Expanding the Role of K-5 Science Instruction in Educational Reform: Implications of an Interdisciplinary Model for Integrating Science and Reading

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Addressed is the current practice in educational reform of reducing time for science instruction in favor of traditional reading/language arts instruction. In contrast, presented is an evidence-based rationale for increasing instructional time for K-5 science instruction as an educational reform initiative. Overviewed are consensus interdisciplinary research and complementary multi-year findings of the Science IDEAS model demonstrating the effectiveness of integrating conceptually-relevant reading within science instruction in improving student achievement in both science and reading comprehension. Based on research summarized, increasing time for integrated K-5 science is advocated as a meaningful reform-based approach to science learning and reading comprehension proficiency that, in turn, better prepares students for subsequent success in science and content-area reading comprehension across upper elementary and middle school grades (3–8).

Even after several decades of educational reform, student achievement in science and reading as presented in international and national reports has remained a systemic problem (Grigg, Lauko, & Brockway, 2006; Lutkus, Lauko, & Brockway, 2006; National Assessment of Educational Progress (NAEP), 2003, 2005a; National Center for Education Statistics (NCES), 2009; Schmidt, McKnight, & Raizen, 1997; Schmidt, McKnight, Cogan, Jakwerth, & Houang, 1999; Schmidt et al., 2001; Stephens & Coleman, 2007). In a related fashion, another significant barrier to achievement is the inability of K-12 students across all socioeconomic status (SES) strata to deepen their learning by building the conceptual representations necessary to comprehend science textbooks (American Federation of Teachers [AFT], 1997; Donahue, Voeki, Campbell, Mazzeo, 1999; Feldman, 2000; Snow, 2002). This finding is particularly damaging for low SES students who depend on school to learn (Gamse, Bloom, Kemple, Jacob, 2008; Kemple, et al., 2008; James-Burdumy et al., 2006, 2009; NCES, 2009). From a combined perspective, when reaching high school, students from all SES strata have neither the prior conceptual science knowledge to perform successfully in secondary science courses nor the more general capacity for building the coherent mental representations necessary for content-area text comprehension (van den Broek, 2010).

This paper presents implications for curricular policy by addressing the need to increase time for science instruction for all K-5 students. These implications are based primarily on the extensive multi-year research of an interdisciplinary instructional model (Science IDEAS) in which in-depth, daily science instruction (e.g., multiple conceptually focused, inquiry-based instructional learning experiences) incorporating reading and writing replaces traditional reading/language arts instruction in grades 3–5 (Romance & Vitale, 2001, 2011). Also presented are the results of a modified grades 3–5 version of Science IDEAS, which expanded daily science instruction in grades K-2 (Vitale & Romance, 2010, 2011) and other related findings in the literature (Duke, 2010; Guthrie & Ozgungor, 2002; Pearson, Moje, Greenleaf, 2010). All of these are suggestive of changes in curricular policy that would increase the allocated instructional time for science across grades K-5.

In focusing on the issue of systemically reforming K-5 science, this paper addresses five important and interrelated considerations including: (a) lack of time for science instruction as a barrier in K-5 reform, (b) implications following from the lack of conceptually-linking science and reading on short- and long-term science achievement, (c) interdisciplinary research perspectives providing a strong rationale for explaining how and why content instruction (e.g., science) supports reading comprehension proficiency development, (d) the potential contribution of an integrated science and reading instructional model on improving K-5 reading comprehension, and (e) considerations for engineering changes in curricular reform for increasing the instructional time allocated to K-5 science instruction. The argument advanced is that consensus research showing how science instruction incorporating conceptually-related reading and writing experiences is a key factor for enhancing science learning while also developing general student reading comprehension proficiency. Such an argument can be used by science educators to advocate for increased instructional time allocated to science instruction in grades K-5. In describing the effects of the K-5 Science IDEAS instructional model (discussed in a later section), the paper also will present parallel reform issues on student achievement outcomes identified by Johnson, Fargo, and Kahle (2010).

