2012), are based upon an integrated curriculum structure. Furthermore, the national and state standardized tests mandated by the *No Child Left Behind* legislation (NCLB, 2002), which are used to gauge the nation's and state's science achievement, are predicated upon these integrated science standards. In Connecticut, these tests are the Connecticut Master Test ([CMT], CSDE, 2009a), administered in grades five and eight for science, and the Connecticut Academic Performance Test (CAPT; Connecticut State Board of Education [CSBE], 2012), administered in grade ten. Because neither the national nor Connecticut state science standards were mandated for adoption, there has been a patchwork adoption of integrated curriculum both nationally and in Connecticut school districts (Common Core, 2009). Many science teachers have continued to be certified in individual disciplines and have continued to teach science in a predominantly topical curriculum structure. Variations in curriculum and a lack of standards for student learning have translated directly into inconsistent teaching and learning in science classrooms across the United States (George & Alexander, 2003) and Connecticut. These inconsistencies have been blamed for low scores on tests of science literacy and the international decline of U.S. science leadership (Ellis, 2003; Olson, 2009).

In summary, and despite the development of national and state models and standardized tests based on upon an integrated science curriculum structure, there has been insufficient empirical data to examine whether, in fact, integration actually improves student science literacy, especially in the important middle-level years. As stated by Rennie, Venville, and Wallace (2011, p. 140): "clearly, curriculum integration remains contested ground, both in terms of its nature and its learning outcomes." This study aimed to begin filling the gap in the literature by providing the first empirical research investigating a relationship between middle-level integrated science curriculum structure and student achievement on a standardized test.

Study Methodology

Design of the Study

A quantitative, correlational study design was selected to explore and describe the relationship between middle-level science curriculum structure and student science literacy. An exploratory design permitted a broad opportunity for generating hypotheses among the variables, given there was little pre-existing research into the concept. Specifically, the study compared Connecticut science curriculum specialists' characterizations of the degree to which their school districts' middle-level science curriculum was integrated with their school districts' mean scale-scores on the Middle School Science CMT. Science curriculum specialists were defined as professional school district personnel who had some formal responsibility for overseeing the adoption and implementation of middle-level science curriculum.

Two conceptual frameworks guided this study. Drake and Burns' (2004) conceptual model for integrated curriculum was adapted to explicate four processes to be examined when assessing the degree of integration in a curriculum structure—*Planning Integration, Designing Instruction, Implementing Instruction, and Evaluating Instruction*. Drake and Burns' model was selected because it provides a clear set of measurable factors, which they term *dimensions*, with which to distinguish the degree of integration used by a school or school district. Descriptions of the processes and their associated dimensions are presented in Table 1.

Table 1

Processes and Dimensions of Curriculum Integration (adapted from Drake & Burns, 2004)

Process Dimension	Description
Planning Integration	
Organizing Center	Defines the extent to which disciplines are organized around a theme, embed interdisciplinary skills and concepts, and reflect real-life context.
Role of Disciplines	Defines the extent to which individual disciplines are evident in the pedagogical approach.
Degree of Integration	Defines a continuum of relationships of the disciplines to each other in terms of the level of distinction or integration of the individual disciplines.
Designing Instruction	
Planning Process	Identifies the teacher's pedagogical approach to the unit, including backwards-design; basis in standards; and alignment of instruction, standards, and assessments.
Instruction	Specifies the approach used by the teacher to deliver instruction.
Assessment [design]	Identifies the assessments of learning used throughout teaching as well as the culminating or final evaluation of learning at the end of the unit of study. Includes traditional and authentic assessments
Implementing Instruction	
Conception of Knowledge	Defines how students structure their learning internally, ranging from a few interdisciplinary connections to completely merged, indistinct individual disciplines.
Role of Teacher	Defines the teacher's role on a continuum from a facilitator and specialist to a co-planner, co-learner, and generalist.
Starting Place	Designates the initial expectations for the degree of integration among the individual disciplines, and thereby sets student anticipation for the structure of knowledge acquisition.
Know?	Identifies the concepts and essential prior understandings across disciplines.
Do?	Identifies the activities used within a teaching unit, including the focal point of instruction, disciplinary skills, and interdisciplinary skills.
Be?	Defines the outcomes of the unit in terms of democratic values, character education, habits of mind, and alignment of instruction, standards, and assessment.
Evaluating Instruction	
Assessment	Identifies the degree of integration of the disciplines used in teaching unit assessments.

