

Chapter 87

Interdisciplinary Perspectives Linking Science and Literacy in Grades K–5: Implications for Policy and Practice

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Recent appraisals of interdisciplinary research related to meaningful learning summarised in the report by the National Academy Press, *How People Learn* (Bransford et al. 2000), provide a foundation for why and how science as a form of in-depth, content-area instruction can serve as a core element in literacy development (e.g. reading comprehension, writing) in elementary schools. In their overview, Bransford et al. summarised consensus research into expert behaviour and expertise as a unifying concept for meaningful learning. Such studies have established that, in comparison to novices, experts demonstrate a highly developed organisation of knowledge that emphasises an in-depth understanding of the core concepts and concept relationships in their discipline (i.e. domain-specific knowledge) that, in turn, they are able to access efficiently and apply with automaticity. Although the instructional implications of such perspectives (discussed below) are highly supportive of the importance of in-depth, content-area learning, these same implications are in direct conflict with the present lack of emphasis on meaningful curricular content in popular approaches to reading and language arts that presently dominate elementary schools (e.g. Hirsch 1996, 2006; Walsh 2003) and have resulted in a de-emphasis on science instruction (Dillon 2006; Jones et al. 1999). In the following sections, a combination of theoretical perspectives and empirical findings is presented as a foundation for establishing the relevance of elementary science instruction implemented as a form of in-depth, content-area learning to the development of student proficiency in reading comprehension and writing. In doing so, this evidence-based argument provides a rationale for in-depth science instruction within which reading comprehension and writing are integrated

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29 as a major curricular strategy that has the potential for providing a curricular
30 solution to systemic problems presently associated with school reform (Gonzales
31 et al. 2008; Lee et al. 2007; Lutkus et al. 2006).

32 **Interdisciplinary Research Underlying Meaningful Learning:** 33 **Knowledge-Based Instruction Models**

34 Interdisciplinary foundations of meaningful school learning draw from the comple-
35 mentary areas of cognitive science, cognitive psychology, applied learning, instruc-
36 tional design/development and educational research. Although there is a wide variety
37 of such work, several key research-based perspectives represent primary tenets. The
38 first has to do with the architecture of knowledge-based instruction systems (Luger
39 2008) originally developed for implementing computer-based intelligent tutoring
40 systems. The second (Kintsch 1994, 1998, 2004) involves the importance of having
41 a well-structured curricular environment for learning (Schmidt et al. 1997, 1999).
42 The third (Bransford et al. 2000) is the role of knowledge as applied in the problem-
43 solving behaviour of experts (i.e. expertise) relative to that of novices. The fourth has
44 to do with cognitive research dealing with the linkage of declarative knowledge to
45 procedural knowledge and automaticity (Anderson 1982, 1987, 1992, 1993, 1996).

46 *Cognitive Science Foundations of Knowledge-Based* 47 *Instruction Models*

48 Implemented originally in computer-based intelligent tutoring systems (ITS), the dis-
49 tinguishing characteristic of knowledge-based instruction is that all aspects of instruc-
50 tion (e.g. teaching strategies, student activities, assessment) are related explicitly to an
51 overall design that represents the logical structure of the concepts in the subject-matter
52 discipline to be taught, a curricular structure that, while grade-appropriate, should
53 parallel the knowledge organisation of disciplinary experts. In considering this design
54 characteristic as a key focus for meaningful learning, knowledge-based instruction is
55 best illustrated by the original ITS architecture developed in the early 1980s (e.g.
56 Kearsley 1987; Luger 2008). As Figure 87.1 shows, in ITS systems, the explicit rep-
57 resentation of the knowledge to be learned serves as an organisational framework for
58 all elements of instruction, including the determination of learning sequences, the
59 selection of teaching methods, the specific activities required of learners, and the eval-
60 uative assessment of student learning success. In considering the implications of
61 knowledge-based instruction for education, it is important to recognise that one of the
62 strongest areas of cognitive science methodology focuses on explicitly representing
63 and accessing knowledge (e.g. Luger 2008; Kolodner 1993, 1997; Sowa 2000).

64 The research foundations of knowledge-based instruction models are consistent
65 with well-established findings from cognitive science. In particular, Bransford et al.