Time Devoted to K-5 Science Instruction as a Systemic Barrier to Reform in Science Education

The current lack of instructional time devoted to in-depth science teaching in elementary schools (Dillon, 2006; Jones et al., 1999; Klentschy & Molina-De La Torre, 2004) has been identified as a key issue in science education reform (Hirsch, 1996; Vitale, Romance, & Klentschy, 2006) as has the ability of students to comprehend science text materials (Chall & Jacobs, 2003; Guthrie & Ozgungor, 2002; Pearson et al., 2010). The present reform-driven reduction in time devoted to science instruction (Dillon, 2006; Rillero, 2010) is in direct contrast to the growing body of research (Duke, 2010; Guthrie, Wigfield, & Perencevich, 2004; Hapgood, Magnusson, & Palincsar, 2004; Klentschy & Molina-De La Torre, 2004; Romance & Vitale, 1992, 2001, 2007, 2011) indicating that combining forms of literacy (e.g., reading multiple sources and genres, writing/journaling, oral discourse) with in-depth science learning results in student achievement gains in both domains.

At present, elementary students seldom engage in the forms of content-area reading that enable them to develop the natural linkage between everyday language and the discourse practices of science (Klentschy & Molina-De La Torre, 2004; Norris & Phillips, 2003; Romance & Vitale, 2011; Webb, 2010). As a result, K-5 students have few contextually rich opportunities to build the background knowledge and inquiry/reasoning skills associated with meaningful conceptual understanding in science and reading comprehension proficiency in content domains. Even with strong advocacy from reading researchers to integrate literacy with science (Chall & Jacobs, 2003; Duke, 2010; Guthrie & Ozgungor, 2002; Pearson et al., 2010; Snow, 2002), little increase in time for "reading to learn" is occurring in schools. When considered from a broader perspective, the evidence suggests that the United States is neither providing the general population with the levels of literacy in science (Krajcik & Sutherland, 2010) necessary to support learning complex science concepts (van den Broek, 2010) nor the level of reading comprehension proficiency necessary for being successful in the workplace and acting as informed citizens (Duschl, Schweingruber, & Shouse, 2007; NAEP 2003, 2005a).

Current research in elementary science instruction and learning has focused on improving specific science teaching practices in limited contexts rather than on systemic changes that would broadly affect student achievement outcomes (Vitale, Romance, & Crawley, 2010). Given the complexity of science teaching and learning as well as the need to engender improvements in science achievement outcomes, it is no surprise that focusing on singular factors associated with science teaching and learning (e.g., hands-on science; professional learning communities) has not lead to achieving the desired systemic reform goals in science education (Johnson, Fargo, Kahle, 2010). Both the research literature and national commission reports suggest that there are important instructional and curricular factors (e.g., teacher content knowledge, sustained professional development, the availability of core concept curricular frameworks as the basis for identifying and sequencing content standards and as the blueprint for school curriculum linking science and literacy, school-level support infrastructure, evidence-based decision making) that after over 20 years have not yet been addressed in a coordinated fashion in authentic educational settings (Johnson et al., 2010).

Certainly, the present instructional approach that addresses science separately from conceptually related reading/writing experiences has not contributed to an overall improvement in either science or reading comprehension outcomes across grades K-5. Even more troubling are the externally mandated factors stemming from local, state and national accountability-driven policies (e.g., No Child Left Behind [NCLB]—Reading First requirement for 90 minutes of uninterrupted daily reading across K-5) which negatively impact time for K-5 science instruction (Johnson & Marx, 2009). In further supporting this point, Jones et al. (1999) reported that in an effort to improve reading outcomes, increases in instructional time have been allocated to the use of basal reading programs which have little to no content focus and are not designed with science learning in mind. Some researchers have suggested that current instructional practices essentially deny students the opportunities they need to develop the rich background knowledge necessary for cumulative science learning (Romance & Vitale, 2006) and for propelling reading comprehension (Hirsch, 1996, Norris & Phillips, 2003; Walsh, 2003).

From a broader K-12 perspective, (AFT, 1997; Feldman, 2000; Schmidt et al., 1997), the lack of student success in high school science courses is readily understood. Specifically, to be successful in high school science, students must have developed the prior conceptual knowledge, which serves as a major foundation of subsequent meaningful learning (Bransford, Brown, & Cocking, 2000; Hirsch, 1996, 2003). When students lack the relevant prior understanding required for success, teachers must alter their curricular focus by addressing more basic, remedial content-based deficiencies instead of the appropriate level of rigor required of high school subject matter courses (e.g., biology, chemistry). When they do so, teachers essentially are forced to build the prerequisite science content knowledge not acquired by students in preceding grades. Thus, lack of effective science instruction in K-5 classrooms has a cascading negative effect on the degree to which middle school science instruction can adequately prepare students for high school science courses (e.g., biology, physical science) and, for many students, possible Science, Technology, Engineering, and Mathematics (STEM) careers.

