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Science IDEAS: A Research-Based K-5 Interdisciplinary Instructional Model Linking Science and Literacy

Abstract

Science IDEAS is an evidence-based model that reflects interdisciplinary research findings that support the integration of literacy (e.g., reading comprehension) within science instruction in grades K-5. Presented is a framework for planning integrated science and literacy instruction in which six elements (hands-on investigations, reading, journaling/writing, propositional concept maps, application activities, prior knowledge/cumulative review) serve as a means of providing students with conceptually-coherent, in-depth science instruction. Reviewed is a multi-year Science IDEAS research initiative whose findings demonstrate the effectiveness of the model in engendering student science and reading achievement growth in grades K-2 and in grades 3-5 in a manner that facilitates positive transfer to grades 6-8. Based on the results presented and related research, curriculum policy changes that would increase the time allocated to science instruction in grades K-5 are suggested as a means of improving the present school reform movement.

Introduction

Given recent trends that indicate minimal changes in student achievement outcomes in science and reading comprehension (NCES, 2009a,b; 2012), science educators and the general public continue to be concerned about the performance of K-12 students in these two critical curriculum areas. Clearly, in providing a potential academic foundation for later success at the secondary level, instruction in elementary science in combination with content-area reading comprehension proficiency plays a critical role across grades 3-5. Yet, even with consistent recommendations from a variety of national reports (e.g., Duschl et al., 2007; NCES, 2009a,b; NRC, 2011; Snow, 2002), the amount of instructional time allocated to science education at the elementary school level has been substantially reduced in favor of increased time for narrative reading instruction (Cervetti, et al., 2006; Dillon, 2006; Jones et al., 1999). However, even with additional instructional time, reading achievement across grades K-12 remains a major unsolved problem in school reform (NCES, 2009a,b).

Given the preceding trends, an increasing number of researchers are investigating the feasibility of instructional models that lead to evidence-based solutions in which reading is embedded as an element of effective science instruction in grades K-5. In effect, there has been increased interest, advocacy and a growing body of research evidence from science education (Romance & Vitale, 2001, 2006, 2011a,b, 2012, in press) and reading researchers (Duke, 2000b; Guthrie, Wigfield, Barbosa, 2004; Guthrie, Wigfield, & Perencevich, 2004; Palincsar & Magnussom, 2001; Pearson et al., 2010) suggesting that linking science learning with forms of literacy (reading, writing, journaling, discussion) provides an effective way of accelerating student achievement in both science and literacy (e.g., reading comprehension) at the elementary level.

Keywords: science and reading, science and literacy, integrated science instruction

Science IDEAS Model: Integrating Literacy within Science

In addressing approaches for linking literacy within science in a manner that is feasible for schools to use, this article describes an integrated science-literacy model, Science IDEAS, and summarizes a series of research findings from 1992 through 2011 that provide cumulative evidence of the effectiveness of the model in simultaneously increasing student achievement in science and reading comprehension.

The Science IDEAS model was initially validated within a grade 4 upper elementary setting (Romance & Vitale, 1992) and subsequently broadened across ethnically and academically diverse classroom settings in grades 4-5 (Romance & Vitale, 2001). In more recent studies (Romance & Vitale, 2011a, 2012), the Science IDEAS model was implemented schoolwide for an entire year across grades 3-5. As a result, students in participating schools experienced three years of in-depth science instruction that impacted learning outcomes in science and reading. In such cumulative learning settings, 5th grade Science IDEAS teachers were able to offer a richer science curriculum than teachers in comparable schools because Science IDEAS students entered their classrooms with two years of prior coherent science instruction. Additionally, in many Science IDEAS schools (see following section), K-2 teachers also implemented an adaptation of the grade 3-5 model. In these schools, the cumulative growth of in-depth science learning and the associated growth of literacy proficiency were further accelerated (Vitale

& Romance, 2011). Overall, the K-5 implementation of Science IDEAS has the effect of making science instruction a schoolwide focus while also motivating other school-related events (e.g., family science night, field-trips, special assembly programs, resources for instruction) for students, teachers, and parents.

The Science IDEAS architecture combines science, reading comprehension, and writing through multi-day science lessons that integrate six Science IDEAS instructional elements (hands-on activities, reading comprehension, journaling/writing, propositional concept maps, prior knowledge/cumulative review). These six elements (see Table 1) are implemented within a conceptually-organized and grade-articulated science curriculum framework that serves as the basis for identifying, organizing, and sequencing all instructional activities (Bransford, et al., 2000; Duschl et al., 2007; NRC, 2011; Romance & Vitale, 2006; Vitale & Romance, 2011) in a manner that promotes meaningful student understanding of core science concepts.

Requirements for Implementing the Science IDEAS Model

As a validated instructional intervention (see review in following section), the Science IDEAS model is based upon an explicit set of requirements designed to insure quality implementation across multiple sites. These requirements for implementing the model are described below.

