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USING IN-DEPTH SCIENCE INSTRUCTION TO ACCELERATE STUDENT ACHIEVEMENT IN SCIENCE AND READING COMPREHENSION IN GRADES 1 – 2

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ABSTRACT. This study focused on accelerating development of science knowledge and understanding at the primary level (grades 1 – 2) as a means for enhancing reading comprehension (i.e. early literacy). An adaptation of a grade 3 – 5 cognitive-science-based, instructional model (*Science IDEAS*) that integrated science with reading and writing, this year-long study implemented daily 45-min instructional periods emphasizing in-depth, cumulative learning of science core-concept "clusters" while integrating science and literacy in a manner that provided teachers with a thematic focus for all aspects of instruction. Results (a) confirmed the feasibility of implementing the integrated, in-depth science model at the primary level and (b) showed that experimental students obtained significantly higher achievement on Iowa Tests of Basic Skills Science and Reading tests than comparable controls. Discussed are curricular policy implications for increasing the instructional time for content-area instruction at the primary level.

KEY WORDS: integrated science and reading, primary science instruction, reform

The current status of science and reading education in American schools as reflected in numerous national and international reports continues to present considerable challenges to researchers and practitioners alike. Unfortunately, even after 20 years of educational reform, many of the recommendations from key publications such as the 1989 *Science for All Americans* by the American Association for the Advancement of Science (AAAS, 1994), the 1996 National Research Council's (NRC, 1996) *National Science Education Standards*, the 2007 National Research Council's *Taking Science to School: Learning and Teaching in Grades K – 8* (Duschl, Schweingruber & Shouse, 2007), and the 2000 RAND Report *Reading for Understanding* (Snow, 2002) have had little impact on student performance as evidenced by large-scale assessments. Specifically, student achievement trends in both science and reading continue to decline from elementary through high school (Mullis, Martin, Gonzalez & Kennedy, 2003, Mullis, Martin & Kennedy, 2007; Schmidt, McKnight, Cogan, Jakwerth & Houang, 1999; Schmidt, McKnight, Houang, Wang, Wiley & Cogan, 2001; NCES, 2002, 2010). Of particular significance is the additional issue of how meaningful content-area learning from text remains as a significant barrier (e.g. AFT, 1997; Donahue, Voekl, Campbell & Mazzeo, 1999; Duke, 2010; Feldman, 2000; Snow, 2002) for low socioeconomic status students who depend on school to learn.

Addressing these issues developmentally, this study focused on accelerating science learning at the primary level (grades 1 – 2) as a means for enhancing reading comprehension. In using a model that integrates science and reading instruction, the intent was to strengthen an argument for the importance of the role of in-depth science instruction in grades 1 – 2 as the means to prepare students for future success in grade 3 and beyond. In adapting a cognitive-science-based instructional model, *Science IDEAS*, previously shown to accelerate science and reading achievement in grades 3 – 5 (e.g. Romance & Vitale, 1992, 2001, 2011; Vitale & Romance, 2006), this study addressed a recognized need to develop student science understanding and reading comprehension proficiency at the primary levels (see Duke, 2010; French, 2004; Gelman & Brenneman, 2004; Krajcik & Sutherland, 2010; Pearson, Moje & Greenleaf, 2010; Webb, 2010; Yore, Hand, Goldman, Hildebrand, Osborne, Treagust & Wallace, 2004) in a manner that would raise achievement expectations for primary grade students.

The present year-long study extended a previous 8-week study (Vitale & Romance, 2007b) which found significant achievement growth in Iowa Tests of Basic Skills (ITBS) Reading and Science in grade 2, but not in grade 1. Given the mixed results of the 8-week study, the primary objective of this study was to investigate the effects of implementing the integrated instructional model for a full school year on student achievement in science and reading in grades 1 – 2. Overall, the goal of the year-long study was to advance knowledge regarding the bridging of research and practice by applying a broad set of interdisciplinary research findings (e.g. Romance & Vitale, in press) to systemic issues regarding the interdependence of meaningful learning of science and the development of reading comprehension proficiency at the primary levels.