Impact of Disconnectedness among Science and Reading Educators on Reading Comprehension within K-12 Science Education

A related perspective as to why students do not develop adequate prior knowledge at the elementary and middle school levels is that schools approach "reading comprehension" as a major curricular emphasis, presumably in preparation for high-stakes tests mandated by state accountability systems. By doing so, they position both reading comprehension and writing as separate curricular categories across grades 3–12. Further, the definition offered by the NAEP Framework (2005b, 2008) for reading assessment purposes is instructive. In that document, the stated framework for what constitutes reading comprehension and its assessment has virtually no relevance to the requirements students encounter when they are engaged in understanding the conceptual relationships presented in science textbooks and related content-oriented materials. Rather, because NAEP testing guidelines are consistent with established reading standards, schools are able to address NAEP skills superficially through non-content-oriented basal reading materials used across K-5. However, such basal reading materials cannot engender meaningful academic learning because they have no rigorous academic content by design (Norris & Philips, 2003; Walsh, 2003).

To the detriment of overall K-12 educational reform, the opportunity-cost of allocating extensive amounts of student instructional time to narrative-oriented, basal reading programs that emphasize non-content materials is that such time replaces the critical opportunity for all K-5 students to interact with the very forms of content-oriented science instruction and associated science reading materials that would provide a foundation for future academic success. Within such a curricular framework, it is understandable why schools allocate substantial amounts of instructional time to test-preparation in order to ensure low SES students reach state accountability achievement goals in reading. However, at the same time, it is no surprise that when low-SES students reach the secondary level, they perform poorly in content-based science and other courses as well as on informational passages presented on tests of reading comprehension. This scenario amplifies the importance of Hirsch's (1996) views on why schools' lack of emphasis on the development of prior knowledge for low-SES students is the equivalent of withholding the exact form of intellectual capital they need for subsequent academic success.

Interdisciplinary Research Perspectives Addressing the Importance of Knowledge-Oriented Instruction in Science and Content-Area Reading Comprehension

The theoretical and research foundations of knowledge-oriented instructional models are well established (Bransford et al., 2000; Luger, 2007; Schmidt et al., 2001). Knowledge-oriented instruction requires: (a) the explicit representation of and focus on the knowledge to be taught and learned in the form of core concept relationships, and (b) the subsequent explicit linkage of all specific instructional methods, strategies, and/or activities chosen for classroom use by teachers to the same overall core science concept framework. Within such contexts: (a) curricular mastery is considered and approached as a form of expertise that reflects the logical structure of the discipline, and (b) the development of curricular prior knowledge is recognized as the most critical determinant of learning success.

In emphasizing the critical role of prior knowledge in learning, Bransford et al. (2000) reported how expert knowledge (i.e., expertise) is organized in a conceptual fashion and how the application of such curricular knowledge by experts (e.g., analyzing/solving problems) is primarily a matter of accessing and applying prior knowledge (Kolodner, 1993, 1997) under conditions of automaticity. Also related to this view is earlier work by Anderson and others (Anderson, 1992, 1993, 1996; Anderson & Fincham, 1994) who distinguished the "strong" problem solving processes of experts that are highly knowledge-based and automatic from the "weak" strategies that novices with minimal knowledge are forced to adopt. Further, applying the perspectives of Bransford et al. (2000), building student conceptual understanding in science not only establishes the prior knowledge and knowledge-structures necessary to support future science learning; but also, by extension, serves as a key element in reading comprehension development as well (Vitale & Romance, 2007; Shanahan, 2010). Because the disciplinary structure of science knowledge is highly coherent, cumulative in-depth instruction in science provides a learning environment well suited for the development of such understanding (e.g., Duschl et al., 2007; Lehrer, Catley, & Reiser, 2004; Smith, Wiser, Anderson, Krajcik, & Coppola, 2004; Smith, Wiser, Anderson, & Krajcik, 2006).

Comprehension of content-oriented materials (e.g., textbooks, trade books) requires students to link relevant background knowledge to their construction of a coherent, highly organized mental representation that reflects the intended meaning of the text (Vitale & Romance, 2007; Kintsch, 1998, 2004; van den Broek, 2010). When this occurs, there is a greater likelihood that the knowledge can be accessed more readily in support of gaining new knowledge and understanding. In a similar fashion, prior conceptual knowledge also serves as the conceptual basis for investigating scientific phenomena, interpreting authentic, hands-on inquiry experiences and for developing evidenced-based explanations presented within science instruction.