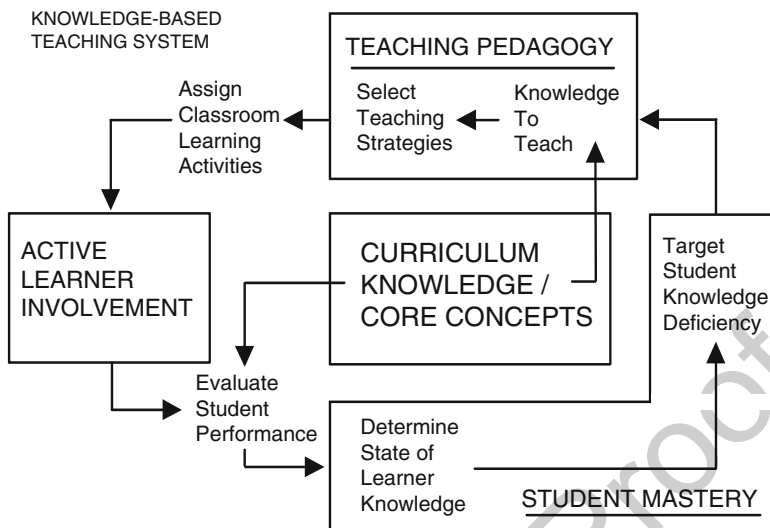


Fig. 87.1 Architecture for a knowledge-based intelligent tutoring system

(2000) stressed the principle that explicitly focusing on the core concepts and relationships that reflect the logical structure of the discipline and enhancing the development of prior knowledge are of paramount importance for meaningful learning to occur (see also Schmidt et al. 2001). Closely related to this view is work by Anderson and others (e.g. Anderson 1992, 1993, 1996; Anderson and Fincham 1994; Anderson and Lebiere 1998) who distinguished the ‘strong’ problem-solving process of experts as highly knowledge-based and automatic from the ‘weak’ strategies that novices with minimal knowledge are forced to adopt in a heuristically oriented, trial-and-error fashion. Also directly related are key elements in earlier versions of Anderson’s (1996) ‘ACT’ cognitive theory that (a) consider cognitive skills as forms of proficiency that are knowledge-based, (b) distinguish between declarative and procedural knowledge (i.e. knowing about vs. applying knowledge) and (c) identify the conditions in learning environments that determine the transformation of declarative knowledge to procedural knowledge.

In considering the role of prior knowledge in learning, the consensus research findings presented by Bransford et al. (2000) emphasised that both the conceptual understanding and use of knowledge by experts in application tasks (e.g. analysing and solving problems) are primarily a matter of accessing and applying prior knowledge (Kolodner 1993, 1997; Rivet and Krajcik 2008) under conditions of automaticity. As characteristics of learning processes, the preceding emphasises that extensive amounts of varied experiences (i.e. practice) focusing on knowledge in the form of the concept relationships to be learned are critical to the development of the different aspects of automaticity associated with expert mastery in any discipline. In related research, Murray Sidman (1994) and others (e.g. Artzen and Holth 1997; Dougher and Markham 1994) have explored the conditions under which extensive

91 practice in automaticity focusing on one subset of relationships can result in addi-
92 tional subsets of relationships being learned without explicit instruction. In these
93 studies, the additional relationships were not taught but, rather, were implied by the
94 original set of relationships that were taught (i.e. formed equivalence relationships).
95 In related work, both Mark Niedelman (1992) and Anderson and others (e.g.
96 Anderson 1996) have offered interpretations of research issues relating to transfer
97 of learning that are consistent with the knowledge-based approach to learning and
98 understanding. Considered together, these findings represent an emerging knowl-
99 edge-based emphasis on the linkage between the logical structure of what is to be
100 taught with the instructional means for accomplishing meaningful learning.

101 *A Knowledge-Based Framework for Approaching Comprehension* 102 *Through Content-Area Instruction*

103 The well-defined structure of the science knowledge (e.g. NSES Standards) appro-
104 priate for in-depth science instruction in K–5 schools fits well with knowledge-based,
105 ITS-type instructional models. However, in order for such in-depth science instruc-
106 tion to be adopted as a primary means for developing student reading comprehen-
107 sion, schools must have an evidence-based rationale as a foundation for justifying
108 increased time for science instruction. Because of the strong dependence of the role
109 of prior knowledge in meaningful learning (Kintsch 1994, 1998, 2004), a knowledge-
110 based approach to reading comprehension would consider reading comprehension as
111 a subset of comprehension in general (Vitale and Romance 2007b). With this view in
112 mind, all of the instructional strategies for engendering the development of science
113 students' in-depth understanding (e.g. hands-on activities, inquiry-oriented question-
114 ing, journaling), therefore, are also applicable to building student proficiency in read-
115 ing comprehension.