Theoretical Perspectives on Science and Literacy

Cognitive Science Foundations of the Original Science IDEAS Intervention

The research foundations of the original grade 3 – 5 *Science IDEAS* intervention consisted of consensus findings from cognitive science and related disciplines (e.g. instructional design) that, in turn, were directly applicable to the grade 1 – 2 *Science IDEAS* adaptation used in the present study (Romance & Vitale, in press; 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 learning activities chosen by teachers to the same core concept framework.

In implementing the model, teachers select and use a wide variety of inquiry-oriented, hands-on activities in which reading and writing are linked in order to develop and expand student in-depth knowledge and understanding of the science concepts being learned. This instructional framework enables teachers to adopt a cumulative inquiry style that (a) focuses on what is being learned over a multi-day sequence of different learning activities that build cumulative student conceptual knowledge and understanding and (b) guides students to relate what they have learned as elaborations of the core concepts taught.

Central to the foundations of the *Science IDEAS* model is a report by the National Research Council, *How People Learn* (Bransford, Brown & Cocking, 2000). As an emerging 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 the core concepts that reflect the logical structure of the discipline as an instructional architecture for building student meaningful learning as a form of age-appropriate curricular expertise (see also French, 2004). A number of other articles (Beane, 1995; Hirsch, 2001, 2006; Schmidt, McKnight, Cogan, Jakwerth & Houang, 1999; Schmidt, McKnight, Houang, Wang, Wiley & Cogan, 2001) have discussed curricular issues and findings that support curriculum interventions represented by knowledge-based instructional approaches such as that used in the present study.

Other Research Relevant to In-Depth Science Instruction and Comprehension

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. Romance & Vitale (2001) replicated and extended their initial study over an additional 3-year period and obtained similar achievement outcomes in science and reading. In subsequent years, Romance & Vitale (2011) reported cross-sectional effects on science and reading in grades 3 – 5 and transfer of effects from grades 3 – 5 to grades 6 – 8. In related work, Klentschy & Molina-De La Torre (2004) demonstrated how a multi-year science-focused instructional program in grades K – 5 positively impacted student achievement as measured by the California Reading Test. Guthrie & Ozgungor (2002) and Guthrie, Wigfield & Perencevich (2004) showed that the use of content-oriented reading materials at the upper elementary levels significantly affected reading proficiency and student motivation (see also Armbruster & Osborn, 2001), and Block & Pressley (2002) reported that many of the strategies encompassed in the original *Science IDEAS* model and the present grade 1 – 2 adaptation (e.g. relating prior knowledge, imagery, questioning, and summarization) were effective in improving reading comprehension (see also Palincsar & Magnusson, 2001).

Research Trends Recognizing the Importance of Informational Text in Primary Grades

The present grade 1 – 2 intervention focused on developing meaningful knowledge in science, in part, by emphasizing informational text (Palmer & Stewart, 2003) for developing reading comprehension proficiency at the primary level (for related reviews see also Gould, Weeks & Evans, 2003; Holliday, 2004; Klentschy & Molina-De La Torre, 2004; Ogle & Blachowicz, 2002). Pearson & Duke (2002) noted that the terms "reading comprehension instruction" and "primary grades" seldom appear together. Further, they reported that teachers erroneously believed comprehension instruction must wait until students develop decoding proficiency. In doing so, Pearson and Duke listed and refuted major unsupported beliefs that serve as barriers to the use of informational text at the primary grades. Duke and others (e.g. Duke, 2000, 2010; Duke, Bennett-Armistead & Roberts, 2003; Pressley, Rankin & Yokoi, 1996) found that primary students have minimal opportunities for learning that involves meaningful comprehension, despite extensive research on how such instruction should (and should not) be pursued (see Hirsch, 2001, 2003; Jones, Jones, Hardin, Chapman, Yarbrough & Davis, 1999; Klentschy & Molina-De La Torre, 2004; Pretti-Frontczak, 2003; Walsh, 2003).

