A Research-Based Model for Integrating Elementary Science and Reading Comprehension: Implications for Research and Practice

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Abstract

The goal of this paper is to raise the awareness of educational practitioners and researchers regarding possible mechanisms for advancing the potential for in-depth meaningful learning in elementary science as a critical element in school reform by embedding reading comprehension/literacy instruction within in-depth science instruction. Presented is an interdisciplinary framework and associated research findings supporting such integrated applications in general and the multi-year pattern of student achievement outcomes in science and reading across grades K-8 stemming from the implementation of one such model, Science IDEAS, in particular. Implications of the research foundations and empirical findings are discussed for practitioners and for educational researchers.

Objectives

An emerging trend in education is the attempt to link ongoing research initiatives for advancing the quality of K-12 teaching and learning with the process of systemic school reform. In advocating a strategy to apply interdisciplinary research perspectives (e.g., Bransford et al., 2000) to the problems of science education reform, the objective of this paper is to raise the awareness of educational practitioners and researchers regarding possible mechanisms for advancing the potential for in-depth meaningful learning in science as a critical element in school reform efforts.

Theoretical Framework

Despite numerous studies, the quality of science in the US, student achievement in science (and reading comprehension) has remained a systemic problem (e.g., Lutkus, et al, 2006; NAEP 2003, 2005). When reaching high school, many students from all SES strata do not have sufficient prior knowledge in the form of conceptual understanding necessary to perform successfully in secondary science courses. It is not surprising that the lack of instructional time devoted to in-depth science teaching in elementary schools (see Dillon, 2006; Jones et al., 1999; Klentschy & Molina-De La Torre, 2004) has been identified as an issue that is key to successful school reform in science (Hirsch, 1996; Vitale, Romance, & Klentschy, 2006) and to reading comprehension (Chall, 1985; Guthrie et al., 2002). Representing views addressing such science and literacy concerns, Duke and Pearson (2002) noted that there is little involvement in 'doing' science and reading informational text at the primary level, with many teachers erroneously

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believing instruction in science comprehension must wait until students become proficient decoders in reading (see Holliday, 2004; Klentschy & Molina-De La Torre, 2004; Ogle & Blachowicz, 2002; Gould, Weeks, & Evans, 2003, for related views).

Consensus interdisciplinary research perspectives about meaningful learning in science. Current interdisciplinary research related to meaningful learning summarized by Bransford et al. (2000) provides a foundation as to how early conceptual understanding in content domains such as science establishes the prior knowledge and eventual organizational knowledge-structures necessary to support future learning while also serving as a core element in literacy development (e.g., reading comprehension as a form of understanding, coherent writing). Bransford et al summarized research studies of experts and expertise as a unifying concept for meaningful learning. Because the disciplinary structure of science knowledge is highly coherent, cumulative in-depth instruction in science provides a learning environment that is well-suited for the development of such understanding. As such, coherent curricular structures (e.g., Duschl et al, 2007; Lehrer et al, 2004; Smith et al, 2004, 2006), can readily incorporate elements associated with the cumulative development of curricular expertise by students. In turn, with the active development of such in-depth conceptual understanding serving as a curricular foundation (e.g., Carnine, 1991; Glaser, 1984; Kintsch, 1998; Vitale & Romance, 2000), the use of existing knowledge in the acquisition and communication of new knowledge provides the basis for engendering meaningful learning outcomes in science as well as scientific literacy and general comprehension.

Representative research in K-3. At the K-3 level, researchers (Conezio & French, 2002; French, 2004; Smith , 2001) reported the feasibility of curricular approaches in which science experiences provide rich learning contexts for early childhood curriculum resulting in science learning and early literacy development Related work has been reported by a variety of science education researchers (e.g., Asoko, 2002; Gelman & Brenneman, 2004; Ginsberg & Golbeck, 2004; Rakow & Bell, 1998; Revelle et al., 2002; Sandall, 2003; Schmidt et al., 2001; Smith, 2001; Newton, 2001).