The second conceptual framework was an adaptation of BSCS' (2000) conceptual model for integrated science curriculum, which provided a continuum of six sequential models of middle-level science curriculum-integration. Together, the models characterized a continuum of integration from a traditional, topical curriculum to a multi-year, fully integrated science curriculum. As the models proceeded from topical to fully integrated, so, too, did content and concept integration. The continuum was defined as follows:

Model I: A traditional sequence of earth science, biology, and physical science/ chemistry, with no conceptual connections among the sciences. This model includes no integrated content.

Model II: A traditional, discipline-based sequence with some conceptual connections either (a) within each discipline or (b) between the disciplines. This model includes no integrated content.

Model III: A coordinated program with each discipline being taught each year (grades six through eight). Several variations are possible here, some with equal emphasis given to each science and some with certain sciences predominating at specific points. There is some conceptual integration and limited content integration.

Model IV: A discipline-based or coordinated program for most of each year of the three-year program, with one integrated science unit included at some point during each year, perhaps as an initial or a final unit. Conceptual integration is included in some units, and content integration is more common.

Model V: One full year of integrated science, with the other two years following the traditional, discipline-based curriculum. The integrated year would include deliberate interdisciplinary conceptual and content integration.

Model VI: Three years of a fully integrated science program, with coordinated, constant integration of concepts.

Research Questions

1. How do Connecticut science curriculum specialists characterize the degree of middle-level science curriculum-integration, as measured by the Degree of Science Curriculum Integration Survey (DSCIS; Faulkner, 2012)? Five sub-questions were included, examining each of the subscales corresponding to Drake and Burns' (2004) four processes (e.g., *Planning Integration*), and comparing the four subscales.
2. What is the relationship between respondents' DSCIS (Faulkner, 2012) scale-scores and their school districts' mean scale-scores on the Middle School Science CMT?

Data Collection Procedures

Two data sources were used in this exploratory, correlational research. The first was science curriculum specialists' responses to the DSCIS (Faulkner, 2012), which is the researcher-developed, Internet-based questionnaire created specifically for use in this study. The DSCIS was designed following the principles outlined in Dillman, Smyth, and Christian's (2009) Tailored Design Method (TDM). It contained 36 items and should have taken less than 15 minutes to complete. The survey was divided into two sections. Section I collected demographic information about respondents. Section II comprised structured statements that asked respondents to characterize their understandings of their districts' curriculum implementation in the 2010-2011 school year. Survey items were aligned with Drake and Burns' (2004) four processes, and consisted of statements such as "In my school district, middle-level assessments include content and concepts from more than one science discipline". Participants selected a response on a 5-point Likert scale (1 = *Not at all true of my district*, 2 = *Not very true of my district*, 3 = *Somewhat true of my district*, 4 = *Very true of my district*, 5 = *Completely true of my district*) that best reflected the degree to which each statement was true for their district. A pilot test of the survey, as well as three detailed verbal critiques, preceded full administration of the survey.

The study population consisted of one science curriculum specialist from each of 163 Connecticut public school districts that included one or more of the middle-level grades (grades 6, 7, or 8). This represented a purposeful sample and one of convenience, both nonprobability sampling-strategies. Participants were recruited via e-mail using their individual professional e-mail addresses through Zoomerang™ . The population that returned the survey was 49, yielding a 30% response rate. Table 2 summarizes participants' demographic characteristics.

The second data source was respondents' school districts' mean scale-scores on the Middle School Science CMT. The CMT is the State of Connecticut's standardized test for grades 3-8, mandated under NCLB (2002). All students enrolled in grades three through eight are assessed in mathematics, reading, and writing. Administration of the science test was begun in 2008 and only students in grades five and eight are assessed. CMT scores were used for this study because they are considered a valid, common, and consistent measure of student science literacy and science achievement (CSDE, 2008; NCLB, 2002). This study focused exclusively on eighth-grade test data because the middle-level years are considered by many advocates of integrated curriculum to be the most important years for developing science conceptual integration that will lead to more advanced science literacy (Beane, 1995; George & Alexander, 2003; NRC, 2011). CMT data were publically available over the Internet.

