Applying a Cognitive-Science Framework for Developing Reading Comprehension through Content Area Learning in Grades K-5

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Abstract

Presented are the results of a multi-year series of longitudinal studies conducted in grades 1-5 that have applied consensus cognitive science principles to developing reading comprehension proficiency. Presented are the underlying perspectives for how cumulative conceptual learning in science results in accelerated learning in both science and reading. Discussed are the implications of the findings for facilitating systemic school improvement in grades 1 through 5.

Keywords: Integrating reading and content area learning; improving reading comprehension

Consensus interdisciplinary research findings over the last decade have identified major factors associated with the development of student reading comprehension proficiency in content areas and literature (Kintsch, 1998a; Vitale & Romance, 2007). Specifically, this research has emphasized the critical importance of student prior knowledge, how it is organized, accessed, and expanded through cumulative meaningful learning that is based on what is read, how one understands what is read, and what is taught (Bransford, Brown, & Cocking, 2000; Chi, 1978; Glaser, 1984; National Research Council [NRC], 2006). Opportunities for students to gain the necessary prior knowledge result from their interaction with a school curriculum that is focused, conceptually organized and meaningfully sequenced across the K-12 grade span such as models advocated in the learning progressions research (Alonzo & Gotwals, 2012; Schmidt et al, 1997). In turn, expertise research (NRC, 2006) suggests that prior knowledge is key determinant underlying abilities to understand and comprehend what one is learning or reading (Sawyer, 2006). Yet, for the U.S., two decades of K-12 reform efforts have resulted in only minimal progress in accelerating student reading comprehension proficiency as reported by the National Assessment of Educational Progress (NCES, 2009, 2012). As such, students are unprepared to comprehend progressively more complex texts prevalent at the secondary level in content courses such as science, social studies, mathematics, and literature (NRC, 2014). The overall research findings cited above suggest that addressing learning and instruction from a knowledge-based perspective has not yet been incorporated into K-12 education as an approach to deepen understanding and optimize reading comprehension achievement.

In recent years, the findings and recommendations across a wide variety of researchers have provided a strong theoretical foundation for the incorporation of cognitive science principles when addressing the linkage between content area learning and reading comprehension. The first has to do with the architecture of knowledge-based instruction systems (Luger, 2008) originally developed to implement computer-based instructional tutoring systems. The second (Kintsch, 1994, 1998a,1998b, 2004; McNamara & Kintsch, 1996; McNamara, Vega, & O'Reilly, 2007) has to do with the importance of having a well-structured curricular environment for learning. The third (Bransford et al., 2000; Sowa, 2000) has to do with the role of knowledge in all new learning and as applied in the problem-solving behavior of experts (i.e., expertise). The fourth has to do with cognitive research dealing with the linkage of declarative knowledge to procedural knowledge and automaticity (Anderson, 1982, 1987, 1992, 1993, 1996). And, finally, the fifth has to do with principles for the design and development of validated instructional systems (Dick, Cary, & Cary, 2007; Engelmann & Carnine, 1991). Building upon this framework, this paper reports the findings of a series of longitudinal research studies comparing the effects- direct (grades 1-5) and transfer (grades 6-8)- of content-focused instruction incorporating consensus interdisciplinary principles on reading comprehension to traditional grade 1-5 reading instruction in the U.S.

An Informal Analysis of the Role of Content Area Learning on Reading Comprehension

An emphasis on cumulative content area learning supports students learning more about what they have been learning. This knowledge-based perspective enables students to organize what they have learned conceptually so that past