Scheduling time for integrated Science instruction.

In meeting this requirement, schools establish a schedule that earmarks from 1½ to 2 hours daily for science (with integrated reading/writing) across grades 3-5. In grade 3-5 implementations, Science IDEAS replaces all or a significant part of instructional time typically assigned to traditional reading/language arts instruction (student literature is typically addressed within a different time slot). Further, the project scheduling requirements emphasize the importance of maintaining instructional coherence by reducing the number of students (e.g., ELL, ESE, Title I) pulled-out of class during the Science IDEAS instructional block.

Providing in-depth professional development and continuing teacher support.

The Science IDEAS model does not have a specific curriculum because all schools typically follow a state or local district grade-level plan. However, within a school, teachers at each grade level are required to meet and collaboratively plan the sequence of Science IDEAS elements that will provide instruction within the established curriculum framework to be followed. As a result, professional development for grade 3-5 teachers focuses on two major areas: (a) insuring all teachers have a sound conceptual foundation of the science concepts to be taught and (b) insuring all teachers are proficient in using the six Science IDEAS elements as classroom instructional strategies.

In order to insure consistency across classrooms in implementation of the Science IDEAS model, all participating schools are required to enroll their teachers in a comprehensive professional development consisting of an initial two-week Summer Science Institute designed to accelerate teacher science knowledge and skill in using/integrating the elements of the model within the context of teaching science. Following the initial institute, teachers participate during the first and second years of the project and subsequent summers in on-going professional development opportunities as a support for and enhancement to their implementation of the Science IDEAS model within their classrooms.

Developing leadership support for intra- and inter-school implementation.

In building school capacity for sustainability, requirements include the development of school-based leadership roles for teachers to support implementation and for principals to address scheduling issues (e.g., necessary instructional time, reduction of pull-outs). In addition, leadership is necessary to insure adequate resources such as non-fiction trade book libraries, establish a schoolwide K-5 science curriculum articulation committee, involve media specialists, and incorporate Science IDEAS into school improvement plans. Eventually, in Science IDEAS, lead teachers provide an important form of capacity development for insuring sustainability of the model and for expansion to other schools (Vitale & Romance, 2009).

Monitoring fidelity of implementation.

Insuring teacher fidelity of implementation by principals is a key requirement for implementing the Science IDEAS model effectively. In monitoring fidelity of implementation, the project utilizes several approaches, including principal clinical judgment of classroom implementation complemented by classroom visitations by Science IDEAS specialists external to the school, teacher reflective surveys, and informal input from teacher leadership members. Summary reports of principal judgments are typically shared twice annually with area administrators.

Committing to evaluation activities.

Initially, participating schools have been required to cooperate with a researcher plan for assessment of student learning outcomes in science and reading comprehension through use of the Iowa Test of Basic Skills (ITBS) and, in some settings, a survey of student science attitude/self-confidence. However, as the implementations evolve, district-adopted assessment measures will replace those used for research. In addressing sustainability, a "value added" component is used to explicate how the Science IDEAS model advances district-adopted systemic goals.

Using the Science IDEAS Elements for Integrated Classroom Science Instruction

The six complementary Science IDEAS instructional elements shown in Table 1 provide teachers with the instructional components to be used in planning integrated science instruction. Teachers begin curriculum planning by focusing on the core science concepts and concept relationships (e.g., standards, benchmarks, common core standards) that are to be taught (e.g., NRC K-12 Framework for Science Education, 2011). Given this concept-oriented focus, teachers next identify specific activities and materials for investigations (i.e., hands on experiments) and reading in combination with journaling/writing and concept-mapping tasks.

Next, teachers select and sequence the different Science IDEAS elements to develop multi-day lessons that integrate reading and journaling/writing with student investigations. These instructional elements may be followed by students constructing their own concept maps and by engaging in related application tasks that include explorations of students' own questions (see Goldston & Downey, 2013; Krajcik & Merritt, 2012; NRC, 2011; Zembal-Saul et al., 2012). When completed, teachers have developed a comprehensive curriculum unit that links the elements of the Science IDEAS model with meaningful student experiences.

Initially teachers use previously constructed concept maps as a guide for planning. However, with more experience, they are able to construct multi-day lessons by using or creating curricular concept maps that represent the core concepts to be taught. Figure 1 shows an example of a curricular concept map that teachers could construct as a way of showing how the concepts that make-up the standards can be organized for instruction. This particular map illustrates how the authors thought about representing concepts that are contained within Earth Systems and Patterns, a topic area from Florida's Next Generation Science Standards for grade 5. With the map, teachers would have a conceptual framework that insures meaningful student understanding of climate, the major factors that influence both climate and the hydrologic cycle, and how, in turn, these phenomena support student understanding of the differences across the Earth's major climatic zones (e.g., tropical, temperate, polar).