Table 2

Sample Demographic Characteristics (*N = 49*)

Characteristic	*n*	%
Gender		
Male	18	36.7%
Female	31	63.3%
Highest Level of Education		
Bachelor's Degree	—	—
Master's Degree	11	22.4%
Sixth Year Certificate or Equivalent	31	63.3%
Doctoral Degree	7	14.3%
Years Worked in Education		
1 - 4 years	1	2.0%
5 - 9 years	1	2.0%
10 - 19 years	18	36.7%
20 - 29 years	15	30.6%
30 - 39 years	12	24.5%
40 or more years	2	4.1%
Experience with Middle-Level Science Curriculum		
A little experience	2	4.1%
Moderate experience	25	51.0%
Extensive experience	22	44.9%
Current, Primary Position in School District		
Teacher	10	20.4%
Head/Lead Teacher	2	4.1%
Science Dept. Supervisor/Chairperson	20	40.8%
District Science Curriculum Specialist	10	20.4%
School Administrator	—	—
District Administrator	7	14.3%
Held Multiple Roles	—	—
Supervisory Responsibility		
Yes	20	40.8%
No	29	59.2%
Certified to Teach Science in Connecticut		
Yes	40	81.6%
No	9	18.4%

Data Analysis

The DSCIS (Faulkner, 2012) was administered and submitted via Zoomerang™, an online survey service. The raw survey data was downloaded online into a Comma Separated Value (.CSV) file, which was imported into an SPSS ® file for analysis. The 2011 Middle School Science CMT scale-score data was likewise downloaded online from the State of Connecticut Internet source (CSDE, 2011) and imported into SPSS® for analysis. For each participant, a mean district Middle School Science CMT scale-score was downloaded. Participants' zip codes, which they had entered in item 9 of the survey, were used to link respondents with their respective school district. The 5-point Likert items in Section II of the DSCIS were treated as ordinal data and summed in SPSS® to establish a DSCIS total score for each respondent. Likewise, four subscale scores, one for each of the four processes in Drake and Burns' (2004) model, were calculated by summing their related items (i.e., *Planning Integration*, *Designing Instruction*, *Implementing Instruction*, *Evaluating Instruction*). These scores were used to determine quantitative findings, such as patterns that emerged regarding participants' reports of the degree to which their school districts' middle-level science curriculum was integrated. Item frequencies, percentages, means, and standard deviations were calculated.

The DSCIS total scores were converted into DSCIS scale-scores based on the BSCS curriculum integration characterization scale. To better report and describe the results of the study, the researcher also calculated three levels—*low, moderate, and high*—for characterizing the raw total and subscale scores. For example, a DSCIS scale-score that correlated with BSCS Models I or II would be characterized as indicating a *low* level of integration. The DSCIS scale-scores then were used in a bivariate correlational analysis with the CMT data. A non-parametric Kruskal-Wallis test for independent samples was used to test for significance between the DSCIS raw subscale median scores. A series of post hoc Mann-Whitney tests were conducted to examine significance between individual DSCIS subscale groups.

Finally, the DSCIS (Faulkner, 2012) scale-scores were correlated statistically with the participants' school districts' mean scale-scores on the Middle School Science CMT by matching district scores with respondents' scores via zip code. The scale-scores assigned to data from the DSCIS (Faulkner, 2012) and the CMT scores were treated as ordinal level data. The Spearman rank (r_s) correlation coefficient was used to examine the relationship between the scores.

Findings

The first research question investigated science curriculum specialists' characterizations of the degree of curriculum integration used in their districts. Overall, participating science curriculum specialists' (N = 49) characterized their school districts' middle-level science curriculum as moderately (67.3.3%, n = 33) or highly (32.7%, n = 16) integrated. Further, each of the DSCIS subscales based on Drake and Burns' (2004) conceptual model, *Planning Integration, Designing Instruction, Implementing Instruction*, and *Evaluating Instruction*, resulted in characterizations of moderate integration. Participants' median raw DSCIS subscale scores and the frequencies and percentages of distribution of their raw subscale scores relative to the level of integration characterizations are shown in Table 3. As can been seen, the median raw scores for the four subscales range from a high of 23.00 to a low of 17.49. A non-parametric, independent-samples Kruskal-Wallis test run on the four normalized subscales revealed that there were significant differences between the DSCIS subscale scores, H (3) = 67.193, $p \leq$. .000 (significance level = .05), indicating that statistically significant differences were found in the planning, design, implementation, and assessment subscales of integration. Results of these tests are provided in Appendix A.