Table 1: *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
Early Studies in Grades 4, 5				
1992 [a]	4	1 year	3 classes	Initial Science IDEAS study: +.93 GE difference on MAT Science, and +.33 GE difference on ITBS Reading
1993 [b]	4	1 year	3 classes	Replication: +1.5 GE difference on MAT Science, and +.41 GE difference on ITBS Reading
1996 [b]	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 [b]	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
Longitudinal Study: Direct Effects in Grades 3, 4, 5 and Indirect/Transfer Effects to Grades 6, 7, 8				
2002-2007 [c]	3-5	multi-year	6 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 in grades 6-8 demonstrating consistent transfer effects from grade 3-5 on both science and reading.
2003-2008 [d]	3-5	multi-year	6 schools	Replication study paralleling preceding 2002-2007 findings. Schoolwide implementations in grades 3-5, cross-sectional longitudinal study with transfer effects assessed in grades 6-7: +1.30 GE differences on ITBS Science. and +.71 GE differences in ITBS Reading across grades 3-7, with the differences in grades 6-7 demonstrating consistent transfer effects from grade 3-5 on both science and reading.
Studies in Primary Classrooms (K, 1, and 2)				
2005 [e]	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 [f]	1-2	1 year	2 schools	Schoolwide implementation: +.16 GE difference on ITBS Science, and +.58 GE on ITBS Reading
2014 [g]	1-2	6 Months	9 schools	Schoolwide implementation: +.52 GE difference on ITBS Science, and +.26 GE difference on ITBS Reading

Note 1. MAT: *Metropolitan Achievement Test,* ITBS: *Iowa Tests of Basic Skills*, GE: *Grade Equivalent Scale Score*. Grade Equivalent adjusted/mean difference scores (see Note 2) were reported as the outcome metric because they are directly meaningful instructionally .

Note 2. Comparable numbers of demographically-comparable classes/schools used as controls. All analyses findings presented are statistically-adjusted mean differences between Science IDEAS and Control students. For purposes of interpretation, the adjusted mean differences in the Table show the improvement in academic achievement for science or reading that resulted from participation in the Science IDEAS instructional model. For consistency in later studies, non-standardized HLM coefficients (coded as 1 = Experimental, 0 = Controls) as adjusted means were reported rather than OLS adjusted means.

Note 3. Publication/paper references for each study are (a) Romance & Vitale (1992), (b) Romance & Vitale (2001), (c) Vitale & Romance (2009), (d) Vitale & Romance (2011b), (e) Vitale & Romance (2011a), (f) Vitale & Romance (2012), and (g) Romance, Vitale, & Palincsar (2015) learning can support new learning. Reading researchers and learning scientists, alike, clearly recognize the critical importance of students being able to access their prior knowledge as the basis for new learning and for reading comprehension and writing (Romance & Vitale, 2011a, 2011b, 2012a, 2012b; Vitale & Romance, 2007). One direct result of student involvement in such cumulative instruction is that they are better prepared to perform more successfully in content-area learning tasks that involve reading comprehension (see Table 1). Application of a knowledge-based perspective to instruction at the elementary school level is in direct conflict with the long-standing approach to K-5 reading instruction in the U.S. in which students engage on a daily basis with over ninety minutes of instruction focused on a disconnected array of story selections which have been designated as "literature" and with lists of isolated reading strategies.

Design and Results of a 20-Year Series of Studies Investigating the Effect of Content Area Learning on Reading Comprehension

Experimental Intervention

The experimental treatment was implemented through a content-oriented, instructional model in science (Science IDEAS) (Romance & Vitale, 2012) which incorporated the use of five distinct, but highly interrelated, instructional elements (Hands-on activities, Reading science materials, Propositional Concept Mapping, Journaling/Writing, Project applications). In the model, all instruction focused on the concept relationships to be learned. And, through repeated use of the five elements across multi-day lessons, the students have multiple opportunities to focus continuously on a set of conceptually-linked science concepts.

From a cognitive science perspective, the Science IDEAS Model can be described in terms of eight "principles" that form the foundation for the model in the area of science. These are:

1. Use the logical structure of concepts in the discipline as the basis for a grade-articulated curricular framework.
2. Insure that the curricular framework provides students with the necessary and relevant prior knowledge in order to maximize learning and understanding (comprehension) of "new" content to be taught.
3. Focus instruction on core disciplinary concepts (and relationships) and explicitly address prior knowledge and cumulative review.
4. Provide adequate amounts of initial and follow-up instructional time necessary to achieve cumulative conceptual understanding emphasizing "students learning more about what they are learning".
5. Guide meaningful student conceptual organization of knowledge by linking different types of instructional activities (e.g., hands-on science, reading comprehension, propositional concept mapping, journaling and writing, applications).
6. Provide students with opportunities to represent the structure of conceptual knowledge across cumulative learning experiences as a basis for oral and written communication (e.g., propositional concept mapping, journaling/writing).
7. Reference a variety of conceptually-oriented tasks for the purpose of assessment in order to distinguish between students with and without in-depth understanding (e.g., distinguishing positive vs. negative examples, use IF/THEN principles to predict outcomes, apply abductive reasoning to explain phenomena that occur in terms of science concepts).
8. Recognize how and why in-depth, meaningful, cumulative learning within a content-oriented discipline provides a necessary foundation developing proficiency in reading comprehension and written communication.

