Adaptation of a Knowledge-Based Instructional Intervention to Accelerate Student Learning in Science and Early Literacy in Grades 1-2 [1, 2]

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Abstract

This study focused on accelerating the development of in-depth science knowledge at the primary level (grades 1-2) as a means for enhancing reading readiness/comprehension (i.e., early literacy). Using an adaptation of a grade 3-5 cognitive-science-based, instructional model (*Science IDEAS*), the study implemented daily 45-minute instructional periods emphasizing in-depth, cumulative learning of science core-concept "clusters" that provided teachers with a thematic focus for all aspects of science instruction. Results (a) confirmed the feasibility of implementing in-depth science instruction at the primary level and (b) showed through ANCOVA that experimental students obtained significantly higher achievement on nationally-normed *ITBS Reading* and *ITBS Science* subtests than comparable controls. Discussed are curricular policy implications for increasing the instructional time for content-area instruction at the primary level.

Despite a continuing national emphasis on educational reform over the past 20 years, student achievement in science and student proficiency in reading comprehension have remained a continuing systemic problem (NCES, 2006, 2007; Schmidt et al., 1999, 2001). In particular, for content-area learning, the problem of meaningful learning from text in content areas is a significant barrier (e.g., AFT, 1997; Donahue et al., 1999; Feldman, 2000; Snow et al., 2002), particularly with low socioeconomic status (SES), at-risk students who depend on school to learn.

Addressing these needs in a developmentally preventative fashion, the focus of this "proof of concept" study was to accelerate the development of in-depth science knowledge at the primary level (grades 1-2) as a means for enhancing reading readiness/comprehension (i.e., early literacy). In adapting a cognitive-science-based, instructional model (*Science IDEAS*) that has been shown effective (e.g., Romance & Vitale, 1992; 2001, 2006; Vitale & Romance, 2006) in accelerating science understanding and reading comprehension proficiency of older children in grades 3-5, this study addressed a recognized need to develop student science understanding and comprehension proficiency at the primary levels (see French, 2004; Gelman & Brenneman, 2004) in a fashion that would raise school achievement expectations for both at-risk and non at-risk students.

The theoretical and research foundations for the original grade 3-5 *Science IDEAS* intervention are based on well-accepted findings from cognitive science that, in turn, are directly applicable to the grade 1-2 *Science IDEAS* adaptation used in the present study (Vitale & Romance, 2006). As a knowledge-based instructional model, *Science IDEAS* requires (a) the explicit representation of the knowledge to be taught and learned in the form of core concepts and concept relationships and (b) subsequent linkage of all instructional methods and activities chosen for use by teachers to the same framework of core concept relationships. In implementing the model, teachers are able to select and use a wide variety of reading/language arts and hands-on activities that expand student in-depth science knowledge about what is being learned. This instructional framework enables teachers to adopt a cumulative inquiry style that (a) emphasizes for students how what is learned over the sequence of

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different activities results in additional knowledge and understanding and (b) guides students to relate what they have learned as elaborations of the core concepts taught.

Central to the foundational ideas underlying the *Science IDEAS* model is a report by the National Academy Press, *How People Learn*, edited by Bransford et al. (1999). As an emergent research trend, Bransford et al stressed the development and access of core concepts and concept relationships as critical elements in the development of any form of expertise. In a parallel fashion, the *Science IDEAS* model emphasizes using the core concepts that reflect the logical structure of the discipline as an instructional architecture for building student cumulative, meaningful learning as a form of expertise (see also French, 2004; Schmidt et al., 2001). A number of other articles (Beane, 1995; Ellis, 2001; Hirsch, 2001; Schug & Cross, 1998; Yore, 2000) have discussed curricular issues and findings that support curriculum interventions represented by knowledge-based instructional approaches such as that in the present study.

The National Reading Panel (2000, p.464) recognized the original grade 3-5 *Science IDEAS* study (Romance & Vitale, 1992) as one of the few scientifically-based research studies demonstrating combined student achievement in science and reading comprehension. In addition, Romance and Vitale (2001) replicated and extended their initial study over an additional two-year period and obtained the same achievement outcomes in science and reading. However, other research initiatives have obtained positive outcomes as well. Klentschy et al. (2004) found a significant impact of the number of years of science-focused instruction in grades K-5 on student achievement on state-administered reading comprehension tests. Guthrie & Ozgungor (2002) and Guthrie et al. (2004) showed that content-oriented reading materials at the upper elementary levels significantly improved both general reading proficiency and student motivation to engage in reading. Armbruster and Osborn (2001) summarized research findings demonstrating positive student achievement in reading comprehension resulting from integrating science content with reading/language arts. Cumulative research reported by Block and Pressley (2002) showed that many of the strategies encompassed in the *Science IDEAS* model (Romance & Vitale, 2006) and the present adaptation emphasizing science and early literacy (e.g., relating prior knowledge, mental imagery, questioning, and summarization) were effective in improving reading comprehension.

