Abstract Title Page

Title:
Implications of a Cognitive Science Based Model for Integrating Science and Literacy in Grades 3-5: Replication of Multiyear Direct and Transfer Effects in Science and Reading from Grades 3-5 to 6-8

Author(s):
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Abstract Body

Background / Context:

Based on findings from the National Assessment for Educational Progress (1996-2005), the pattern of science achievement by U.S. students shows a decreasing degree of proficiency from elementary to secondary grades that has remained unchanged, much in the same fashion as that of the White-Black achievement gap (Grigg et al., 2006; Lutkus et al., 2006; USDOE 2001, 2005). Parallel trends in reading comprehension (NCES, 2009) are important to note also because meaningful content-area learning from text has continued to be a significant barrier to both science learning and reading comprehension (e.g., AFT, 1997; Braun et al., 2009; Donahue et al., 1999; Feldman, 2000; Snow et al., 2002), particularly for school-dependent, low socioeconomic status (SES) students (see Gamse et al., 2008; Kemple, et al., 2008; James-Burdumy et al., 2006; NCES, 2009). International assessments reflect similar trends in science and reading achievement (Schmidt et al, 1999, 2001; Stephens & Coleman, 2007).

In effect, present evidence-based reform efforts in science education (see Vitale et al., 2010) and content-area reading comprehension (see Shanahan, 2010) have contributed minimally to improving student achievement outcomes. And, even with the present status of reform, neither field has pursued interdisciplinary research emphasizing cognitive science principles (see Duschl et al., 2007; Romance and Vitale, in press) that have the potential to reverse present achievement trends. More specifically, reform efforts have failed to address the ineffective operational dynamics of most K-5 schools, including: (a) curricular policies resulting in a serious reduction in time allocated for K-5 science (Dillon, 2006; Jones et al., 1999; McMurrer, 2008), (b) curricular policies focusing on basal (narrative) reading rather than emphasizing content-area reading comprehension (Chall & Jacobs, 2003; Guthrie et al., 2002; Pearson et al., 2010; van den Broek, 2010), (c) adoption of conceptually weak science standards and curriculum (e.g., AFT, Petrilli et al., 2006 [Thomas B. Fordham Institute]; Schmidt et al., 1999, 2001; Wilson & Bertenthal, 2006), and (d) ignoring the expanding evidentiary base of the mutual benefits associated with the linking of science and literacy achievement outcomes (Duke, 2000a, 2000b, 2010; Guthrie et al., 2002; Guthrie et al., 2004a, 2004b; Guthrie & Ozgungor, 2002; Guthrie, Wigfield, & Perencevich, 2004; Heller & Greenleaf, 2007; Klentschy 2003, 2006; Klentschy & Molina-De La Torre, 2004; Norris & Phillips, 2003; Romance & Vitale, 1992, 2001, 2010; Snow, 2002; Yore et al., 2004).

With the preceding in mind, approaching these longstanding educational issues through the application of consensus cognitive science research and instructional systems development principles has the potential to accelerate the rate of student learning in both science and reading comprehension in a manner that also has systemic implications for K-5 curricular policy.

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 conceptual understanding in content domains such as science establishes the prior knowledge and knowledge-structures necessary to support future learning 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 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 content-area reading comprehension.

**Science Learning and Comprehension.** Comprehension of printed materials (e.g., texts, science trade books, leveled readers) requires students to link relevant prior knowledge to their construction of a coherent mental representation that reflects the intended meaning of the text (Kintsch, 1998; van den Broek, 2010). If learner prior knowledge is organized coherently around core concept relationships, there is a greater likelihood for gaining understanding. If prior knowledge is not strong, then understanding becomes more dependent on the logical coherence of the text (or any other learning experience). Because the domains of science knowledge are well-structured, cumulative in-depth instruction in science provides a learning environment that is well-suited for the development of understanding as expertise.

In developing cumulative science knowledge, students are able to (a) link together different events they observe, (b) make predictions about the occurrence of events (or manipulate conditions to produce outcomes), and (c) make meaningful interpretations of events that occur, all of which are key elements of meaningful comprehension (see Vitale & Romance, 2007). In turn, with the active development of such in-depth conceptual understanding in science serving as a foundation, the use of prior knowledge in the comprehension of new learning tasks and in the communication of what knowledge has been learned provides a basis for key aspects of literacy development.