In implementing the model, instructional time traditionally allocated to reading/language arts instruction was re-assigned to science. In grades 3-5, science instruction was allocated from 1.5 to 2 hours daily effectively replacing time traditionally given to reading instruction. Complementing science instruction at grades 3-5, a separate daily 30 minute time "block" was recommended for literature. In grades 1-2, science was allocated 45 minutes daily, but regular reading instructional time was not modified. In the studies, the control students experienced business-as-usual. That is, on a daily basis, they experienced 1.5 hours of traditional literature-based reading programs and 30 minutes for science.

Research Design

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, 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 (HLM) modeling approach (in later years) 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 reading (ITBS, SAT) and science (ITBS, MAT) achievement measures. The findings from the research studies (Romance & Vitale, 1992, 2001, 2011a, 2012a, 2012b) report the effectiveness of the K-5 Science IDEAS model when (a) the specific amount of instructional time needed to implement the model is allocated, (b) teachers have a sufficient amount of effective professional development and support needed to implement the model with fidelity, and (c) classrooms have adequate resources (e.g., non-fiction trade books). The elements of effectiveness were continually assessed throughout the duration of the research study using direct observations and validated instrumentation.

Multi-Year Research Findings

Table 1 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 2014. The research completed from 1992 through 1998 consisted of a series of studies conducted in authentic school settings, typically over a school year. While the earlier studies were conducted in a variety of classrooms, the studies from 2002 through 2007 consisted of school-wide implementation across grades 3-5. Finally, complementing prior work in grades 3-5, the research involving the model was extended to grades 1-2.

A major conclusion from the multi-year pattern of findings shown in Table 1 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 1 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 (Table 1, Note 1). Because in grades 3-4-5 Science IDEAS replaces regular traditional reading instruction, the effectiveness of the Science IDEAS model which emphasizes in-depth, cumulative, conceptual learning offers major implications for rethinking and reconfiguring curricular policy at the upper elementary levels and for increasing the instructional time for an interdisciplinary approach to science instruction in which reading and writing are inextricably linked to science teaching and student learning activities.

Discussion and Implications

In focusing on the multi-year pattern of student achievement in reading comprehension (and science), the cumulative development of conceptual knowledge differentiated the treatment classrooms from the traditional approach to elementary school instruction in which reading and academic subjects are separated. Such traditional classrooms expend no effort in using the power of an interdisciplinary model to advance student learning by changing curricular practice. These interdisciplinary perspectives are suggestive of a view of effective school learning that is paradigmatically different from the present practices in a majority of schools. The research implications from those reviewed here and elsewhere are supportive of a strong, knowledge-based, curriculum approach to school reform that focuses on the knowledge to be learned in the form of the structural properties of a grade-level articulated and core- concept-oriented curricular framework (Achieve, 2013; Schmidt, et al, 1999) as the foundation for accelerating the rate and depth of student academic expectations. In particular, the idea of knowledge-based instruction provides an operational mechanism for achieving such student achievement outcomes. Within such a knowledge-based framework, a variety of instructional dynamics (e.g., focus on core concepts and concept relationships, effective use of examples to gain conceptual understanding, representation of the organizational structure of concepts and concept relationships learned, and the explicit interplay in a cumulative learning environment between review and accessing of prior knowledge required for learning) can be used to make classroom instruction more optimal in terms of engendering student learning mastery that results in greater reading comprehension proficiency.

The interdisciplinary perspectives presented in this paper have significant implications for the pursuit of reform of reading comprehension instruction by educational practitioners. Overall, the idea of knowledge-based instruction in conjunction with a concept-focused curriculum provide a framework that would establish any systemic reform initiative as “curriculum-based”. Moreover, in operation, such a curricular framework would provide the degree of structure that is necessary (a) to insure that the forms of instruction used result in cumulative, meaningful learning and (b) to insure that the methodological innovations for reform evaluation would result in improved reading comprehension

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