Table 3

DSCIS (Faulkner, 2012) Median Raw Subscale Scores, and Frequencies and Percentages of Distribution of Participants' (N = 49) Raw Subscale Scores Relative to Levels of Integration

		Levels of Integration					
		Low		*Moderate*		*High*	
	Median	*n*	%	*n*	%	*n*	%
Planning Integration	23.00	1	2.0%	43	87.8%	5	10.2%
Implementing Instruction	21.00	—	—	47	95.9%	2	4.1%
Designing Instruction	18.66	17	34.7%	32	65.3	—	—
Assessing Instruction	17.49	6	12.2%	43	87.8%	—	—

A series of post hoc Mann-Whitney tests were conducted on the six possible combinations of the four subscales (*Planning Integration* vs. *Designing Instruction*, *Planning Integration* vs. *Implementing Instruction*, etc.). The results showed a significant difference between all subscales ($Z > 1.96$) except for between the *Designing Instruction* vs. *Assessing Instruction* subscales ($Z = -.738$). Figure 2 depicts the normalized ranges of raw DSCIS (Faulkner, 2012) subscale scores.

These findings revealed three issues. First, according to science curriculum specialists, most school districts were only partially employing an integrated curriculum. Second, many districts were inconsistent in their implementation of integrated curriculum in terms of its design, planning, implementation, and assessment. Finally, the finding of no correlation between participants' reports curriculum integration and student science achievement raised anew many of the curriculum design questions posed over the last five decades.