As a focus for meaningful learning in K-5 school settings, science conceptual knowledge is grounded on the everyday events that students typically experience. When such experiences are linked with conceptually-relevant instruction, elementary students are able to (a) conceptually link together different events they observe, (b) make predictions about the occurrence of events (or manipulate conditions to produce outcomes), and (c) offer explanations (e.g., argumentation built on evidence) of events after they have occurred. Considered together, the elements in the preceding process are keys to both reading and non-reading comprehension in a parallel fashion (Kintsch, 1998, 2004; Vitale & Romance, 2007). In turn, with in-depth, conceptual understanding in science as a foundation, the use of prior conceptual knowledge in the development of subsequent understanding/comprehension in new learning tasks and the communication of what has been learned applies directly to literacy development.

Overview of the Alignment of the Integrated Science IDEAS K-5 Instructional Model with Systemic School Reform

The Integrated Science IDEAS Model

The key implementation requirements for the Science IDEAS model in grades 3–5 included: (a) regularly scheduled, daily, school-wide instruction in science across the school year, (b) regular monitoring of classroom fidelity of implementation, (c) a grade-articulated and coherent curricular framework, (d) implementation of the six Science IDEAS elements (discussed below) that emphasize inquiry-based, interdisciplinary instruction, (e) teacher grade-level planning and development of multi-day lesson sequences, (f) participation by all teachers in professional development support opportunities, and (g) development of and subsequent leadership by school administrators and a teacher leadership cadre. These implementation requirements align with attributes of effective reform-based science instructional models (Banilower, Smith, Pasley, & Weiss, 2006; Geier et al., 2008).

The grades 3–5 Science IDEAS model is implemented through daily 1 ½ -2-hour time blocks in which integrated science instruction replaces the time formerly allotted to traditional reading/language arts instruction. In the grade K-2 model, the standard reading instruction block is not replaced. Rather the K-2 model consists of 45 minutes of daily science instruction in addition to regularly scheduled reading. The architecture of the Science IDEAS model consists of 6 key conceptually linked instructional elements (e.g., empirical inquiry/hands-on activities, content-area reading comprehension, propositional concept-mapping, journaling and writing, projects, prior knowledge/cumulative review) that are linked to the core concept curricular framework and are flexibly arranged by teachers to engender student conceptual understanding (Romance & Vitale, 2001). In doing so, the model provides students with opportunities to always learn more about what is being learned in a cumulative fashion that builds core science concepts and concept relationships (Donovan, Bransford, & Pellegrino, 2003; Duschl et al., 2007; Romance & Vitale, 2011; Vitale & Romance, 2010). In addition, the implementation emphasizes the importance of maintaining instructional coherence for all students by avoiding pullouts (e.g., ELL [English Language Learners], ESE [Exceptional Student Education], Title I) during Science IDEAS instruction.

Implemented schoolwide for the entire school year, Science IDEAS begins with teacher construction and use of propositional concept maps (see Figure 1) to represent the coherent conceptual structure of the science concepts (identified within state and national science standards) to be taught. In turn, these concept maps provide a coherent framework for identifying, organizing, and sequencing all instructional activities (i.e., six key instructional elements of the Science IDEAS model) and assessments (Pellegrino, Chudowsky, & Glaser, 2001; Vitale, Romance, &