Representative research in grades 3-5. The building of student background knowledge for cumulative learning within a discipline (i.e., science) has been evidenced repeatedly by the work of Guthrie and his colleagues (e.g., Guthrie et al., 2004; Guthrie & Ozgundor, 2002) with upper elementary students as having the additional benefit of enhancing student reading comprehension. Numerous other researchers (Armbruster & Osborn, 2001; Beane, 1995; Ellis, 2001; Hirsch, 1996, 2001; Schug & Cross, 1998; Yore, 2000) also have presented findings that support interventions in which core curriculum content serves as a powerful framework for building background knowledge and greater proficiency in the use of reading comprehension strategies. Research findings associated with the *Science IDEAS* model (below) have repeatedly demonstrated that replacing traditional reading/language arts with in-depth science instruction within which reading comprehension and writing are embedded consistently results in higher achievement outcomes in both reading comprehension and science on norm-referenced tests (Romance & Vitale, 1992, 2001, 2008).

The Science IDEAS instructional model. As a cognitive-science-oriented model, Science IDEAS in grades 3-5 exemplifies an in-depth, instructional approach (e.g., Mintzes et al., 1998) to science teaching and learning that emphasizes students learning more about what is being learned in a meaningful fashion. The architecture of the model involves sequencing different types of classroom activities (e.g., hands-on activities, reading, concept-mapping, journaling/writing) based upon a conceptually coherent framework of concepts (see Figure 1), consistent with recommendations in the literature (e.g., Donovan et al 2003; Romance & Vitale, 2006; Vitale & Romance, 2006b). This framework also provide the means for an embedded approach to assessment (e.g., Pellegrino et al., 2001; Vitale, Romance, & Dolan, 2006).

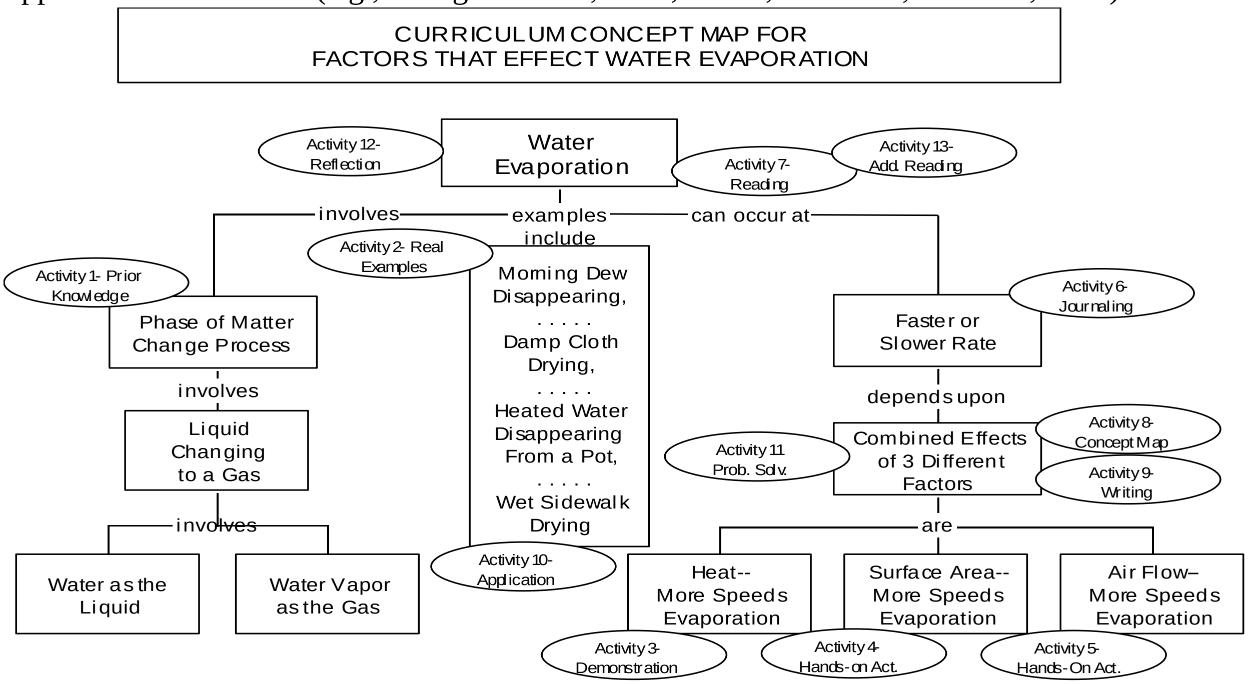

Figure 1. Simplified illustration of a propositional curriculum concept map used as a guide by grade 4 *Science IDEAS* teachers to plan a sequence of instructional activities.