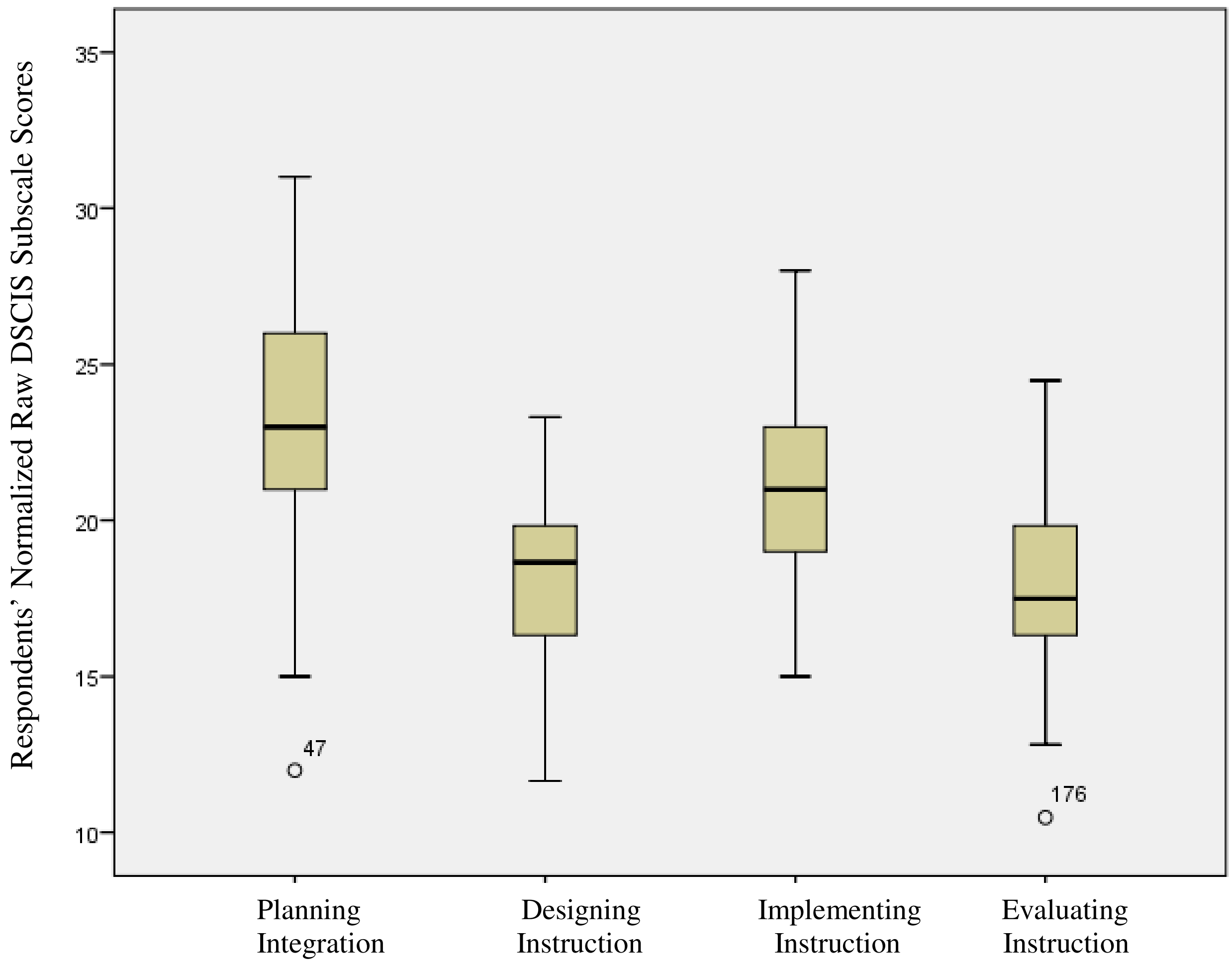


Figure 2. Comparing the normalized ranges of raw DSCIS (Faulkner, 2012) subscale scores, based on Drake and Burns' (2004) conceptual model of integrated curriculum. The vertical line for each plot indicates the full range for that subscale data set. The box encompasses the range for the second and third quartiles of the data set, and the mid-line in the box indicates the median value for that data set.

The second research question examined the relationship between respondents' DSCIS (Faulkner, 2012) scale-scores and their school districts' mean scale-scores on the Middle School Science CMT. First, the raw DSCIS (Faulkner, 2012) subscale scores for each of Drake and Burns' (2004) four processes, *Planning Integration, Designing Instruction, Implementing*

Instruction, Evaluating Instruction, were converted to the scale-scores of the six-model BSCS (2000) conceptual framework. The conversion showed that 89.8% (n = 44) of the respondents' (N = 49) characterized their curriculum as either Model III (20.4%, n = 10) or Model IV (69.4%, n = 34), indicating a *moderate* level of integration. The correlation between DSCIS scale-scores and Middle School Science CMT mean scale-scores was not statistically significant (r_s = .063, p = .334). Table 4 shows the conversion of the respondents' degrees of curriculum integration based on the BSCS scale.

Table 4
Frequencies and Percentages of Participants' (N = 49) Degrees of Integration As Characterized by the BSCS (2000) Framework and Corresponding DSCIS Scale-Scores

Level of BSCS Models	*DSCIS Scale-Scores*	*n*	%
Model I	1	—	—
Model II	2	—	—
Model III	3	10	20.4%
Model IV	4	34	69.4%
Model V	5	5	10.2%
Model VI	6	—	—

Next, a one-tailed, bivariate correlational analysis was conducted using the Spearman rank (r_s) correlation coefficient (N = 49). According to Field (2009), values of ±.50 are considered strong correlations, values of ±.30 are considered moderate correlations, and values of ±.10 indicate low correlations. As shown in Table 5, there were no statistically significant correlations. Figure 3 illustrates this lack of correlation.