Figure 1, on next page, also illustrates how adding numbers to a curricular

Table 1: *Overview of Six Science IDEAS Elements for Classroom Integration of Science and Literacy*

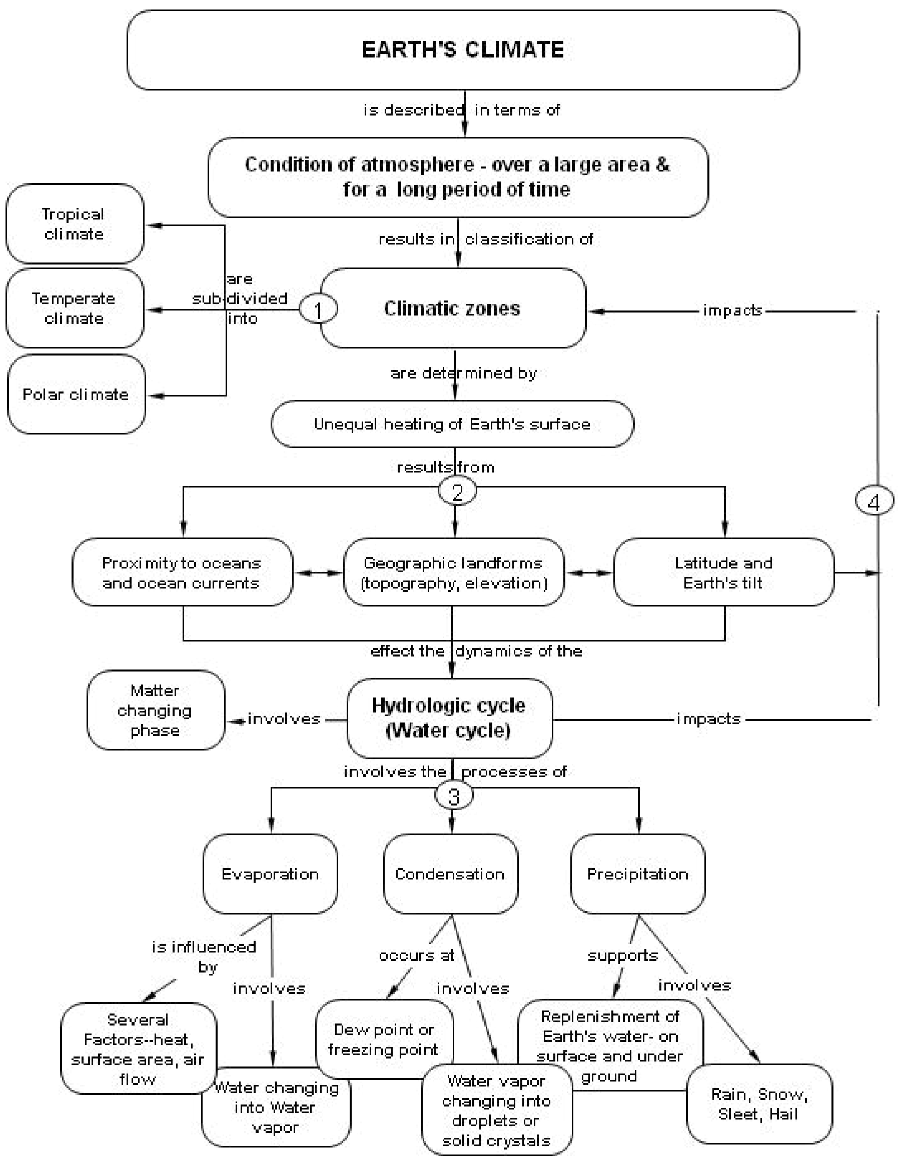
Classroom Element	Description
Prior Knowledge/Cumulative Review	All Science IDEAS instructional activities begin with a teacher assessment of student prior knowledge when introducing a new unit/topic. When the topic is a continuation of prior instruction, then a cumulative review of previously taught material is conducted. In assessing Prior-Knowledge, teachers use a strategy in which the class is asked to respond to questions about the topic(s) and then provided with differential feedback. Teachers respond to wrong answers by stating the actual question answered rather than providing negative feedback. In cumulative reviews, teachers identify and or have students identify and then describe prior activities completed on the topic(s) reviewed.
Hands-On Activities/ Inquiry/ Investigations	Student investigations and teacher demonstrations are an essential part of the Science IDEAS model. Over multi-day instructional lessons, hands-on activities provide a referential basis for introducing/teaching concepts or broadening the understanding of concepts previously introduced. Across multiple investigations addressing a specific concept/topic, students are asked to describe what happened, offer explanations as to why something happened, engage in argumentation from evidence and link the concepts being learned (and illustrated in the activity) to their explanations of the observations made and data collected. This can be done both orally and using different written formats.
Reading Comprehension	This element is a teacher-guided strategy that develops student consistency in enhancing their comprehension of the science being read by relating it to their prior knowledge. This strategy is implemented through a series of steps applied regularly to science reading materials and which evolve across the school year. Using a questioning process, teachers first model identifying prior knowledge relevant to specific parts of what is being read. Next, in re-reading, students are asked and then answer the same questions modeled by teachers. Finally, a second re-reading, students are asked to indicate prior knowledge that makes what they are reading understandable. In each phase of the process, students are guided to summarize what has been read in a section by section (cumulative) manner.
Journaling/Writing	Student journals and other writing applications involve students recording and then reflecting on what they have learned or are learning about through different learning activities. Student journals and other forms of expository writing address the concepts, facts, and details that are essential in science. Through journaling and expository writing students learn to organize and re-organize their science knowledge and learning experiences in a coherent form around core concepts and concept relationships. Student writing serves as a means for student to establish plans for and conduct investigations, construct their own explanations, ask questions, and communicate their ideas to others.
Propositional Concept Mapping	Propositional concept maps focus on the meaningful organization of conceptual knowledge. All propositional concept maps have two important characteristics: (a) concepts are arranged hierarchically with core ideas on the top, subordinate ideas below, and examples at the bottom and (b) each concept is linked to at least one other concept in a manner that each concept-link-concept (i.e., noun-verb-noun) forms a simple sentence (i.e., proposition) that represents a unit of knowledge showing concept relationships. Concept maps are used in two ways: (a) by teachers to form a coherent conceptual framework for instruction and (b) by students (with teacher guidance) to organize what has been learned and as a guide for writing.
Application Activities	These consist of individual student or group projects that involve extensions of concepts learned in multi-day lessons. Included among the types of such open-ended investigations are (a) student-generated extensions of investigations, (b) identification of internet-based sources on a selected science concept(s), and (c) reading and reporting additional information using all other available resources on selected science concept(s). All completed student application projects are reported to classmates and displayed in classroom or school bulletin boards for inspection by visitors and parents.