Implementation of the Science IDEAS model (see Figure 1) involves teacher construction of propositional concept maps representing the conceptual structure of the science concepts to be taught which, in turn, serve as the framework for identifying, organizing, and sequencing all instructional activities and assessments.

Method

The data presented in this paper share certain commonalities: (a) all studies were conducted in multicultural urban school systems in southeastern Florida. Second, (b) student demographics of comparison groups matched those of experimental groups, (c) a general linear models data analysis approach incorporated student demographic factors (e.g., minority status, gender, Title I status) and, in most cases, prior reading and/or science achievement as statistical controls, and (d) student achievement outcomes consisted of nationally-normed science (ITBS, MAT) and reading (ITBS, SAT) measures.

Data Sources and Evidence in Support of the Effectiveness of the Science IDEAS Model

Reported pattern of research evidence: 1992-2001. The research studies from 1992 to 2001 consisted of studies conducted in authentic school settings over a school year. In the first (Romance & Vitale, 1992), grade 4 classrooms in an average performing school implemented the Science IDEAS model. The achievement measures were ITBS Reading and MAT Science subtests. Results showed 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). A follow-up replication in year 2 again obtained 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 robustness of the model was tested by (a) increasing the number of participating schools and teachers, (b) broadening the grade levels to grades 4 and 5, and (c) enhancing the diversity of participants by including district-identified at-risk students. Results of the year 3 study (Romance & Vitale, 2001) found that Science IDEAS students outperformed comparison students in a similar fashion and 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.

In the year 4 study, the number of participants was increased to 15 school sites and 45 classroom teachers. Results of the study found that Science IDEAS again students displayed greater overall achievement on both science (+1.11 GE) and reading (+.37 GE). In addition, no treatment by at-risk status interactions were found, indicating that Science IDEAS was effective consistently across grade levels (grades 4-5) and with both regular and at-risk students.

Reported pattern of research evidence: 2004-present. Beginning with 2002, the Science IDEAS research framework was composed of two different 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 13 over the multi-year project). The increasing 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 second initiative consisted of two small-scale studies embedded within the overall scale-up project that explored extrapolations of the Science IDEAS model to grades K-2 (Vitale & Romance, 2007) and as a setting for reading comprehension

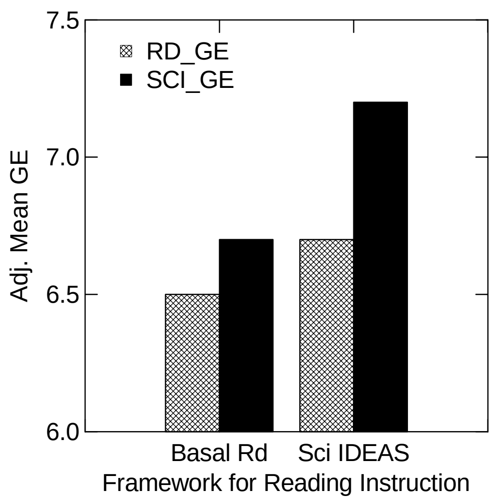

Figure 2. Adjusted grade-equivalent means on ITBS Reading and Science for Science IDEAS and Comparison (Basal) students.

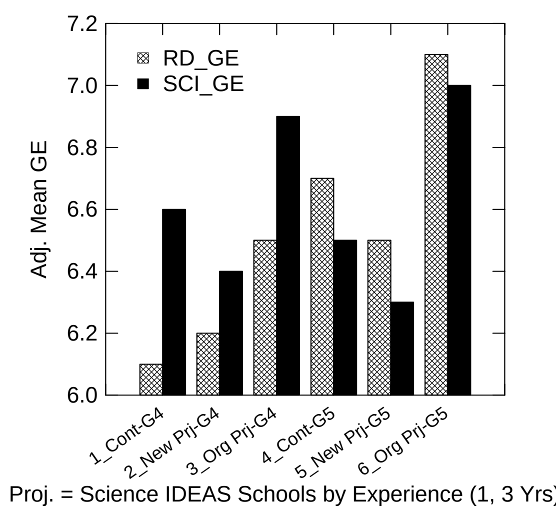

Figure 3. Adjusted grade-equivalent means on ITBS Reading and Science for Continuing and New Science IDEAS and Comparison (Basal) students.

strategy effectiveness (Vitale & Romance, 2006a).