116 One approach to addressing the linkage of comprehension development to a
117 knowledge-based approach to meaningful learning is the construction–integration
118 model developed by Kintsch and his colleagues (e.g. Kintsch 1994, 1998, 2004).
119 Kintsch's model explains the process of reading comprehension (and, by inference,
120 comprehension) by distinguishing between the propositional structure (i.e. semantic
121 meaning) of the conceptual content of a text that is being read and the prior knowl-
122 edge that the reader brings to the process of reading. In this context, meaningful
123 comprehension results when the prior knowledge of the learner can be joined with
124 the propositional structure of the text. If the propositional structure of the text is
125 highly cohesive (i.e. knowledge is explicitly well-organised in propositional form),
126 then there is less demand upon readers' prior knowledge. But, if the text is not cohe-
127 sive (i.e. contains significant semantic gaps), then the reader's prior knowledge is
128 critical for understanding. In either case, comprehension consists of the integration
129 of the propositional structure of the text with reader prior knowledge.

130 Within this framework, much of the research conducted by Kintsch and his col-
131 leagues (e.g. McNamara et al. 2007) has focused on the interplay of meaningful text

structure and the prior knowledge of the reader considered as a learner. However, as noted above, the elements of the Kintsch model are readily generalisable to any form of meaningful learning in school settings that involves the interaction of students' prior knowledge with a (cohesive) curricular structure that, together, provide the context for meaningful learning. In this sense, Kintsch's model offers an evidence-based framework (e.g. McNamara and Kintsch 1996; Weaver and Kintsch 1995) that is supportive of the appropriateness of in-depth science instruction through knowledge-based models and of the linkage of such knowledge-based models focusing on science to the development of reading comprehension.

Combining the architecture of knowledge-based instruction with the construction-integration model of Kintsch (1994, 1998, 2004) allows a reinterpretation of research in reading comprehension in a manner that is directly relevant to the use of K-5 science curricula that are 'coherent' (see Schmidt et al. 2001) as a vehicle for building reading comprehension. Within the field of reading, both individual researchers (e.g. Block and Pressley 2002; Farstrup and Samuels 2002) and research groups (RAND Report, Catherine Snow 2002; National Reading Panel 2000) have investigated and evaluated different aspects of reading comprehension instruction. However, in evaluating such research, the RAND report concluded that present knowledge in the field is not yet adequate to systemically reform reading comprehension instruction, particularly the type of content-area reading comprehension that ultimately is required for success in textbook-oriented high school courses in science and other areas. In contrast, in recent interdisciplinary-oriented reading comprehension research, McNamara et al. (2007) concluded that skilled comprehenders are more able to use knowledge (and strategies) actively and efficiently to help them to comprehend text and, further, that individual differences in reading comprehension depend on the dynamics associated with such knowledge activation. Clearly, the activation of prior knowledge in combination with coherent curricular structure are key components of any instructional environment that focuses on the development of in-depth content-area understanding such as science or reading comprehension.

While education has addressed the role of knowledge in meaningful learning and comprehension (e.g. Carnine 1991; Glaser 1984; Hirsch 1996, 2001; Kintsch 1998), such attention was minimal until the publication of the Bransford et al. (2000) book (see Sean Cavanagh [2004] interview with David Klahr). However, consistent with McNamara et al.'s (2007) conclusions, Bransford et al. (2000) emphasised how conceptual frameworks as a form of prior knowledge facilitated new meaningful learning (i.e. comprehension in learning tasks). When these perspectives are considered together, it is the cognitive science perspective that provides the means to understand the dynamics of the important differences between what the reading comprehension literature has identified as proficient vs. struggling readers, particularly in instructional settings requiring content-area reading (see Snow 2002) and the field of cognitive science.

One additional implication from Bransford et al. (2000) supported by others (e.g. Carnine 1991; Glaser 1984; Kintsch 1998; Vitale and Romance 2000) is that, from a knowledge-based perspective, curriculum mastery in schools should be approached as a form of expertise and that student conceptual mastery of academic content

177 should be consistent with how experts perceive the discipline (see also Schmidt et al.
178 2001). In this regard, emphasising the in-depth understanding of core concepts and
179 concept relationships in grade-appropriate form is a critical element of general com-
180 prehension and, by inference, of reading comprehension as well. In fact, a knowl-
181 edge-based perspective of reading comprehension that is consistent with the broad
182 idea of meaningful comprehension presented by Bransford et al. (2000) would sug-
183 gest that the nature of comprehension in both general learning and reading-to-learn
184 settings is equivalent (see Vitale and Romance 2007b), with the exception that the
185 specific learning experiences associated with reading comprehension are text-based.