concept map can provide a framework for insuring coherent science instruction using the six Science IDEAS elements. For example, teachers would first insure students understood the different characteristics of tropical, temperate, and polar climatic zones. Second, using multiple investigations, teachers would develop student understanding of how unequal heating of the Earth's surface results from proximity to oceans and currents, topography, latitude and Earth's tilt on its axis. Third, teachers would engage students in explorations of and readings about the hydrologic (water) cycle and how it is affected by unequal heating of the Earth's surface that, in turn, (fourth) determines the characteristics of the three climatic zones.

The following illustrates how the Science IDEAS elements could be used to provide meaningful instruction within the curricular Earth's Climate concept framework in Figure 1.

Figure 1: *Concept Map*

Illustration of a propositional curriculum concept map used as a guide by grade 5 *Science IDEAS* teachers to plan a multi-lesson sequence of instructional activities. Numbers 1-2-3-4 indicate the general sequence of instruction.



1. ***Accessing and Building Relevant Prior Knowledge (plus reading and writing).*** Once the conceptual framework has been established (i.e., Earth's Climate concept map), instruction would begin with teachers querying students to determine their prior knowledge about how the Earth's climatic conditions differ around the world. Teachers could use world maps or globes and have students describe what they know about each of the major climatic zones on Earth. As necessary, teachers also could describe the different characteristics of Earth's climatic zones. For example, teachers might select the polar zone and begin a class discussion by having students recall their prior knowledge about the polar climatic zone. Teachers could then add details to the discussion such as the location of the polar zone (e.g., using the idea of latitude to show how far north or south of the Equator the polar zones are located). In doing so, teachers would be both accessing and building relevant prior knowledge. As a follow-up, teachers also could include student journaling/writing and introductory reading about climate, in general, and about specific climatic zones.
2. ***Science Investigations (plus reading and writing).*** After establishing the conceptual context (e.g., Earth's climatic zones) for learners, teachers could then engage students in a variety of investigations and related activities (e.g., hands-on activities, reading non-fiction trade books, using journaling/writing to create informational booklets) that together lead to student understanding of the contributing factors that influence the Earth's climatic zones (e.g., unequal heating of the Earth's surface, proximity to bodies of

water and ocean currents, geographic landforms/topography, and latitude and tilt of the Earth). Considered together, the sequencing of multiple investigations and reading across multiple sources of science materials complemented by journaling/writing all deepen student understanding of factors that affect the hydrologic (water) cycle. For example, teachers could have students generate a list of common characteristics that exist across climatic zones that would be confirmed or disconfirmed by the evidence gathered through investigations or additional reading, or both. Students also could investigate the impact of a strong heat source (e.g., heat lamp or sun) on the heating and cooling of a sample of Earth materials (e.g., sand, soil, water, and rocks).