**Representative research integrating reading and science in grades K-5.** 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 and literacy researchers (e.g., Asoko, 2002; Duke, 2010; Gelman & Brenneman, 2004; Ginsberg & Golbeck, 2004; Newton, 2001; Rakow & Bell, 1998; Revelle et al., 2002; Sandall, 2003; Schmidt et al., 2001; Smith, 2001; Vitale & Romance, 2010).

In grades 3-5, the potential promise of building student prior knowledge for cumulative learning within science as a means for enhancing reading comprehension has been established repeatedly by the work of Guthrie and his colleagues (e.g., Guthrie et al., 2004; Guthrie & Ozgundor, 2002) with upper elementary students. In complementary work, Walsh (2003) noted in an analysis of basal reading series that the non-content oriented focus represented a lost opportunity for students to build the cumulative background knowledge necessary for comprehension. Other researchers (Armbruster & Osborn, 2001; Beane, 1995; Ellis, 2001; Hirsch, 1996, 2001; Palincsar & Magnusson, 2001; Pearson et al., 2010; Romance & Vitale, 2010; Schug & Cross, 1998; van den Broek, 2010; Yore, 2000) have presented findings that support interventions in which core curriculum content in science serves as a framework for building background knowledge and greater proficiency in the use of reading comprehension strategies. Research findings associated with the Klentschy model and the *Science IDEAS* model (described below) have repeatedly demonstrated that replacing traditional reading/language arts time with in-depth science instruction within which reading comprehension and writing are embedded have consistently resulted in higher achievement outcomes in both reading comprehension and science on norm-referenced tests (Klentschy, 2003, 2006; Romance &
The Science IDEAS instructional model as a cognitive-science approach for integrating reading within science. Science IDEAS is a cognitive-science-oriented model that integrates reading and writing within in-depth K–5 science instruction. In grades 3-5, Science IDEAS is implemented schoolwide in 1.5 to 2 hour daily instructional lessons which focus on science concepts. The model emphasizes students learning more about what is being learned in a cumulative fashion that builds upon core science concept relationships. The architecture and cognitive science principles of the model (see Figures 1-2-3-4) emphasize the logic of the discipline on one hand and the role of knowledge in learning. Figures 5 (density) and 6 (convection) illustrate coherent curricular frameworks that would support the design of multi-day instructional lessons. Figure 7 (evaporation) shows how a curricular concept map serves as a framework for sequencing different Science IDEAS instructional elements (e.g., hands-on activities, reading, concept-mapping, journaling/writing) across multi-day lessons in accordance with a conceptually-coherent curricular framework consistent with recommendations in the literature (e.g., Donovan et al., 2003; Duschl et al., 2007; Romance & Vitale, 2001, 2009; Vitale & Romance, 2010). Figure 8 shows advanced teaching components for enhancing instruction that reflect cognitive science findings and instructional design principles (Vitale & Romance, 2006). This advanced framework also provides the means for an embedded approach to assessment (e.g., Pellegrino et al., 2001; Vitale, Romance, & Dolan, 2006).

Purpose / Objective / Research Question / Focus of Study:
The multiyear research findings documenting the effectiveness of the Science IDEAS model beginning in 1992 through the present are shown in Table 1. The findings reported here are based on new data (i.e., not reported in earlier papers). Specifically, the cross-sectional findings reported here investigated whether the grade 3-8 cross-sectional findings across 2002-2007 reported by Romance and Vitale (2011) could be replicated in grade 3-7 across 2003-2008. The objective of this cross-sectional study was to report multi-year effects of the Science IDEAS model on reading comprehension and science achievement measured by the ITBS on (a) grade 3-5 students receiving the model, and (b) associated transfer effects of the model on students in grades 6-7.

In doing so, an important goal of the study was to suggest implications for advancing school reform following cognitive science principles that would increase the instructional time for in-depth science instruction and emphasize core science concepts as a curricular framework leading to the acceleration of student achievement in both reading and science.

Setting:
The study was conducted in a large (185,000 students), diverse (African American: 29%, Hispanic: 19%, Other: 5%, Free Lunch: 40%) urban school system in southeastern Florida.