186 **Support for Using Content-Area Instruction in Science** 187 **as a Means of Enhancing Literacy Development** 188 **at the Elementary Levels**

189 Following from the preceding framework, the question of empirical support for and
190 the relevance of linking in-depth science instruction to literacy development can be
191 addressed. Because the disciplinary structure of science knowledge is highly cohesive,
192 cumulative in-depth instruction in science provides a learning environment well-
193 suited for the development of understanding as expertise. As a focus for meaningful
194 learning in school settings, science conceptual knowledge is grounded on the every-
195 day events that students experience on a continuing basis. In developing science
196 knowledge, elementary students are able to (a) link together different events that
197 they observe, (b) make predictions about the occurrence of events (or manipulate
198 conditions to produce outcomes) and (c) make meaningful interpretations of events
199 that occur, all of which are key elements of meaningful comprehension (Vitale and
200 Romance 2006a). As discussed in the following sections, meaningful learning in
201 science naturally incorporates critical elements associated with the development of
202 curricular-based science expertise by students (e.g. acquisition and organisation of
203 conceptual knowledge, experiencing a potentially wide range of application experi-
204 ences that provide varied practice in learning). In turn, with the active development
205 of such in-depth conceptual understanding in science serving as a foundation, the
206 use of prior knowledge in the comprehension of new learning tasks, and in the com-
207 munication of what knowledge has been learned, provides a basis for key aspects of
208 literacy development.

209 ***Research Trends Recognising the Importance of Content-Area*** 210 ***Instruction in Science in Primary (K–2) Grades***

211 Because literacy development is a major focus in grades K–2, the lack of informa-
212 tional science materials to which young children are exposed in school settings is an
213 important curricular policy issue. In this regard, David Pearson and Nell Duke (2002)

noted that the terms 'comprehension instruction' and 'primary grades' seldom appear together and, along with others (e.g. Duke et al. 2003; Pressley et al. 1996), reported that primary students experience minimal content-area instruction, despite an extensive research base that provides guidance on how and why such instruction should be pursued. Specifically, Pearson and Duke (2002) listed a series of research-based approaches involving teacher story reading (i.e. read-alouds) for building student content-area comprehension as early as kindergarten (e.g. asking meaningful questions about story elements, engaging students in retelling summarisations, using elaboration strategies such as theme identification, intensive text study through elaborative discussion). All of these approaches are highly knowledge-focused and inquiry-oriented and result in the development of domain-specific knowledge as long as such knowledge is available to be learned. As a result, such approaches fit well with an in-depth focus upon science and other content in instruction.

In addressing resistance to the use of informational text at the primary grades, Pearson and Duke (2002) also refuted major unsupported beliefs that serve as barriers (e.g. young children cannot handle them and are uninterested; comprehension is best at upper elementary grades). In a complementary analysis, Walsh (2003) noted that current basal reading series at the primary level are unable to engender meaningful knowledge development because they are designed specifically not to contain such knowledge. Walsh also noted that the problems subsequently evidenced by students in content-area text comprehension are due to lack of prior knowledge rather than deficiencies in reading skills or strategies.

In recent years, emerging K–2 curricular trends have emphasised an increased use of both informational texts in science and reading instruction and a more in-depth approach to science instruction in primary grades. In general, K–2 instructional interventions which emphasise the development of meaningful knowledge in science and other content areas are consistent with emerging literacy trends (Palmer and Stewart 2003) that emphasise the use of informational text for developing comprehension proficiency at the primary levels (see also Holliday 2004; Klentschy and Molina-De La Torre 2004; Ogle and Blachowicz 2002; Gould et al. 2003).

Other researchers have extended the notion of linking science with literacy in early childhood (preschool) programmes and have identified several benefits. For example, Lucia French (2004) has reported the feasibility of a curricular approach in which science experiences provide a rich learning context for an early childhood curriculum that results in early literacy development as well as science learning. Gelman and Brenneman (2004) have shown, from the standpoint of feasibility, how a preschool science programme which incorporates guided hands-on activities can be used as a framework for instruction that engenders the development of domain-specific knowledge in young children. Working with students aged 3–6 years, Carol Smith (2001) described how the active involvement of young children in gaining science knowledge is naturally motivating (see also Conezio and French 2002) if topics are approached with sufficient depth and time, a position consistent with the 1995 National Science Education Standards (NRC 1996). In representative work supporting different facets of science instruction at the primary level, Gould et al. (2003) informally described an approach for early science instruction with gifted

259 students; Russel Tytler and Suzanne Peterson (2001) summarised the meaningful
260 changes in 5-year-olds' explanations of evaporation as a result of extended in-depth
261 science instruction; Jacqueline Jones and Rosalea Courtney (2002) addressed the
262 processes of curricular planning for instruction and assessment in early science
263 learning; Carol Armga et al. (2002) and Laura Colker (2002) suggested guidelines
264 for teaching science in early childhood settings; and Michelle Lee et al. (2000)
265 described the benefits of school-wide thematically oriented instruction in science.