3. ***Science Investigations (plus reading and writing).*** Using a combination of multiple investigations and the reading of multiple print and Internet-based resources along with supporting journaling/writing, teachers next would guide student understanding of the processes that underlie the hydrologic (water) cycle and how these processes are affected by factors (addressed in 2 above) resulting in unequal heating of the Earth's surface. For example, students could investigate the factors that slow down or speed up the processes of evaporation and condensation (e.g., change in temperature, air flow, surface area, changes in pressure).
4. ***Cumulative Review, Further Reading and Writing, and Construction of Concept Map.*** Finally, based on what students have learned in (2) and (3), teachers engage students in a class discussion designed to guide student explanations as to why the general atmospheric conditions of Earth's climatic zones vary and why climatic zones may persist for long periods of time. As a multi-lesson review, teachers guide students in remembering how the data and observations resulting from their investigations along with what has been read, class discussions, and reflective and expository journal writing all contribute to their understanding of climatic differences. For each of these related science concepts teachers could engage students in application projects that illustrate key practices of science as identified in the NRC (2011) Framework for K-12 Science Education (e.g., constructing explanations, engaging in argumentation from evidence, obtaining, evaluating, and communicating information). In doing so, teachers can enhance and deepen different aspects of understanding of the Earth's climate. For example, upon completion of investigations and reading across multiple sources, teachers may guide whole class construction of a concept map on climate (similar to the one illustrated in Figure 1). In turn, in Science IDEAS, the concept map also serves as an organizing structure for expository writing with each cluster of concepts potentially representing a paragraph.

Although the role of investigations (experiments, demonstrations) and journaling/writing are recognized as key elements of science instruction, it is important to elaborate on the role of reading comprehension/literacy development, propositional concept mapping, and applications tasks within the Science IDEAS model. In the present illustration, science learning is enhanced by embedding multiple sources of non-fiction, content-area reading materials (e.g., NSTA recommended trade books and web sites [www.scilinks.org, key word: weather/climate] that describe Earth's climatic zones) directly into science teaching in a manner that results in a synergistic relationship between science learning and content-area reading comprehension in science. Unlike narrative stories in basal reading series, the integrated Science IDEAS model provides teachers with an explicit strategy (see Table 1) for guiding students accessing relevant prior knowledge gained through instruction (e.g., reading, hands-on experiences) as they cumulatively deepen their understanding of the topic.

In Science IDEAS, propositional concept maps (see Figure 1) initially serve as tools for teachers to organize the science concepts into a coherent conceptual framework that serves as the basis for the multi-day lessons (see Scienceideas.org). Eventually, as both teachers and students gain experience with Science IDEAS, teachers guide student construction of an overall (e.g., Earth's Climate) or sub-concept map (e.g., hydrologic [water] cycle). Student construction of even simplified concept maps helps them visualize the concept relationships and serves as a blueprint for expository writing. Constructing concept maps involves writing the concepts on sticky notes, arranging the sticky notes in a hierarchically meaningful fashion, and then adding the links (verb phrases) to represent a complete conceptual relationship. An important benefit is the discussion among students regarding the concept relationships comprising the maps and how to organize them.

Although application/project tasks were mentioned in the illustrative lesson, it is important to emphasize that the scope of such student projects is broader than just hands-on investigations. Rather, application/project tasks provide students with an opportunity to expand and deepen their understanding of what has been learned by engaging in different types of expansion tasks (e.g., applying the concepts learned to new situations, conducting new open-ended investigations) that are designed to apply what has been learned to novel contexts. Within Science IDEAS, application/project tasks are an important way of encouraging students to learn more about what they have been learning.

Characteristics of Mature Science IDEAS Implementations

As implementations of Science IDEAS evolves in school settings, teachers become able to engage in a variety of mutually supportive initiatives. Included among these are continuing efforts to refine and enhance their grade-level science planning and their schools K-5 science curriculum articulation process. These two factors insure that as students progress through grades, they experience a conceptually coherent curriculum (along with progressively more advanced levels of understanding of core science concepts, see Duschl et al., 2007). Paralleling this is the capability of experienced Science IDEAS teacher leaders to provide ongoing mentor support to new teachers as well as to engage in collaborative activities between schools and in professional presentations for disseminating the model. In general, Science IDEAS has been an effective vehicle for supporting the professional growth of participating teachers.

Another important characteristic of Science IDEAS schools is the display of student work (e.g., writings, graphs/pictures, concept maps, journals, scientific models, experiments, projects) in classrooms and throughout the school. Such displays are highly motivating to students and of great interest to parents and other visitors to schools.

Research Evidence in Support of the Effectiveness of the Science IDEAS Model

The proposition that replicability of research findings in diverse settings is the goal of all scientific enterprises (Sidman, 1960) provides a framework for interpreting the multi-year findings associated with the Science IDEAS model presented in this section. In a parallel sense, the multi-year findings are consistent with the concept of "patch" experiments and the associated implications for external validity outlined by Campbell and Stanley (1963). The cumulative findings reported in this section provide an aggregate form of evidence of the effectiveness of the Science IDEAS model.