Population / Participants / Subjects:
The study intervention (Science IDEAS) was implemented schoolwide in grades 3-5 in 12 elementary schools representative of the student diversity of the school system. Students in 12 demographically-similar schools served as controls. In addition, former Science IDEAS grade 6-8 students and comparison students in feeder middle schools were tested to assess transfer effects of the intervention. Overall, the number of students sampled from the project database consisted of a total of N= 3671 experimental and control students prior to elimination for missing science or reading data.
**Intervention / Program / Practice:**

The Science IDEAS model (described previously) implemented in grades 3-5 served as the experimental intervention. The Science IDEAS model integrated reading and writing within in-depth science instruction across daily 1.5 to 2 hours instructional lessons which focused on science concepts along with additional ½ hour daily instruction in literature. The comparison students received the district-adopted basal reading/language arts program as well as ½ hour daily instruction using the district-adopted science curriculum.

**Research Design:**

The project was implemented over a 5-year period. In data preparation, middle school students were linked back to their grade 5 elementary schools, in effect creating a grade 3-7 elementary school for data analysis. The overall cross-sectional design was a 2 x 2 factorial (Treatment, Grade), with two outcome measures (ITBS Reading, ITBS Science). Student demographic characteristics (Minority vs. non-Minority status, Gender, and Title 1 eligibility) functioned as student covariates. Analysis was conducted using HLM Version 6.08 (Raudenbush & Byrk, 2001) with students designated as level 1 and teachers as level 2. Treatment and grade were coded at level 2.

**Data Collection and Analysis:**

The nationally-normed *Iowa Tests of Basic Skills (ITBS)* *Reading Comprehension* and *Science* subtests served as measures of student learning. These were administered to participating students in grades 3-8 by classroom teachers under supervision of the researchers. Fidelity of implementation was monitored by researchers on a regular basis throughout the school year.

**Findings / Results:**

**Clinical assessment of implementation fidelity.** Monitoring of implementation fidelity showed that between 82-95 percent of grade 3-5 Science IDEAS teachers implemented the model effectively (with fidelity).

**ITBS student performance outcomes.** Tables 2 and 3 (refer to Tables 2 and 3 here) summarize the HLM analysis results. As Tables 2 and 3 show, the same overall pattern of significant findings was obtained for both ITBS Reading and Science. For both achievement measures, the Science IDEAS model resulted in higher achievement (+.54 GE for reading, +.82 GE for science), with grade level and non-minority status both being positively related to achievement and with eligibility for Title 1 and Male (vs. Female) being negatively correlated with achievement. The final paper will explore and report the analysis of treatment x grade and cross-level interactions of the treatment with student demographic characteristics.

**Conclusions:**

The multi-year findings replicate previously reported research (Romance & Vitale, 2011a,b) demonstrating the effectiveness of content-area learning in science as a means for improving student reading comprehension, both when directly implemented with grade 3-5 students and on a transfer basis in grades 6-7. In doing so, this study is suggestive of the potential benefits of applying cognitive science principles to reverse K-5 curricular policy that emphasizes the major allocation of student instructional time to non-content-oriented basal reading programs in place of meaningful content-area instruction organized around a core concept framework. Implications of this study and related work are that a curricular approach integrating literacy within in-depth science instruction has the benefit of directly and, on a transfer basis, increasing student academic achievement in these two critical areas.
Appendices

Appendix A. References


Association.


Snow, C. E. (2002). Reading for understanding: Toward a research and development program in reading comprehension. Santa Monica, CA: RAND.


Yore, L. (2000). Enhancing science literacy for all students with embedded reading instruction and writing-to-learn activities. *Journal of Deaf Students and Deaf Education*, 5, 105-122.