Research Trends Recognizing the Importance of Science Instruction in Primary Grades

Emphasized in this study is how science knowledge provides a context within which primary students experience cumulative meaningful learning in a fashion that enhances their capacity for comprehension. French (2004) reported the feasibility of a curricular approach in which science experiences resulted in early literacy development as well as science learning. Gelman & Brenneman (2004) showed how a preschool science program including guided hands-on activities served as a framework for instruction that supported the development of domain-specific knowledge in young children. In working with 3 to 6 year olds, Smith (2001) described how active involvement of young children in science learning is naturally motivating (see also Conezio & French, 2002) if topics are approached with sufficient depth and time, a position consistent with "National Science Education Standards" (see Rakow & Bell, 1998). Gould et al., (2003) described an approach for early science instruction with gifted students, Tytler & Peterson (2001) summarized the meaningful changes in 5-year-old's explanations of evaporation as a result of extended in-depth science instruction, Jones & Courtney (2002) addressed the processes of curricular planning and assessment in early science learning, Armga, Dillon, Jamsek, Morgan, Peyton & Speranza, (2002) and Colker (2002) suggested the guidelines for teaching science in early childhood settings, and Lee, Lostoski, & Williams (2000) described the benefits of schoolwide thematically oriented science instruction.

Method

Participants

The grade 1 – 2 study was implemented in two elementary schools representative of the student diversity (African-American 29%, Hispanic 19%, other non-White 5%, free lunch 40%) in a large (185,000 students) school district in southeastern Florida. Students in two demographically similar schools served as controls. Table 1 summarizes the demographic characteristics of the participating students by school.

TABLE 1

Participant numbers (teachers, students) and school demographic characteristics

	School	*N of teachers*	*N of students*	*% Minority*	*% White*	*% African-American*	*% Hispanic*	*% Other*
Science IDEAS	A	6	101	61	30	41	20	9
	B	5	79	69	21	17	52	10
Controls	C	6	104	78	16	41	37	6
	D	5	79	80	15	13	67	5

For demographic purposes, "Minority" category consisted of African-American and Hispanic students. The "Other" category consisted of students of all other ethnicities, including multi-ethnic students

Instrumentation

The nationally normed *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 achievement during the last 2 weeks of the school year. The *ITBS* is a nationally normed, group-administered achievement test battery that is used by many US schools across grades 1 through 10. The design of the test and the test-norming procedure provide a strong and consistent linkage between versions for different grade levels.

Experimental Intervention

The study was implemented over the school year during which 45-min lessons taught each school day emphasized the core-concept "clusters." In grade 1, the concept clusters encompassed life, Earth, and physical science within an inquiry-oriented instructional framework. Key topic clusters included *Using your senses*, *Measuring tools*, *Phases of matter* (*solids*, *liquids*, *gases*), *Forms of energy*, *Energy transfer*, *Pushes and pulls*, *Types of forces*, *Simple machines*, *Plants*, and *Animals.* In grade 2, the concept clusters were *Using your senses*, *Measuring tools*, *States of matter*, *Physical changes*, *Forms of energy*, *Heat energy*, *Energy transfer*, *Pushes and pulls*, *Simple machines*, and *Living things and the environment.*