Although the cumulative research findings associated with Science IDEAS encompass a variety of student performance outcomes (e.g., affective judgments of students, qualitative observations of Science IDEAS classrooms, student-constructed products), this section is limited to student achievement outcomes as measured by nationally-normed standardized tests in science and reading.

Table 2 (Romance & Vitale, in press) overviews the series of student achievement outcomes associated with implementation of the Science IDEAS model reported in the literature and other professional outlets from 1992 through 2011. Because the emphasis here is on the pattern of findings, methodological details in the original sources are not presented. However, it is important to note the methodological commonalities in all of the following overviews. First,

Table 2. *Multi-Year Research Findings: Implementing Science IDEAS across Multiple Classrooms and Schools*

Year(s)	Grade(s)	Duration	Participants	Significant Effects of the Science IDEAS Intervention on Student Achievement [a, b]
Early Studies in Grades 4, 5				
1992	4	1 year	3 classes	*Initial Science IDEAS study:* +.93 GE difference on MAT Science, and +.33 GE difference on ITBS Reading
1993	4	1 year	3 classes	*Replication:* +1.5 GE difference on MAT Science, and +.41 GE difference on ITBS Reading
1996	4-5	5 months	15 classes	*Primarily at-risk students:* Grade 5- +2.3 GE mean difference on MAT Science, and +.51 GE difference on ITBS Reading. Note- Grade 4 effects were not significant in this 5-month study
1998	4-5	1 year	45 classes	*Regular and at-risk students:* + 1.11 GE difference on MAT science, and +.37 GE difference on ITBS Reading
Recent Longitudinal Study: Direct Effects in Grades 3, 4, 5 and Indirect/Transfer Effects to Grades 6, 7, 8				
2002-2007	3-5	multi-year	12 schools	*Schoolwide implementations in grades 3-5, cross-sectional longitudinal study with transfer effects assessed in grades 6-8:* +.38 GE difference on ITBS Science, and +.32 GE difference on ITBS Reading across grades 3-8, with the differences on grades 6-8 demonstrating consistent transfer effects from grade 3-5 on both science and reading.
Recent Studies in Primary Classrooms (K, 1, and 2)				
2005	1-2	8 weeks	2 schools	*Schoolwide implementation (Note- K and grade 1 students were tested at the beginning of their following year in grades 1 and 2 respectively):* Grades 1-2 Overall: +.42.GE difference in ITBS Science. Grade 2: +.72 GE difference in ITBS Reading. Note- Grade 1 effect was not significant on ITBS Reading.
2007	1-2	1 year	2 schools	*Schoolwide implementation:* +.16. GE difference on ITBS Science, and +.58.GE on ITBS Reading

Note. MAT: *Metropolitan Achievement Test*, **ITBS:** *Iowa Tests of Basic Skills*, **GE:** *Grade Equivalent Scale Score*

[a] Research studies in Table were reported in articles/papers: Romance & Vitale (1992, 2001, 2008, 2011, 2012, in press) and Vitale & Romance (2011, in press) .

[b] All studies used demographically-comparable classes/schools as controls. All statistical analyses models incorporated one or more control variables to statistically equate experimental and control students (e.g., gender, race, Free/Reduced Lunch Status, prior academic achievement) before comparing achievement outcomes. All analyses findings presented in this Table are statistically-adjusted mean differences between Science IDEAS and Control students.

all studies reported here were conducted in multicultural urban school systems in southeastern Florida having a wide range of student demographics (e.g., ability levels, ethnicity, parental income). Second, in each study, both student and school demographics (ability, ethnicity) of comparison groups were similar to those of the experimental groups. Third, the method of data analysis was a general "ordinary least squares" (OLS) linear or a multilevel modeling approach in which prior reading and/or science achievement and/or student demographics typically correlated with prior achievement served as covariates providing statistical controls. And, fourth, all student achievement outcomes reported here consisted of nationally-normed science (ITBS, MAT) and reading (ITBS, SAT) achievement measures.

Patterns of research evidence: Early studies conducted from 1992 through 1998.

The research completed from 1992 through 1998 consisted of a series of studies conducted in authentic school settings, typically over a school year. In the first study (Romance & Vitale, 1992), three grade 4 classrooms in an average performing school implemented the Science IDEAS model over a school year. As Table 2 shows, the achievement results found that Science IDEAS students outperformed comparison students by approximately one year's grade equivalent (GE) in science achievement (+.93 GE) and one-third of a GE in reading achievement (+.33 GE). In the second (replication) study (Romance & Vitale, 2001) conducted the following school year, Science IDEAS again was implemented with the same three teachers/classrooms in grade 4. The results of this second year replication showed similar levels of achievement effects, with Science IDEAS students outperforming comparison students by +1.5 GE in science and +.41 GE in reading (Romance & Vitale, 2001).