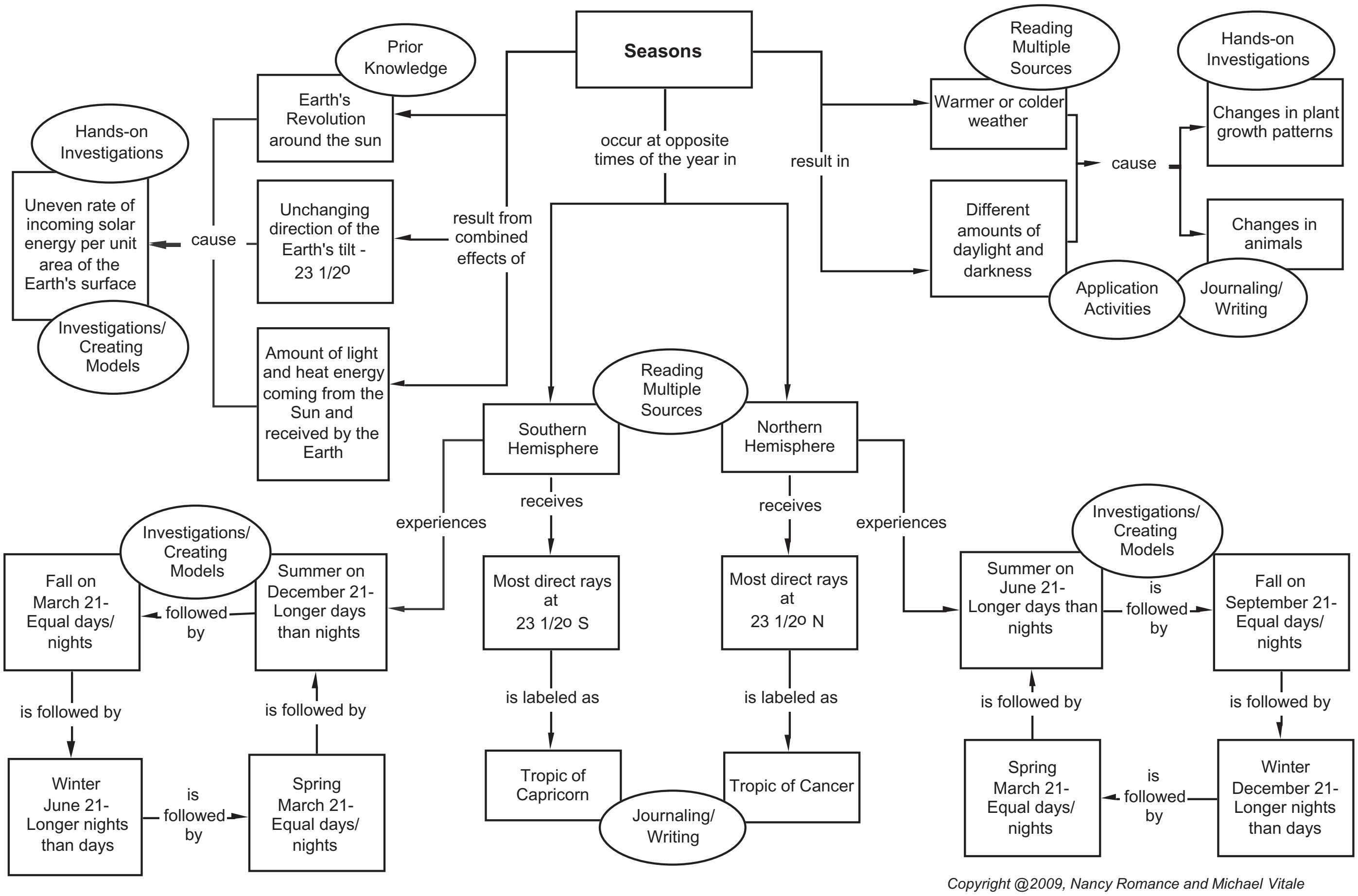

Figure 1. Simplified illustration of a propositional curriculum concept map used by grade 3–5 Science IDEAS teachers to plan a sequence of science instructional activities.

Dolan, 2006). By cumulatively linking together all science learning experiences, students are afforded multiple opportunities to explore and investigate scientific phenomena and engage in fundamental literacy practices such as science discourse, reading multiple sources on the same topic, writing and developing forms of argumentation based on their inquiry/explorations, and learning from text and non-text-based instructional activities (Donovan et al., 2003).

Within this knowledge-oriented instructional context, teachers are able to adopt an inquiry-oriented style that emphasizes how what is learned over a sequence of different activities (e.g., empirical inquiry/hands-on activities, journals/notebooks, concept maps, reading multiple sources, review and application tasks) results in cumulative knowledge development that guides students toward understanding what they have learned as representations or elaborations of the core concepts (National Research Council (NRC) Framework for K-12 Science Education, 2011). And, because of the implementation requirements, students who remain at the participating Science IDEAS schools experience multiple years of in-depth, integrated science instruction leading to meaningful conceptual learning.

In monitoring fidelity of implementation, several complementary approaches are used. These include school/classroom visitations by staff, teacher reflective surveys of fidelity, principal clinical judgment, and informal input from teacher leadership members. Summary reports of clinical findings are shared with principals and area administrators.