Unlike the grade 3 – 5 *Science IDEAS* model which actually replaces traditional reading/language arts instruction, the daily 45-min science instructional blocks in grades 1 – 2 did not replace but rather complemented existing reading/language arts instruction. In planning their daily lessons, teachers relied upon the core clusters as the curricular framework for selecting and sequencing all the science concepts being taught. In effect, the activities and lessons always built upon the previous science concepts learned thus affording students' opportunities to build cumulative knowledge across a series of lessons. Classroom instruction focused on large and small groups of students actively exploring their world while also helping them develop skills that are important components of the scientific process (e.g. observing, measuring). In addition, teachers used the integration of reading and writing as a way to enhance the science concepts being taught. For example, teachers used "read-alouds" and group discussions as a means to guide student understanding of age-appropriate science materials. The integration of both reading and writing complemented what students were learning through the hands-on activities as well as supporting simple concept mapping and journaling. Learning centers (e.g. additional activities and rich print-based materials) provided another avenue to support student understanding of the underlying concepts. In grade 2, the instructional activities included all of the grade 1 activities but placed an increased emphasis on teacher-guided student reading and more in-depth comprehension of science materials. In grade 2, concept mapping was used to represent conceptual knowledge learned, and writing (or drawing) was used to communicate what was being learned. In comparison to grades 1 – 2 experimental classrooms, teachers in demographically comparable control schools followed the regular District science program. However, all of the curricular materials used were purchased by the experimental and control schools following District guidelines for "age-appropriate" science and reading materials. Both experimental and control schools implemented the district-adopted, basal-oriented Reading/Language Arts program.

Teacher Professional Development and Implementation Support for the Grade 1 – 2 Intervention

The teacher professional development modules and support strategies used were developed and validated in the previous 8-week study (Vitale & Romance, 2007b). Prior to the start of the school year, participating teachers completed a 2-day professional development "start-up" module. Subsequently, teachers participated in 2.5 additional days of follow-up training. The primary focus of project professional development was on (a) insuring teachers had a sound understanding of the science concepts they were to teach (including proficiency on age-appropriate hands-on activities) and (b) providing assistance in teacher curriculum/lesson planning that focused on the science concepts within the "core clusters" to be taught. Because both experimental and control schools were implementing the grade 3 – 5 *Science IDEAS* model, grades 1 – 2 teachers in all schools were able to gain mentor support from more experienced science teachers as well as from the researchers.

Design, Analysis, Data Sources, and Procedure

The four schools participating in the study were selected from a larger group of elementary schools implementing Science IDEAS in grades 3 – 5 because they had the most similar patterns of student demographics (see Table 1). In turn, the treatment and control conditions were assigned randomly to each of two schools, respectively. In addition, the fact that both the experimental and control schools were implementing the *Science IDEAS* model in grades 3 – 5 served as a control for possible differential school science teaching support for the grades 1 – 2 teachers within their schools.

The overall design "framework" of the study consisted of a 2×2 factorial design (Treatment, Grade) with two outcome measures (ITBS Reading, ITBS Science). As shown in Table 1, a total 11 experimental (grade 1: N = 5, grade 2: N = 6) and 11 control classrooms (grade 1: N = 5, grade 2: N = 6) participated in the study. Selected student demographic variables (Gender, Ethnicity) served as covariates. After exploratory OLS linear models analyses, separate two-level multi-level analyses were conducted on each ITBS measure (Reading, Science) using HLM 6. In the HLM analyses, Treatment and Grade were assigned to level 2 (teacher/classroom level) and student demographic characteristics (Gender, Ethnicity—coded as White vs. non-White and as Black vs. Hispanic) were assigned to level 1 (student level). Student title 1 status was not included in the analyses because title 1 status was highly correlated with ethnicity.

Monitoring of Intervention Fidelity

Project staff informally monitored all participating classrooms on a regular/continuing basis. Implementation/fidelity forms adapted from the grade 3 – 5 *Science IDEAS* model were used as monitoring guides (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 identifying any needed follow-up support.

Results

Clinical Assessment of Implementation Fidelity

Assessment of implementation fidelity involved a variety of informal observations leading to clinical judgments. Primarily, these consisted of (a) regular informal visits to grades 1 – 2 classrooms by research staff and (b) status reports and trouble-shooting requests conducted through professional development and follow-up teacher support provided by project staff. In general, grades 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.