In the third and fourth studies, (Romance & Vitale, 2001), the model was tested more broadly by (a) using an increased number of participating teachers, (b) expanding the grade level range to include grades 4 and 5, and (c) increasing participant diversity by including at-risk students. Results of the year 3 study found that low-SES (predominantly African-American) Science IDEAS at-risk students in grade 5 significantly outperformed comparable controls by +2.3 GE in science and by +.51 GE in reading over a 5-month (vs. school year) intervention. However, in contrast with earlier findings, no significant effect was found for the younger grade 4 at-risk students for the 5-month intervention.

In the last study in the series (Romance & Vitale, 2001), the number of teachers was increased to 45 teachers in 15 school sites and the model implemented for a full school year. Results of the fourth study found that Science IDEAS students displayed greater overall achievement on both science (+1.11 GE) and reading (+.37 GE). In addition, grade 5 students outperformed grade 4 students while regular students outperformed at-risk students. However, unlike the 5-month, year 3 study, no interactions were found, indicating that the year-long Science IDEAS intervention was consistent across both grade levels (grade 4 and grade 5) and with both regular and at-risk students.

Patterns of research evidence: Recent longitudinal study from 2002 through 2007.

While all the preceding studies (1992-2001) focused on individual teachers/classrooms located in different school sites, beginning with 2002, the Science IDEAS research framework focused on two complementary initiatives. The primary initiative (Romance & Vitale, 2008) involved implementing Science IDEAS on a schoolwide basis in grades 3-4-5 in an increasing number of participating schools (from 2 to 12 over the multi-year project). Increasing the number of schoolwide interventions provided a framework for the study of issues relating to scale-up of Science IDEAS model through a project supported by the National Science Foundation. The secondary initiative consisted of small-scale studies embedded within the overall scale-up project that explored the adaptation of the Science IDEAS model to grades K-2 (Vitale & Romance, 2011, in press).

This section presents the longitudinal direct and transfer effects of Science IDEAS on student achievement in science and reading across grades 3-8 (Romance & Vitale, 2011a,b). Table 2 shows the cross-sectional effect of Science IDEAS across grades 3-8 on ITBS science and reading achievement across 12 participating and 12 comparison schools obtained in 2007. In the study, students in grades 3-5 received Science IDEAS instruction while students in grades 6-8 had previously received Science IDEAS instruction while in grades 3-5 (e.g., grade 8 students would have received Science IDEAS in grade 3 in 2002). So, middle schools designated as Science IDEAS schools were in feeder patterns aligned with Science IDEAS elementary schools. In considering the research design, students in grades 6-7-8 (who had previously attended Science IDEAS or comparison schools) were considered as extensions of the Science IDEAS or comparison school they attended in grade 5. In this context, performance of Science IDEAS students in grade 6-8 provided evidence of a transfer effect from grade 3-5 instruction. Both Science IDEAS and comparison schools in the study were comparable demographically (approximately 60% minority, 45% free/reduced lunch).

In interpreting the science achievement trajectories reported in Table 2, linear models analysis found Science IDEAS students obtained higher overall ITBS science achievement than comparison students (adjusted mean difference = +.38 GE in Science with grade level differences ranging from +.1 GE to +.7 GE). Both Treatment Main Effect and Treatment x Grade Interaction were significant, indicating that the magnitude of the treatment effect increased with grade level. Covariates were Gender and At-Risk Status (Title I Free/Reduced Lunch).

In interpreting the reading achievement trajectories shown in Table 2, linear models analysis found Science IDEAS students obtained higher overall ITBS reading achievement than comparison students (adjusted mean difference = +.32 GE in reading with grade level differences ranging from .0 GE to +.6 GE). While the overall treatment main effect was significant, the treatment x grade level interaction was not. Covariates were Gender and At-Risk Status (Title I Free/reduced Lunch).

Other results of the analyses were (a) the treatment effect was consistent across at-risk and non-at-risk students for both ITBS science and reading, and (b) girls outperformed boys on ITBS Reading (there was no gender effect on science).

Elaborative Science IDEAS mini-studies in grades K-2.

A supporting research initiative consisted of two small-scale studies embedded within the overall NSF scale-up project that explored extrapolations of the Science IDEAS model to grades K-2. This section overviews the pattern of findings for these two studies.

The objective of the initial K-2 mini-studies (see Vitale & Romance, 2011, in press) was to adapt and assess the effectiveness of the grade 3-5 Science IDEAS model in grades K-2. Unlike the grade 3-5 model in which science replaced reading instruction, in grades K-2, teachers only incorporated a 45 minute science instruction block into their daily schedules consisting of developmentally appropriate Science IDEAS elements while continuing their daily basal reading instruction. Because of test scheduling issues at the end of this 8-week study (Vitale & Romance, 2011), participating experimental and comparison grade K and grade 1 students could not be tested until the beginning of the following school year as grade 1 and grade 2 students, respectively. The results (see Table 2) of this initial 8-week study found an overall main effect in favor of Science IDEAS students on both ITBS science (+.28 GE) and reading (+.42 GE). However, for ITBS reading, a significant treatment x grade level interaction was found and subsequent simple effects analysis showed a significant difference of +.72 GE in grade 2 on ITBS reading, but no effect in grade 1.