Table 5
Correlational Analysis Between DSCIS Scale-Scores and Science CMT Mean Scale-Scores

Correlational Elements		*N*	Correlation Coefficient r_s (Spearman's rank)	Significance *p* (1-tailed)
DSCIS Scale-Scores	Middle School Science CMT Mean Scale-Scores	49	0.063	.334

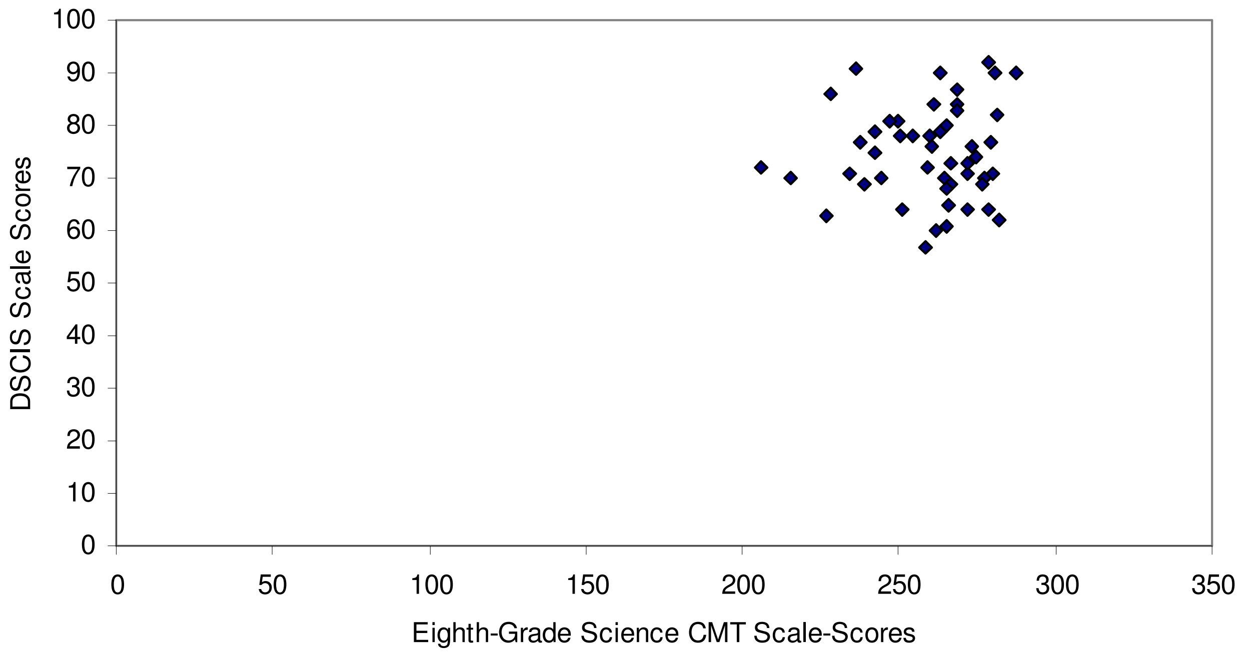


Figure 3. Correlating district DSCIS (Faulkner, 2012) scale-scores with their corresponding eighth-grade science CMT scale-scores.

Validity and Limitations of the Study

This quantitative study did not involve any experimentation. Potential threats to the study validity included mono-method bias due to the single method of measuring the dependent variable; participant selection since the science curriculum specialists were selected as a group that was both purposeful and convenient; instrumentation internal validity because this was the first application of the exploratory, researcher-developed DSCIS (Faulkner, 2012); and design reliability since this was the first time this instrument was used and there was no reliability or validity data available on the survey.

The proposed study had five limitations needing identification. First, this study was conducted using a single measure, the DSCIS (Faulkner, 2012). Second, this study used a cross-sectional survey research method based on only one point in time. The analysis was conducted with only one year of Middle School Science CMT data and one administration of the DSCIS. The results did not provide any longitudinal trend information regarding the correlation of CMT data with curriculum structure, nor did it address any other grades besides middle levels. Third, because the DSCIS collected self-reports from science curriculum specialists, data collected from respondents might not have accurately reflected the degree of curriculum integration in their respective districts, nor provided generalizable data for districts for which there was no response. Fourth, because this study was conducted only in the state of Connecticut, its conclusions might not be generalizable to other states or regions. Finally, this study assumed that the Middle School Science CMT was an accurate measure of student science literacy and was indicative of conceptual achievement by eighth-graders. Since no CMT test elements have ever been released by the State of Connecticut, this was an assumption that was unable to be verified.