Student Performance Outcomes

Table 3 summarizes the results of the HLM analysis for ITBS Science and Table 4 for ITBS Reading. As these tables show, the effects of the Treatment/Intervention were statistically significant in favor of the grade 1 – 2 experimental *Science IDEAS* classrooms for both ITBS Science and Reading. Grade was also significant for both ITBS outcomes, with grade 2 students performing higher than those in grade 1. Because preliminary HLM analyses showed no interactions involving Treatment with Grade, Gender, or Ethnicity, these interactions were omitted from the final HLM analysis models for both Science and Reading.

For ITBS Science, Gender was not significant, but both Ethnicity contrasts were significant, with Whites scoring higher than non-Whites and Hispanics higher than Blacks. For ITBS Reading, Gender was

TABLE 2

Descriptive statistics of academic outcome measures by grade and school

		ITBS Science[a]			*ITBS Reading*[b]		
Grade/treatment group	*School*	*N*	*M*	*SD*	*N*	*M*	*SD*
Grade 1							
Science IDEAS	A	43	1.3	0.10	52	2.5	0.62
	B	34	1.4	0.15	32	2.5	0.35
Control	C	50	1.1	0.22	48	2.2	0.76
	D	31	1.2	0.18	29	2.2	0.45
Grade 2							
Science IDEAS	A	49	2.1	0.22	48	3.7	1.2
	B	45	2.3	0.29	47	3.4	1.0
Control	C	54	1.9	0.27	52	2.4	0.91
	D	48	2.1	0.35	43	2.9	0.71

[a]ITBS Science mean grade-equivalents (unadjusted)
[b]ITBS Reading mean grade-equivalents (unadjusted)

TABLE 3

Results of HLM analysis of achievement outcomes on ITBS Science

Fixed effect	*Coefficient*	*Standard error*	*T ratio*	*Approximate d.f.*	*p value*
For INTRCPT1, B0					
INTRCPT2, G00	1.79	0.01	64.35	19	0.000
Grade, G01	0.83	0.54	15.28	19	0.000
TREAT, G02[a]	0.16	0.05	3.04	19	0.007
For Gender, B1					
INTRCPT2, G10	0.004	0.02	−0.18	348	0.861
For White vs non-White, B2					
INTRCPT2, G20	0.10	0.05	−2.02	348	0.044
For Hispanic vs Black, B3					
INTRCPT2, G30	0.09	0.03	−2.93	348	0.004

[a]95% confidence interval for ITBS Science GE treatment coefficient is: [+0.05, +0.26]

significant, with Females performing higher than Males, but neither Ethnicity contrast was significant.

In the findings reported in Tables 3 and 4, each HLM analysis used raw-score predictor sets in order to use the level 2 regression coefficients as estimates of the effects of the Treatment and of Grade on ITBS achievement. As Tables 3 and 4 show, the resulting estimates of the effects of Treatment in ITBS GE units were +0.16 GE for science and +0.58 GE for reading. The estimates obtained for Grade differences

TABLE 4

Results of HLM analysis of achievement outcomes on ITBS reading

Fixed effect	*Coefficient*	*Standard error*	*T ratio*	*Approximate d.f.*	*p value*
For INTRCPT1, B0					
INTRCPT2, G00	2.78	0.10	30.06	19	0.000
Grade, G01	0.77	0.19	4.15	19	0.001
TREAT, G02[a]	0.58	0.19	3.12	19	0.006
For Gender, B1					
INTRCPT2, G10	0.18	0.08	2.15	345	0.032
For White vs non-White, B2					
INTRCPT2, G20	0.30	0.18	1.66	345	0.097
For Hispanic vs Black, B3					
INTRCPT2, G30	0.08	0.11	0.69	345	0.486

[a]95% confidence interval for ITBS reading GE treatment coefficient is: [+0.21, +0.95]

(between grade 1 and grade 2) were +0.82 GE in science and +0.77 GE in reading.