Figure 2 shows the adjusted GE means for grade 4-5 Science IDEAS and Basal Reading classrooms during the 2003-2004 school year. After statistically equating students for differences on the preceding years state-administered FCAT Reading achievement, Science IDEAS students displayed significantly higher ITBS achievement on reading and science.

Figure 3 shows the effect of Science IDEAS on student achievement in new and continuing project schools during the 2004-2005 school year. Science IDEAS students in schools with 3 years experience (N = 4) displayed significantly higher ITBS achievement than Basal Reading schools on both reading and science. However, at the same time, results for Science IDEAS schools in their initial year (N = 4) were varied, suggesting that more than 1 year for implementation experience is required before the *Science IDEAS* model is implemented with effectiveness.

Figure 4 shows the cross-sectional (longitudinal) effect of Science IDEAS across grades 3-8 on ITBS science and reading achievement across 13 participating and 12 comparison schools. Both groups of schools were comparable demographically (60% minority, 45% free/reduced lunch). In interpreting these figures, it should be noted that students in grades 6-7-8 (who had previously attended Science IDEAS or comparison schools) were expressed as extensions of the Science IDEAS or comparison school they attended in grade 5.

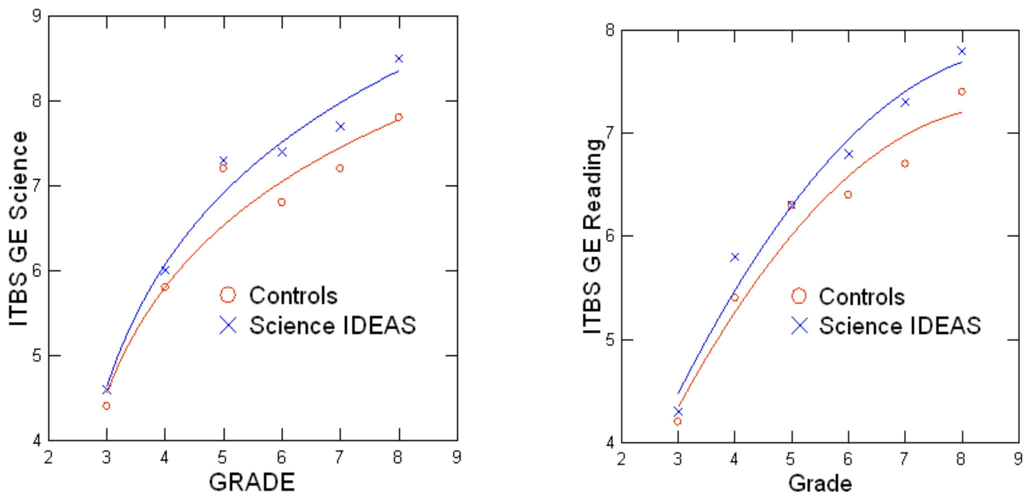

Figure 4. 2006-2007 Achievement Trajectories for Science IDEAS and Control Schools for ITBS Science and Reading. Since project was implemented in grades 3-4-5, performance of students in grades 6-7-8 represents a treatment-transfer effect.

The achievement trajectories in science showed 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.

The achievement trajectories in reading showed 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.

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 K-2 and grade 5. These initiatives consisted of two small-scale studies embedded within the overall -up project that explored extrapolations of the Science IDEAS model to grades K-2 and as a setting for reading comprehension strategy effectiveness in grade 5. The K-2 mini-study (Vitale & Romance, 2007) found a significant difference of .72 GE in grade 2 on ITBS reading, but no effect in grade 1. The grade 5 mini-study (Vitale & Romance, 2006a) found that Science IDEAS students performed significantly higher than basal students on both ITBS science (+.38 GE) and reading (+.34 GE) in a 7-week intervention, but that the reading comprehension strategy use only improved the achievement of Science IDEAS students in both science (+.17 GE) and reading (+.53 GE).

Summary of the pattern of Science IDEAS major research findings. The major conclusion is that the pattern of findings has shown Science IDEAS effective in accelerating student achievement in both science and reading in grades 3-4-5 in an educationally meaningful fashion. Also of importance is the finding that the effect of Science IDEAS in grades 3-4-5 were transferable to grades 6-7-8.

Educational or Scientific Importance of the Study

The findings reported in this paper are suggestive of the importance of teaching in-depth science at the elementary levels to practitioners and of the importance of studying the cumulative effects of such in-depth science instruction to researchers.

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