## Appendix B. Tables and Figures

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

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Grade(s)</th>
<th>Duration</th>
<th>N</th>
<th>Summary of Findings</th>
</tr>
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<tr>
<td><strong>Early grade 3-5 Studies</strong></td>
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<td></td>
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</tr>
<tr>
<td>1992</td>
<td>4</td>
<td>1 year</td>
<td>3 classes</td>
<td>Significant effects on MAT science (+.93 GE adj. mean diff.) and ITBS reading (+.33 adj. mean diff.)</td>
</tr>
<tr>
<td>1993</td>
<td>4</td>
<td>1 year</td>
<td>3 classes</td>
<td>(Replication) Significant effects on MAT science (+1.5 GE adj. mean diff.) and ITBS reading (+.41 adj. mean diff.)</td>
</tr>
<tr>
<td>1996</td>
<td>4-5</td>
<td>5 months</td>
<td>15 classes</td>
<td>(Primarily at-risk students) Grade 5- Significant effects on MAT science (+2.3 GE adj. mean diff.) and ITBS reading (+.51 adj. mean diff.) [Grade 4 effects were not significant in the 5-month study]</td>
</tr>
<tr>
<td>1998</td>
<td>4-5</td>
<td>1 year</td>
<td>45 classes</td>
<td>(Regular and at-risk students) Significant effects on MAT science (+1.11 GE adj. mean diff.) and ITBS reading (+.37 adj. mean diff.)</td>
</tr>
<tr>
<td><strong>Recent Grade 3-8 Longitudinal Studies</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2002-2007</td>
<td>3-5</td>
<td>multi-year</td>
<td>12 schools</td>
<td>(Schoolwide implementations in grades 3-5, cross-sectional longitudinal study with transfer effects assessed to grades 6-8). Significant main effects were obtained on ITBS science (+.38 GE adj. mean diff.) and reading (+.32 GE adj. mean diff.) across grades 3-8, with significant transfer effects from grades 3-5 to grades 6-8.</td>
</tr>
<tr>
<td>2003-2008</td>
<td>3-5</td>
<td>multi-year</td>
<td>12 schools</td>
<td>(Replication of 2002-2007- Schoolwide implementations in grades 3-5, cross-sectional longitudinal study with transfer effects assessed to grades 6-7). Results for 2003-2008 parallel those for 2002-2007. Significant main effects were obtained on ITBS science (+.82 GE adj. mean diff.) and reading (+.54 GE adj. mean diff.) across grades 3-8, with significant transfer effects from grades 3-5 to grades 6-8.</td>
</tr>
<tr>
<td>2002-2008</td>
<td>3-5</td>
<td>multi-year</td>
<td>12 schools</td>
<td>(Multi-year cohort studies tracking achievement growth of individual students from grade 3-8). Presently in progress.</td>
</tr>
<tr>
<td><strong>Recent Grade K-2 Studies</strong></td>
<td></td>
<td></td>
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<tr>
<td>2005</td>
<td>1-2</td>
<td>8 weeks</td>
<td>2 schools</td>
<td>(Schoolwide implementations, K students not tested) 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</td>
</tr>
<tr>
<td>2007</td>
<td>1-2</td>
<td>1 year</td>
<td>2 schools</td>
<td>(Schoolwide implementations, K students not tested) Significant effects in ITBS reading (+.58 GE adj. mean diff.) and ITBS science (+.16 GE adj. mean diff.)</td>
</tr>
</tbody>
</table>

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*a Comparable number of demographically-comparable classes/schools used as controls  
*c For consistency in later studies we report non-standardized HLM coefficients (coded as 1 = Experimental, 0 = Controls) as adjusted means.  
*d NSF/IERI Scale Up Project: 2002-2008 (REC 220853).
### Table 2. HLM Analysis of Intervention by Grade level for ITBS GE Science

<table>
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<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>Approx. df</th>
<th>P-value</th>
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<td>For INTRCPT1, B0</td>
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<tr>
<td>INTRCPT2, G00</td>
<td>2.10</td>
<td>0.29</td>
<td>7.21</td>
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<td>0.000</td>
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<td>GRADE, G01</td>
<td>0.79</td>
<td>0.06</td>
<td>14.25</td>
<td>185</td>
<td>0.000</td>
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<tr>
<td>TRT-C0E1, G02</td>
<td>0.82</td>
<td>0.19</td>
<td>5.38</td>
<td>185</td>
<td>0.000</td>
</tr>
<tr>
<td>For TITLE1_1 slope, B1</td>
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<tr>
<td>INTRCPT2, G10</td>
<td>-0.78</td>
<td>0.10</td>
<td>-8.04</td>
<td>2928</td>
<td>0.000</td>
</tr>
<tr>
<td>For NON-MINORITY slope, B2</td>
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<td>INTRCPT2, G20</td>
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<td>0.10</td>
<td>4.45</td>
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<tr>
<td>INTRCPT2, G30</td>
<td>-0.18</td>
<td>0.08</td>
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<td>2928</td>
<td>0.018</td>
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Final estimation of variance components:

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<th>Variance Component</th>
<th>df</th>
<th>Chi-square</th>
<th>P-value</th>
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<tr>
<td>INTRCPT1, U0</td>
<td>1.12</td>
<td>1.25</td>
<td>185</td>
<td>980.71</td>
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<tr>
<td>Level-1, R</td>
<td>220</td>
<td>4.84</td>
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### Table 3. HLM Analysis of Intervention by Grade level for ITBS GE Reading Comprehension

<table>
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<tr>
<th>Fixed Effect</th>
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<th>Standard Error</th>
<th>T-ratio</th>
<th>Approx. df</th>
<th>P-value</th>
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<td>For INTRCPT1, B0</td>
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<tr>
<td>INTRCPT2, G00</td>
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<tr>
<td>GRADE, G01</td>
<td>0.78</td>
<td>0.05</td>
<td>14.29</td>
<td>213</td>
<td>0.000</td>
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<tr>
<td>TRT-C0E1, G02</td>
<td>0.54</td>
<td>0.15</td>
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<td>For TITLE1_1 slope, B1</td>
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<tr>
<td>INTRCPT2, G10</td>
<td>-0.77</td>
<td>0.07</td>
<td>-10.62</td>
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<tr>
<td>For NON-MINORITY slope, B2</td>
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<td>INTRCPT2, G20</td>
<td>0.37</td>
<td>0.08</td>
<td>4.77</td>
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Final estimation of variance components:

<table>
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<th>Standard Deviation</th>
<th>Variance Component</th>
<th>df</th>
<th>Chi-square</th>
<th>P-value</th>
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<td>INTRCPT1, U0</td>
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<td>.82</td>
<td>213</td>
<td>1011.39</td>
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<tr>
<td>Level-1, R</td>
<td>2.01</td>
<td>4.02</td>
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</tbody>
</table>
Figure 1. Knowledge-based instruction (KBI) represented as an instructional architecture in which core concepts to be taught and instructional activities are based on a curricular framework representing the logic of the discipline.
Figure 2. Knowledge-based instruction (KBI) represented as an instructional process in which core concepts to be taught provide a logical context for all aspects of instruction.
## Cognitive Science Principles Incorporated in Knowledge-Based Instruction

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
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<tbody>
<tr>
<td>Use the logical structure of concepts in the discipline as the basis for</td>
<td>Use the logical structure of concepts in the discipline as the basis for a grade-articulated curricular framework.</td>
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<tr>
<td>a grade-articulated curricular framework.</td>
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<tr>
<td>Insure that the curricular framework provides students with a firm prior</td>
<td>Insure that the curricular framework provides students with a firm prior knowledge foundation essential for maximizing comprehension of &quot;new&quot; content to be taught.</td>
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<tr>
<td>knowledge foundation essential for maximizing comprehension of &quot;new&quot;</td>
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<tr>
<td>content to be taught.</td>
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<tr>
<td>Focus instruction on core disciplinary concepts (and concept relationships)</td>
<td>Focus instruction on core disciplinary concepts (and concept relationships) and explicitly addressing prior knowledge and cumulative review.</td>
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<tr>
<td>and explicitly addressing prior knowledge and cumulative review.</td>
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<tr>
<td>Provide adequate amounts of initial and follow-up instructional time</td>
<td>Provide adequate amounts of initial and follow-up instructional time necessary to achieve cumulative conceptual understanding emphasizing &quot;students learning more about what they are learning&quot;.</td>
</tr>
<tr>
<td>necessary to achieve cumulative conceptual understanding emphasizing</td>
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<tr>
<td>&quot;students learning more about what they are learning&quot;.</td>
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<tr>
<td>Guide meaningful student conceptual organization of knowledge by</td>
<td>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/writing, applications) to those concepts.</td>
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<tr>
<td>linking different types of instructional activities (e.g., hands-on science, reading comprehension, propositional concept mapping, journaling/writing, applications) to those concepts.</td>
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<tr>
<td>Provide students with opportunities to represent the structure of</td>
<td>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).</td>
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<tr>
<td>conceptual knowledge across cumulative learning experiences as a basis</td>
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<tr>
<td>for oral and written communication (e.g., propositional concept mapping,</td>
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<tr>
<td>journaling/writing).</td>
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<tr>
<td>Reference a variety of conceptually-oriented tasks for the purpose of</td>
<td>Reference a variety of conceptually-oriented tasks for the purpose of assessment that distinguishes between students with and without in-depth understanding (e.g., distinguishing positive vs. negative examples, using IF/THEN principles to predict outcomes, applying abductive reasoning to explain phenomena that occur in terms of science concepts).</td>
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<tr>
<td>assessment that distinguishes between students with and without in-depth</td>
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<tr>
<td>understanding (e.g., distinguishing positive vs. negative examples,</td>
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<tr>
<td>using IF/THEN principles to predict outcomes, applying abductive</td>
<td></td>
</tr>
<tr>
<td>reasoning to explain phenomena that occur in terms of science concepts).</td>
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</tr>
<tr>
<td>Incorporate the use of in-depth, meaningful, cumulative learning within</td>
<td>Incorporate the use of in-depth, meaningful, cumulative learning within the content-oriented discipline of science as a necessary foundation for developing student proficiency in reading comprehension and written communication.</td>
</tr>
<tr>
<td>the content-oriented discipline of science as a necessary foundation for</td>
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<tr>
<td>developing student proficiency in reading comprehension and written</td>
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<td>communication.</td>
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</tbody>
</table>