The objective of the next grade 1-2 mini-study (Vitale & Romance, in press) was to assess the effectiveness when implemented over a full school year. Results of this year-long study (see Table 2) found significant overall main effects in favor of Science IDEAS students on both ITBS science (+.16 GE) and reading (+.58 GE). Overall, the treatment was found to have had a consistent effect across grade levels and student demographic characteristics (ethnicity, gender).

Summary of the pattern of Science IDEAS research findings.

The major conclusion from the multi-year pattern of findings shown in Table 2 is that Science IDEAS has been consistently effective in accelerating student achievement in both science and reading in grades 3-4-5. In addition, the longitudinal findings shown in Table 2 provide strong evidence in support of a positive transfer effect of grade 3-5 Science IDEAS intervention on student science and reading achievement in grades 6-8. Of importance in interpreting these findings is that the magnitude of the effects expressed in grade equivalents on nationally-normed tests (ITBS, SAT, MAT) is educationally meaningful. Because in grades 3-4-5 Science IDEAS replaces regular basal reading instruction, the effectiveness of the Science IDEAS model which emphasizes in-depth, cumulative, conceptual learning offers major implications for curricular policy at the upper elementary levels for increasing the instructional time for integrated science instruction. Supporting this policy is the finding that the effects of Science IDEAS in grades 3-4-5 were transferable to improved student achievement in grades 6-7-8.

Other Research Initiatives Linking Science and Literacy

Other ongoing research initiatives reported in the literature also are supportive of the implications presented in this paper. For example, Cervetti et al., (2006) reported the results of studies addressing the role of reading in the service of learning science through their "Roots and Seeds" curriculum. In their model, students first conduct hands-on experiments to illustrate science concepts which are followed by science reading assignments. Duke and her colleagues (Duke, 2000b, 2007; Duke et al., 2002) conducted a series of studies using informational texts in primary grades. These studies addressed an important instructional deficiency identified in earlier work in which Duke (2000a,b) reported a scarcity in the use of informational texts at the primary levels. In related work, Duke and Pearson (2002) reported the results of studies addressing use of informational text to build reading comprehension (see also Maniates & Pearson, 2008).

In research related to the Science IDEAS model, Guthrie and his colleagues (Guthrie & Oztgungor, 2002; Guthrie, Wigfield, Barbosa, 2004; Guthrie, Wigfield, & Perencevich, 2004) conducted a series of studies showing consistent improvement in student reading comprehension and motivation-to-learn resulting from embedding science-focused instructional modules into traditional reading programs using their CORI model. Complementary essays by Hirsch (1996, 2006) addressed the cumulative learning of academic content as a major systemic deficiency in U.S. elementary schools.

In other related research, Palincsar and her colleagues (Hapgood, Magnusson, & Palincsar, 2004; Hapgood & Palincsar, 2007; Magnusson & Palincsar, 2003; Palincsar & Magnusson, 2001) conducted studies investigating the interdependency of hands-on activities and reading about the science concepts on student science and literacy performance. And Weaver & Kintsch (1995) reported investigations of the role of prior knowledge in reading comprehension consistent with Kintsch's (1988, 1998, 2004) reading comprehension model. As a representative sample of related work, all of these studies are consistent with the general interdisciplinary foundations of the Science IDEAS model.

Implications for School Reform

The instructional perspectives and research findings presented offer implications for school reform (Vitale & Romance, 2006). Together, they are suggestive of the means by which K-5 schools and school systems could raise their student achievement expectations in science and reading. From interdisciplinary research (Bransford et al., 2000), the idea of conceptually-focused instruction provides a powerful framework for considering content area learning in science as a necessary basis for reading comprehension development (see Vitale & Romance, 2007). A related implication is that corresponding changes in the design of tests used for accountability in K-5 schools should focus more on content-area understanding (vs. generic reading skills). In addition, research on scale up (Vitale & Romance, 2009) has recognized the importance of explicitly developing an organizational infrastructure and complementary base of specialized expertise (as capacities) as necessary for initiating, sustaining, and expanding the implementation of research-validated instructional interventions such as Science IDEAS.

If the implications from the research presented are sound indicators, redirecting school reform initiatives to emphasize the integration of reading within science instruction could yield a greater degree of systemic improvement in the academic performance of all students. Although working toward the implementation of such research-based implications is a significant challenge, given the present state of progress in education reform, accepting such challenges is a better alternative than simply pursuing "more of the same" (see Walsh, 2003). Within the preceding context, the Science IDEAS model, along with other related research initiatives have the potential to contribute positively toward school reform. As a research-validated, integrative model, Science IDEAS offers K-5 school practitioners an evidence-based alternative to increase student achievement expectations that, potentially, could positively impact different aspects of student learning across the K-12 grade range.

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