Conclusions

The study's results revealed that, although science curriculum specialists characterized their districts as having adopted an overall moderate level of integration (M = 74.82, SD =8.87) with no districts remaining completely topically organized, their characterizations of integration for each of Drake and Burns' (2004) four processes showed an inconsistent and incomplete pattern of integration. This variation indicated that some aspects of instruction were more integrated than others. On the one hand, study participants reported a moderate to high intention to integrate within teaching units (*Planning Integration*, Mdn = 23.00). On the other hand, their reports of the actual implementation of integrated units revealed lower ranges. The highest of these was *Implementing Instruction (Mdn* = 21.00), for which participants reported a moderate level of integration in the implementation process. This was followed by *Designing Implementation (Mdn* = 18.66*)* and *Assessing Integration (Mdn* = 17.49) both of which were reported as having degrees of integration ranging from moderate to low. Data analysis revealed these differences to be statistically significant.

The discrepancy between the characterization by science curriculum specialists of overall science curriculum integration, and their characterization of integration in each of the four processes (Drake & Burns, 2004), revealed two issues. First, according to science curriculum specialists, many school districts are only partially employing an integrated curriculum. Second, many districts are inconsistent in their implementation of integrated curriculum in terms of its overall design, planning, implementation, and assessment. Drake and Burns (2004) exhorted the importance of thoughtful, consistent adoption of curriculum integration to ensure its success. They cautioned that inconsistent implementation of integrated science curriculum might negatively affect a district's overall student science literacy.

Correlational analysis of science curriculum specialists' characterizations of their districts' degree of middle-level science curriculum integration with eighth-grade science CMT scale-scores showed no statistical significance ($p = 0.334$). The predominant body of literature over the last three decades has touted the importance of curriculum integration in student science achievement. In addition, both existing national and Connecticut science standards, as well as the proposed new national science standards, are predicated upon an integrated curriculum structure. Nevertheless, there have been almost no empirical studies that have investigated the claim that students learn science better through an integrated curriculum structure. This study, the first of its kind, explored the claim through a newly designed survey of science curriculum specialists. That no correlation was found between participants' reports of the degree of curriculum integration and student science achievement raises anew many of the curriculum design questions that have been posed over decades.

Significance of the Study

The information gathered through this research study is significant for four reasons. First, this research fills a void in the literature that has been identified repeatedly: that there was almost no data supporting the theoretical assertions that an integrated curriculum structure improves student science literacy. Second, the study adds the voice of middle-level science educators to the national debates about adopting an integrated science curriculum standard. Third, Drake and Burns' (2004) model had not been applied specifically to examine middle-level science integrated curriculum structure, and this study expanded its use as a conceptual framework in education literature. Fourth, the data collected through this study has the potential to provide valuable insight to inform the field of science education about the implementation of integrated curriculum.

Recommendations

The findings of this study point to a number of recommendations. First, science curriculum specialists would do well to conduct an inventory of the level of science curriculum integration currently employed in their districts, to address overall intent of curriculum design, inconsistencies in its implementation, and professional development needs. The DSCIS (Faulkner, 2012) may provide a useful vehicle for such an inventory because the survey design is aligned with the common tenets of integrated curriculum design (Drake & Burns, 2004; Etim, 2005; Krajcik et al., 2007; NSTA, 2005; NRC, 2012). Moreover, the DSCIS's conceptual model is well aligned with the draft NGSS (Achieve, 2012) and may offer districts a vehicle with which to prepare for adoption of the new standards. Further validation of this instrument is needed to accomplish any future use. Second, additional research should be conducted to further explore the relationship between integrated science curriculum and student science achievement. Because there is little research on the correlation between integrated curriculum structure and student achievement, this study should be replicated and expanded. One promising approach could be grounded theory, expanding on the use of Drake and Burns' (2004) model for integrated curriculum. Adding qualitative data to DSCIS survey data could provide a more complete assessment of a district's integrated curriculum implementation. Further, this study should be repeated on a wider scale, including more districts as well as more participants from each district. It is recommended that a Bonferroni correction be applied for multiple tests.