Figure 3. Major cognitive science principles of instruction incorporated in a knowledge-based instruction model.
Figure 4. Initial knowledge-based instruction architecture of the Science IDEAS model. Propositional concept mapping was emphasized as a tool for the design of instruction incorporating the Science IDEAS instructional elements (see text for details).
Density
(Some "Macroscopic" Conceptual Perspectives)

What is it?

Comparative Concept
- - - -
Defined as: Amount of matter in a volume

How can we use it?

Arithmetic Computation?

Compute density as ratio of mass to volume.

Mass (amount of matter)
Density involves
measured with...
Balance Scale

Volume (space taken up)
Density involves
measured with
Graduated cylinders

Gas - - - Liquid - - - Solid
Regular shapes - - - Irregular Shapes

(Density) How to measure operationally?

Two ways of comparing densities of two substances

Compare mass (weight) of substances with same volume
Substance with greater mass (weight) given same volume has higher density

Hands-on / operational density comparisons

Compare volumes of substances with same mass (weight)
Substance with less volume given same mass (weight) has higher density

If volume is made equal

To compare densities of substances that have unequal masses (weights) and unequal volumes make either mass or volume of substances equal and then compare...

Density
("Microscopic" enhancement)
Add idea to Macroscopic perspective- Closeness of molecules in substance determines density

Example-Related to buoyancy of substances (floating/ sinking)


Figure 5. Example of a curricular concept map on the concept of density appropriate for planning instruction across grades 2-5.
Figure 6. Example of a curricular concept map constructed from Core Concepts in Earth Science (Carnine et al., 1982) appropriate for planning instruction across grades 3-8.
Figure 7. Simplified illustration of a curricular concept map used as a guide by grade 4 Science IDEAS teachers in planning a sequence of knowledge-based instructional activities for a multi-day lesson using Science IDEAS elements.
**Knowledge-Based Enhancements to Instructional Practices of Content-Area Teachers**

Focus 1: Develop student in-depth, meaningful understanding of content area
Focus 2: Pursuit of students learning more about what is learned

### Focus Instruction on Core Concepts and Concept Relationships

1. Identify core concepts and concept relationships for in-depth understanding of course content/topics
2. Use core concept propositional concept maps as guide for instructional planning and student learning support
3. Distinguish core concepts from trivial and allocate instructional time to emphasize mastery of core concepts and relationships
4. Reference specific content/topics taught to core concepts and/or prior learning in an ongoing fashion
5. Identify additional reading/study materials to enhance scope of student in-depth understanding (i.e., cumulative inquiry)

### Use Instructional Design Based Strategy Enhancements

6. Use knowledge-based reading comprehension strategy to mode/guide student meaningful comprehension of content-area text materials
7. Involve students in the use of propositional concept mapping as a tool to organize knowledge for meaningful understanding and for writing
8. Use knowledge-focused instructional design strategies to accelerate student learning of concepts, concept relationships, and concept applications
9. Use knowledge-focused strategies to assess student mastery of content area concepts/knowledge
10. Use knowledge-focused strategies for motivating/recognizing student learning

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**Figure 8. Specific advanced instructional strategies for use by grade 3-5 Science IDEAS teachers as enhancements to multi-day lessons using Science IDEAS elements. Strategies are also appropriate for adoption and use on a modular basis by content-area teachers at the secondary level.**