Implementing the Science IDEAS Elements for Integrating Science and Reading

In Science IDEAS, the multiple applications of the six complementary instructional elements (e.g., empirical inquiry/hands-on experiences, concept-focused reading comprehension, propositional concept mapping, journaling/writing, application activities, prior knowledge/cumulative review) are sequenced across concept-focused, multi-day lessons to develop student understanding of the science concepts taught. In sequencing multiple applications of the six instructional elements, teachers focus directly on three important factors that directly impact learning: (a) the conceptually organized and sequenced set of concepts and relationships to be taught, (b) where students are positioned/placed within the curricular sequence, and (c) student levels of prerequisite knowledge needed to support learning of the science concepts. In general, all instruction is preceded by teacher assessment of relevant student prior knowledge and/or cumulative review. In explicating how the Science IDEAS architecture functions as an instructional framework, the propositional concept map shown in Figure 1 illustrates one possible approach to how the six key elements of the model might be sequenced for instruction in order to engender meaningful learning in science (e.g., focused on seasons) and content-area reading comprehension.

Characteristics of Mature Science IDEAS Implementations

As the implementation of the Science IDEAS model evolves in schools, teachers engage in a variety of mutually supportive initiatives. Included among these are continuing efforts to refine and enhance their grade-level science curriculum planning and the schools K-5 curriculum articulation process. These ensure that students experience a conceptually coherent science curriculum in which the Science IDEAS elements are embedded. Complementing this ongoing teacher-based curricular planning is the further development of the capability of experienced Science IDEAS teachers to orient and provide ongoing mentor support to teachers new to the school. In addition to sharing approaches for improving Science IDEAS instruction in their own schools, teachers engage in collaborative activities between schools (and school districts) and in presentations at the state and national science conferences. 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., scientific data represented in 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. Of even greater importance, however, is that such curricular displays provide an important means for establishing the institutional "value" of the integrated model to local educators and parents, alike.

Science IDEAS Multi-Year Achievement Outcomes

Although the rationale for integrating science and reading is well-founded on consensus interdisciplinary research (Bransford et al., 2000; Duschl et al., 2007; Palincsar & Magnusson, 2001), an important question is whether it is feasible for such models (in general) and Science IDEAS (in particular) to be implemented with sufficient classroom fidelity to engender student achievement outcomes. In fact, the Science IDEAS model has established a consistent pattern of effectiveness in improving student achievement outcomes over a number of years. Table 1 summarizes the multi-year achievement findings resulting from the implementation of the Science IDEAS model in grades 3–5 and its adaptation in grades K-2 (Romance & Vitale, 2012). Also included are studies demonstrating the transfer effects of the grade 3–5 model to student science and reading achievement in grades 6–8.

As Table 1 shows, the model has consistently obtained positive achievement effects in both science and reading comprehension. In interpreting Table 1, it is important to distinguish between the implementation of the model in grades 3–5 and K-2. In grades 3–5, Science IDEAS *replaced* regular traditional basal-oriented reading instruction. In grades K-2, Science IDEAS *established* 45 minutes of science instruction that complemented but did not replace traditional reading instruction. Overall, the pattern of achievement findings in Table 1 provide strong support for justifying substantial increases in time allocations for in-depth science instruction in grades K-5 because such instruction not only improved science learning, but also reading comprehension. In addition, no studies yielded interactions between Science IDEAS and student demographics, indicating a consistent effect of the model across gender, race, and SES. Based on Table 1, the pattern of evidence suggests that a concept-focused model in grades K-5 such as Science IDEAS which integrates reading/language arts within time-expanded, in-depth, inquiry-oriented science is both feasible and effective for accelerating student science achievement and reading proficiency.