With the preceding in mind, the intervention in the present study focused on the development of meaningful knowledge in science in a fashion that is consistent with emerging literacy trends (Palmer & Stewart, 2003) that emphasize the use of informational text for developing comprehension proficiency at the primary levels (for related views see Holliday, 2004; Klentschy et al., 2004; Ogle & Blachowicz, 2002; Gould et al., 2003). The specific research question investigated in the study was whether the adaptation of the grade 3-5 *Science IDEAS* model to grades 1-2 would result in the concurrent acceleration of student achievement in science and reading comprehension and, whether the effects of the model would have a consistent effect on diverse students that varied in gender and ethnicity/SES.

Method

Participants. The study was implemented on a schoolwide basis in grades 1-2 of two elementary schools which were representative of the student diversity (African American: 29%, Hispanic: 19%, Other: 5%, Free Lunch: 40%) in a large (185,000 students) school system in southeastern Florida. Students in two demographically-similar schools served as controls. Table 1 summarizes the demographic characteristics of the participating schools.

Instrumentation. The nationally-normed *Iowa Tests of Basic Skills (ITBS) Reading Comprehension* and *Science* subtests (*Level 7* for grade 1, *Level 8* for grade 2) were administered by classroom teachers under supervision of the researchers as measures of student learning.

Experimental intervention. The study was implemented over an 8-month period during which daily 45-minute lessons emphasized the core-concept "clusters" (e.g., grade 1- *Solids and liquids, Using your senses, Measuring tools, Gases, Phases of matter, Forms of energy, Energy transfer, Pushes and pulls, Types of forces, Simple machines*; grade 2- *States of matter, Using your senses, Measuring tools, Physical changes, Forms of energy, Energy transfer, Pushes and pulls, Simple machines, Heat energy*).

Table 1. *Major Demographic Characteristics of Participating Schools in Grades 1-2*

Treatment Group	School	N Tch.	N Stud.	Pct. Male	Pct. White	Pct. Af.Am.	Pct. Hisp.
Science IDEAS	A	9	114	59	49	22	29
	B	6	97	45	27	19	54
Controls	C	11	166	58	52	22	27
	D	7	136	49	14	19	68

Note. Controls engaged in minimal amounts of instruction in science. Rather, their emphasis was in Reading/Language Arts.

Unlike the grade 3-5 *Science IDEAS* model which replaces traditional reading/language arts instruction, the daily 45-minute instructional blocks in grades 1-2 complemented existing reading/language arts instruction. In using core science concept “clusters” as a curricular focus, instructional activities in grade 1 emphasized teacher-guided student reading of age-appropriate science materials complemented by hands-on activities, with follow-up simple concept mapping and journaling. In grade 2, the instructional activities included all of the grade 1 activities, but placed an increased emphasis on student reading and comprehension of science materials, concept mapping to represent knowledge learned, and writing to communicate what had been learned.

Participating teachers completed a three-day professional development “start-up” module. Subsequently, teachers participated in two additional ½ days of follow-up training. The primary focus of professional development was to insure teachers had (a) a sound understanding of the science concepts they were to teach, (b) proficiency on basic elements of the *Science IDEAS* model (e.g., age-appropriate hands-on activities, reading comprehension guidance, journaling, simple concept mapping), and (c) sufficient assistance in curriculum/lesson planning that focused on the science concept clusters to be taught. Project staff informally monitored all participating classrooms on a regular/continuing basis. Implementation/fidelity forms adapted for use from the grade 3-5 *Science IDEAS* .implementation model were used to focus monitoring (e.g., classroom displays, teacher use of *Science IDEAS* elements/activities, active student engagement in learning). The fidelity monitoring process also provided the project staff with a basis for evaluating teacher implementation needs and providing follow-up support.

In comparison to grade 1-2 experimental classrooms, teachers in demographically comparable comparison schools implemented their regular District-adopted, basal-oriented reading/language arts and science programs.

Design, analysis, and procedure. The framework for the overall research design/analysis consisted of a 2 x 2 x 3 x 2 x 2 factorial with repeated measures on the last factor. The primary between-subjects factor was whether the grade 1-2 *Science IDEAS* model was implemented or not (i.e., treatment or control conditions). The additional between-subjects factors investigated were grade level (e.g., grade 1,2), ethnicity (African American, Hispanic, White), and Gender (male, female). The repeated measures factor consisted of the *ITBS Reading Comprehension* and *ITBS Science* subtests. Because the two academic response measures were different, separate univariate linear models/ANCOVAs were conducted for each of the two different achievement outcomes.