Discussion

In interpreting the findings, it is important to note that expansion of the treatment in the present study from 8 weeks (Vitale & Romance, 2007b) to a full school year demonstrated the impact of the intervention on student achievement in science and reading comprehension across both grade levels in a manner consistent with findings of previous research with students in grades 3 – 8 (Romance & Vitale, 1992, 2001, 2011). Consistent with prior research on the *Science IDEAS* model in grades 3 – 5, the present findings resulting from the adapted *Science IDEAS* model in grades 1 – 2 are supportive of the feasibility and effectiveness of in-depth, content-area learning across grades 1 – 5 to accelerate student achievement in both science and reading comprehension. By obtaining this dual achievement outcome, the impact of age-appropriate, in-depth integrated science instruction on reading comprehension justifies the increased time allocated for daily science instruction.

Implications of this year-long study extend well beyond the “proof of concept” findings of the previous 8-week study (Vitale & Romance, 2007b) by demonstrating both the feasibility and effectiveness of the integrated 45 minute per day model, in contrast to literature reviewed by Koch & Appleton (2007). In combination with findings reported by Romance & Vitale (1992, 2001, 2011) in grades 3 – 5 and literature emphasizing the importance of science at the primary level (e.g. Duke, 2010; Pearson et al., 2010), the present findings are supportive of a revised curriculum policy perspective in grades 1 – 5 (see Vitale & Romance, 2010; Vitale, Romance & Klentschy, 2006) that would advocate greater amounts instructional time being allocated to content-area instruction in science that involves cumulative conceptual learning (Armbruster & Osborn, 2001; Guthrie & Ozgungor, 2002; Guthrie et al., 2004; Klentschy & Molina-De La Torre, 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 learning in an age-appropriate, meaningful fashion that enhanced their capacity for reading comprehension. In this regard, the present findings in conjunction with research cited previously (Armga et al., 2002; Colker, 2002; French, 2004; Gelman & Brenneman, 2004; Gould et al., 2003; Jones & Courtney, 2002;

Lee et al., 2000; Smith, 2001; Tytler & Peterson, 2001) are consistent with the argument advanced by Vitale & Romance (2007a) that considered reading comprehension as a subset of comprehension in general (for a related, view see Shanahan, 2010; Shanahan & Shanahan, 2008).

The present findings add support to the perspective that focusing on the development of meaningful knowledge in science provides the means for enhancing student reading comprehension and an instructional setting for the integration of language and literacy-related activities that further support science learning. This is consistent with emerging literacy trends that emphasize the use of informational text at the primary levels (e.g. Duke, 2010; Duke & Pearson, 2002; Gould et al., 2003; Holliday, 2004; Klentschy & Molina-De La Torre, 2004; Ogle & Blachowicz, 2002; Palmer & Stewart, 2003; Pearson & Duke, 2002).

Overall, the findings of the present study provide support for adopting a general curriculum policy at the grade 1 – 5 levels (see Vitale & Romance, 2010; Vitale et al., 2006) that would allocate greater amounts instructional time to content-area learning in science that involves meaningful cumulative learning rather than to the excessive amounts of instructional time focused on use of non-content basal/narrative reading programs presently popular in schools (Cervetti et al., 2006). In providing implications directly relevant to preparing grades 1 – 2 students to be successful in grade 3 and beyond, the study also advanced forms of knowledge that bridge research and practice by applying a broad set of interdisciplinary research findings to the systemic issue of both science and reading comprehension in education reform. In this regard, the interdependence of the meaningful learning of science and the development of reading comprehension proficiency at the primary level are important issues that further research should address (see Krajcik & Sutherland, 2010; Romance & Vitale, in press; Van den Broek, 2010; Vitale & Romance, 2006; Webb, 2010; Yore et al., 2004).

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