Toward Engineering K-5 Curricular Reform for Increasing Science Instruction

The rationale underlying the argument for increased time for science instruction is three-fold. First, increased time for K-5 science instruction would provide a content-rich foundation in science, which middle school teachers could use to enhance their science teaching and, in turn, to better prepare grade 6–8 students for future success in high school science. Second, increased time for K-5

Table 1
Major Multi-Year Research Findings Integrating Science and Literacy: Science IDEAS Model

Year(s)	Grade(s)	Duration	N[a]	Summary of Findings[b c]
Early grade 3–5 Studies				
1992	4	1 year	3 classes	Significant effects on MAT science (+.93 GE adj. mean diff.) and ITBS reading (+.33 GE adj. mean diff.)
1993	4	1 year	3 classes	(Replication) Significant effects on MAT science (+1.5 GE adj. mean diff.) and ITBS reading (+.41 GE adj. mean diff.)
1996	4–5	5 months	15 classes	(Primarily at-risk students) Grade 5- Significant effects on MAT science (+2.3 GE adj. mean diff.) and ITBS reading (+.51 GE adj. mean diff.) [Grade 4 effects were not significant in the 5-month study]
1998	4–5	1 year	45 classes	(Regular and at-risk students) Significant effects on MAT science (+1.11 GE adj. mean diff.) and ITBS reading (+.37 GE adj. mean diff.)
Recent Grade 3–8 Longitudinal Studies				
2002–2007	3–5	multi-year	12 schools	(Schoolwide implementations in grades 3–5, cross-sectional longitudinal study with transfer effects assessed to grades 6–8), Significant main effects on ITBS science (+.38 GE adj. mean diff.) and reading (+.32 GE adj. mean diff.) across grades 3–8, with significant grade x treatment interactions obtained indicating magnification of transfer effects from grades 3–5 to grades 6–8
Recent Grade 1–2 Studies				
2005	1–2	8 weeks	2 schools	(Schoolwide implementations). Significant effect in ITBS reading (+.42. GE adj. mean diff.); significant grade by treatment interaction in ITBS science, with significant effects in grade 2 (+.72 GE adj. mean diff.), but not in grade 1
2007	1–2	1 year	2 schools	(Schoolwide implementations). Significant effects in ITBS reading (+.58. GE adj. mean diff.) and ITBS science (+.16. GE adj. mean diff.)

Note. MAT: Metropolitan Achievement Test, ITBS: Iowa Tests of Basic Skills, GE: Grade Equivalent Scale Score.
[a] Comparable number of demographically comparable classes/schools used as controls.
[b] Research studies were reported in articles/papers Romance & Vitale (1992, 2001, 2008, 2011) and Vitale & Romance (2010,2011).
[c] For consistency in later studies we report non-standardized HLM coefficients (coded as 1 = Experimental, 0 = Controls) as adjusted means.

science would provide more opportunities for students to actively explore their world, design and conduct investigations, construct evidence-based explanations, and expand their knowledge through related literacy practices (e.g., relevant science passages, maintaining science journals). Third, increasing instructional time for K-5 science also would serve as a means for advancing student achievement in reading comprehension across the K-8 grade range. In contrast, the current reform objective to improve reading comprehension achievement by increasing time for the use of basal reading programs and reducing time for content-area reading has been consistently unsuccessful as evidenced by multiple NAEP assessments of reading (NCES, 2009). More specifically, lack of both content-area instruction and related content-area reading in grades K-5 may well be a major underlying reason for the failure of educational reform at the secondary levels in U.S. schools (ACT, 2006; Hirsch, 1996; Walsh, 2003, Snow, 2002).

In providing an accountability framework consistent with the rationale for increasing time for science, a number of components can be identified. First, all student achievement outcomes in grades 3–8 should be interpreted in terms of *projected* levels of achievement desired at the beginning high school level (e.g., grade 9 test achievement, grade 9 course mastery). Without such a perspective, schools will continue to interpret (or over-interpret) student achievement in elementary school in terms of grade-specific state or national norms but without regard for the impact on subsequent science learning outcomes at middle or high school levels.

Second, the structure of K-5 school accountability models should be refined to distinguish the cumulative effect of the school's instructional program on students continuously enrolled from those who have only attended fewer years (e.g., one or two) or who have attended less than a full school year. Establishing the effectiveness of the school in terms of the students continuously enrolled is, in fact, the most direct and valid measure of the instructional impact of a K-5 in-depth science initiative such as Science IDEAS on student achievement growth.

Based on the preceding, arguments by science education advocates for increasing instructional time for science in grades K-5 should include the following rationale: *Increasing time for integrated science instruction in grades K-5 will not only result in stronger preparation of students for secondary science; but also concurrently* *improve student proficiency in reading comprehension (in general) and content-area reading comprehension (more specifically) across grades 3–8*. Rather than reducing instructional time for science, an evidence-based approach for advancing educational reform would be for schools to replace or complement traditional reading/language arts instruction with in-depth science instruction in which reading and writing are integrated.

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