All student achievement and demographic data were collected in collaboration with the district research department. The resulting databasefor data analysis used codes to assure that the identities of schools, teachers, or students could not be determined. For use in the linear models/ANCOVA analysis, all main effects and interactions were coded as contrasts for input to the statistical analysis software.

Results

Assessment of implementation fidelity involved a variety of formal and informal observations leading to clinical judgments. In general, grade 1-2 teachers were judged as effective in implementing the grade 1-2 *Science IDEAS* model throughout the duration of the study.

Descriptive statistics of experimental and control schools. Table 2 summarizes the mean grade-equivalent performance in the treatment and control schools by the academic outcome measures by grade.

Table 2. *Descriptive Statistics of Academic Outcome Measures by School x Grade*

Grade/ Treatment Group	School	N	ITBS Rd.[1] M	ITBS Rd.[1] SD	ITBS Sci.[2] M	ITBS Sci.[2] SD
Grade 1						
Science IDEAS	A	54	1.6	.72	1.6	.92
	B	56	1.6	.66	1.1	.83
Control	C	99	1.4	.83	1.3	.80
	D	83	1.4	.62	1.2	.76
Grade 2						
Science IDEAS	A	43	2.6	1.5	2.2	1.7
	B	58	2.5	.90	1.8	1.3
Control	C	67	2.1	1.1	1.8	1.5
	D	53	1.2	.42	1.5	1.3

[1] ITBS Rd (Reading) mean grade-equivalents
[2] ITBS Sci. (Science) mean grade-equivalents

Student Performance Outcomes. Table 3 summarizes the results of the linear models/ANCOVA analyses for *ITBS Reading* and *ITBS Science.* In interpreting Table 3 it is important to note two aspects of the analysis models used. First, preliminary analyses showed that there was no overall effect of Gender and that Gender did not interact with the experimental treatment. As a result, Gender was fit to a simplified model without interactions involving Gender with other variables. Second, because SES (reduced/free lunch) was highly correlated with ethnicity (white vs. non-white), it was not included in the statistical models used (i.e., minority status should be interpreted as closely related to low-SES in the analyses).

As Table 3 shows, the experimental treatment was significant for both academic outcome measures. Differences in adjusted means in favor of the grade 1-2 *Science IDEAS* students (vs. Controls) were .42 grade equivalents for *ITBS Reading*, and .28 grade equivalents for *ITBS Science.* As Table 3 also shows, the effect of Grade was significant for the *ITBS Reading* and *Science* measures (achievement was higher for grade 2 students). With regard to other main effects, significant differences in ethnicity were found for *ITBS Reading.* Follow-up individual degree of freedom tests of the adjusted mean achievement by ethnicity found the significant differences were due to a White vs. Non-White comparison (mean difference on *ITBS Reading* = .38 grade equivalents, $F(1,500) = 19.27$, $p < .01$), with no difference between Black and Hispanic students. The remaining significant effect consisted of a Treatment x Grade interaction for *ITBS Reading.* Simple effects analysis of this finding showed that the effect of the experimental treatment was magnified significantly for grade 2 students (Grade 1: *Science IDEAS* vs. Controls difference = .11 grade equivalents, $F(1,500) = 1.54$, NS; Grade 2: *Science IDEAS* vs. Controls difference = .72 grade equivalents, $F(1, 500) = 34.19$, $p < .01$).

In interpreting the findings, it is important to note that although significant differences on *ITBS Reading* were found for ethnicity, there were no interaction effects between ethnicity and the experimental intervention. This finding paralleled that of earlier *Science IDEAS* research (Romance & Vitale, 2001) and indicated that although there were achievement differences on *ITBS Reading* between white and non-white students, the effect of the K-2 *Science IDEAS* intervention had a consistent overall effect on all students. Again, it should be noted that in the present analyses, non-white ethnicity (i.e., being African American or Hispanic) was highly correlated with low-SES as indicated by free-lunch, eligibility which, in turn, is indicative of being an "at risk" student.