Throughout the design, execution, and analysis of this study of integrated curriculum, there was an ongoing, broad-based, national initiative to update and revise the national science curriculum framework and standards through the NGSS (Achieve, 2012). Although not yet finalized, several key elements in the new standards are already clear: they are fully integrated among science, technology, mathematics, and engineering; they are much more rigorous both in depth and breadth of content and concepts; and they embrace real-world application at all grade levels. The new standards appear to be substantially different from existing science education standards, and as such are poised to dramatically impact school districts in teacher training, lesson and unit planning, instruction, assessment, and vertical curriculum alignment. In order to meet the demands and design of the new national framework and standards, school districts must increase their level of science curriculum integration. This improvement must be made both overall within a district and in the separate processes of designing, implementing, and assessing science learning within units and grades. This, in turn, will result in broad changes in course descriptions, content, unit sequences, and curriculum mapping. Districts can begin preparation for the NGSS by determining the level of curriculum integration currently being used, assessing teacher knowledge of integration, inventorying teacher skills and content knowledge, and otherwise assembling a profile of the district's existing readiness to change to a fully integrated curriculum. The DSCIS (Faulkner, 2012) may be a useful instrument to aid in this inventory.

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Appendix A

Statistical Analysis of DSCIS (Faulkner, 2012) Subscale Scores

Table A-1

Kruskal-Wallis Test of Normalized DSCIS (Faulkner, 2012) Subscale Scores

	ANOVA Test Field for Kruskal-Wallis Analysis of Four Subscale Groups
Chi-Square	67.193
df	3
Asymp.Sig.	.000

Note: Grouping Variable: ANOVA group for Kruskal-Wallis analysis of four subscale groups. The raw subscale scores for the *Designing Instruction* and *Evaluating Instruction subscales*, which were based on a 30-point scale, were normalized to a 35-point scale so comparisons could be made between all four subscales.

Table A-2

Mean Rank of Normalized DSCIS (Faulkner, 2012) Subscale Scores from Kruskal-Wallis Test

	ANOVA Group for	N	Mean Rank
ANOVA test field for Kruskal-Wallis analysis of four subscale groups	1	49	145.92
	2	49	68.97
	3	49	113.18
	4	49	65.93
	Total	196	

Table A-3

Descriptive Statistics from Kruskal-Wallis Test on Normalized DSCIS (Faulkner, 2012) Subscale Scores

Subscale	N	Range	Minimum	Maximum	Median	Mean	Std. Deviation	Variance
Planning Integration	49	19.00	12.00	31.00	23.00	23.25	3.65	13.34
Designing Instruction	49	11.66	11.66	23.32	18.66	18.06	2.55	6.52
Implementing Instruction	49	13.00	15.00	28.00	21.00	20.82	3.20	10.24
Assessing Instruction	49	13.99	10.49	24.49	17.49	17.80	3.07	9.45
Valid N (listwise)	49							

Table A-4

Mann-Whitney Post Hoc Test Results on Normalized DSCIS (Faulkner, 2012) Subscale Scores

	Planning Integration vs. *Designing Instruction*	*Planning Integration* vs. *Implementing Instruction*	*Planning Integration* vs. *Assessing Instruction*	*Designing Instruction* vs. *Implementing Instruction*	*Designing Instruction* vs. *Assessing Instruction*	*Implementing Instruction* vs. *Assessing Instruction*
U	251.00	719.00	308.00	600.00	1097.50	600.00
Asymp. Sig. (2-tailed)	0.000	.001	.000	.000	.460	.000
Medians	23.00 vs. 18.66	23.00 vs. 21.00	23.00 vs. 17.49	18.66 vs. 21.00	18.66 vs. 17.49	21.00 vs. 17.49
Z	06.76	-3.44	-6.35	-4.28	-.738	-4.276
Null Hypothesis	Reject	Reject	Reject	Reject	Accept	Reject

Note: The null hypothesis was that there are no significant differences ($Z > 1.96$) in the medians of the four DSCIS (Faulkner, 2012) subscale scores *Planning Integration* vs. *Designing Instruction, Planning Integration* vs. *Implementing Instruction, Planning Integration* vs. *Assessing Instruction, Designing Instruction* vs. *Implementing Instruction, Designing Instruction* vs. *Assessing Instruction,* and *Implementing Instruction* vs. *Assessing Instruction.*