Table 3. *Results of Linear Models Analysis of Achievement Outcomes in Reading and Science*

Model Component	ITBS Reading	ITBS Science
Main Effects		
Treatment (Trt.)	F(1,500)= 23.15**	F(1,500)= 6.11*
Grade	F(1,500)= 44.38**	F(1,500)= 20.82**
Ethnicity	F(2,500)= 9.82**	F(2,500)= 0.62
Gender	F(1,500)= 3.41	F(1,500)= 0.03
Interactions		
Trt. x Grade	F(1,500)= 12.39**	F(1,500)= 1.91
Trt. x Ethnicity	F(2,500)= 0.77	F(2,500)= 1.25
Grade x Ethnicity	F(2,500)= 2.80	F(2,500)= 1.89
Trt. x Grade x Ethnicity	F(1,500)= 0.23	F(1,500)= 1.22

Note. Treatment = *Science IDEAS* vs. Controls. * $p < .05$, ** $p < .01$

Discussion

The results of this "proof of concept" study are suggestive of several key issues involving grade 1-2 instructional priorities. Contrary to a review by Appleton (2007) which reported substantial barriers for elementary science instruction, the findings of the present study demonstrated not only the feasibility of implementing a strong 45 minute per day emphasis on science in grades 1-2; but also a significant positive impact on norm-referenced achievement in both reading and science for students of all ethnicities. These findings are consistent with research findings reported by Romance and Vitale (1992, 2001) at the grade 3-5 level and with other literature emphasizing the importance of science instruction at the elementary level (Armbruster & Osborn, 2001; Guthrie & Ozgungor, 2002; Guthrie et al., 2004; Klentschy et al., 2004).

A major emphasis in the present grade 1-2 intervention was that science knowledge provided a meaningful context through which students at the primary levels were able to experience cumulative meaningful learning in a fashion that enhances their capacity for comprehension. In this regard, French (2004) reported the feasibility of a curricular approach in which science experiences provide a rich learning context for an early childhood curriculum that resulted in early literacy development as well as science learning. Gelman & Brenneman (2004) showed how a preschool science program which incorporated guided hands-on activities could be used as a framework for instruction that engendered the development of domain specific knowledge in young children. In working with 3 to 6 year olds, Smith (2001) described how the active involvement of young children in gaining science knowledge is naturally motivating (see also Conezio & French, 2002) if topics are approached with sufficient depth and time, a position consistent with the 1995 "National Science Education Standards" (see Rakow & Bell, 1998). In other representative work, Gould (2003) described an approach for early science instruction with gifted students, Tytler and Peterson (2001) summarized the meaningful changes in 5-year-old's explanations of evaporation as a result of extended in-depth science instruction, Jones and Courtney (2002) addressed the processes of curricular planning for instruction and assessment in early science learning, Armga et al. (2002) and Colker (2002) suggested guidelines for teaching science in early childhood settings, and Lee et al. (2000) described the benefits of schoolwide thematically-oriented instruction in science.

Focusing on the development of meaningful knowledge in science as a means for enhancing student comprehension is also consistent with emerging literacy trends (Palmer & Stewart, 2003) that emphasize the use of informational text at the primary levels (see Holliday, 2004; Klentschy et al., 2004; Ogle & Blachowicz, 2002; Gould, Weeks, & Evans, 2003, for related views). In studying the lack of informational text to which young children are exposed in school settings, Duke and her colleagues (e.g., Duke & Pearson, 2002; Pearson & Duke, 2002) noted that the terms "comprehension instruction" and "primary grades" seldom appeared together. As advocates of increasing primary student involvement with informational material, Pearson and Duke reported that teachers erroneously believe that instruction involving comprehension must wait until students develop decoding proficiency in reading. Pearson and Duke also listed and refuted major unsupported beliefs that serve as barriers to the use of informational text at the primary grades (e.g., young children cannot handle them and are uninterested, comprehension is best at upper elementary grades). Given these conditions, it is not surprising that Duke and others (e.g., Duke, 2000; Duke et al., 2003a, 2003b; Pressley et al., 1996; Walsh, 2003) found that primary students have minimal opportunities for exposure to learning that involves meaningful comprehension, despite an extensive research base that provides guidance on how such instruction should be (and should not be) implemented effectively (see Asoko, 2002; Carnine, 1995, 1997; Ginsberg & Gollbeck, 2004; Hirsch, 2003, 2006; Jones et al., 1999; Klentschy et al., 2004; Pretti-Frontczak, 2003; Sandell, 2003; Thompson & O'Quinn; 2001).

Overall, the findings of the present study provide support for a general curriculum policy at the grade K-5 levels (see Vitale et al., 2006) that would advocate greater amounts instructional time being re-allocated from reading per se to the forms of content-area learning (such as science) that involve meaningful cumulative learning. Because the implications of the study are directly relevant to enhancing the preparation of grade 1-2 students to be successful in grade 3 and beyond, the study also was successful in advancing the forms of knowledge that bridge research and practice by applying a broad set of interdisciplinary research findings to systemic issues in education reform. More specifically, the interdependence of the meaningful learning of science and the development of comprehension proficiency at the primary level are important issues that further research should address. In this regard, the results of the study are supportive of the feasibility of increasing the amount of content-area instruction in science at the primary (K-2) level that such research would require.

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