266 In support of the preceding as an emerging trend, an article on a parallel theme
267 by Robert Siegler (2000) discussed a rebirth of attention to children's learning
268 within developmental psychology. Within this context, Herbert Ginsberg and Susan
269 Golbeck (2004) offered thoughts on the future of research in science learning that
270 encouraged researchers and practitioners to examine critically and to be open to the
271 possibilities of unexpected competence in young children (e.g. Revelle et al. 2002),
272 perspectives related to those of Lynn Newton (2001) and Hilary Asoko (2002) and
273 highly consistent with the importance of in-depth science instruction at the primary
274 level (see also Sandall 2003).

275 ***Research Trends Recognising the Importance***
276 ***of Instruction in Science for Literacy Development***
277 ***in Upper Elementary Grades 3–5***

278 There are an expanding number of research initiatives at the upper elementary grades
279 that have linked science instruction and literacy. Gina Cervetti and Pearson (2006)
280 reported results of a series of studies addressing the role of reading in learning sci-
281 ence through their Roots and Seeds curriculum. Within their model, students first
282 participate in inquiry-based, hands-on experiments to illustrate science concepts
283 which are then followed by science reading assignments. Duke and her colleagues
284 (Duke 2000b, 2007; Duke and Pearson 2002) conducted a series of studies of the use
285 of informational texts at the primary school level. These studies addressed an impor-
286 tant instructional deficiency identified in earlier work in which Duke (2000a) reported
287 a scarcity in the use of informational texts at the primary grade levels. In related
288 work, Duke and Pearson (2002) reported the results of studies addressing use of
289 informational text in building reading comprehension (see also Maniates and Pearson
290 2008; Pearson and Fielding 1995). In related research, Annemarie Palincsar and her
291 colleagues (Hapgood et al. 2004; Hapgood and Palincsar 2007; Magnusson and
292 Palincsar 2003; Palincsar and Magnusson 2001) conducted studies investigating the
293 interdependency of hands-on activities (first-hand investigations) and related reading
294 focused on the same or similar science concepts (second-hand investigations) on
295 student science and literacy performance.

296 Another important series of research studies by Guthrie and his colleagues
297 (Guthrie and Ozgungor 2002; Guthrie et al. 2004a, b) demonstrated consistent
298 improvement in student reading comprehension and motivation to learn resulting
299 from embedding multi-week, science-focused instructional modules into traditional

reading programmes using their Concept-Oriented Reading Instruction (CORI) model. In a broader instructional intervention implemented in classrooms with a majority of K–6 ELL students for whom science instruction replaced traditional reading/language arts, Klentschy (2003, 2006) showed that grade 6 students who participated in the initiative for 4 or more years previously averaged a percentile rank (NPR) of 64 on the nationally normed Stanford Achievement Test in reading. And, Romance and Vitale (1992, 2001, 2008) found that replacing traditional reading/language arts instruction with in-depth science resulted in both higher reading comprehension and science achievement for students in grades 3–5 using nationally normed tests. Finally, in complementary work, a series of analyses by Hirsch (1996, 2006) addressed the cumulative learning of academic content as a major systemic deficiency in US elementary schools.

Major Interdisciplinary Implications Linking Science Instruction and Literacy: Grades K–5

The interdisciplinary perspectives presented in earlier sections have significant implications for educational policy and practice across grades K–5. The idea of knowledge-based instruction in science through a grade-articulated, core-concept-oriented curriculum provides a framework for potentially addressing literacy development within science. Such a knowledge-based curricular framework would provide the degree of cohesive structure that is necessary to insure that the science instructional strategies used in classrooms result in cumulative, meaningful learning in a manner that also engenders literacy development. Although these interdisciplinary perspectives are applicable to any curricular content area, this section summarises their combined implications in the form of eight ‘principles’ that form the foundation for the linkage of science and literacy instruction:

1. Use the logical structure of concepts in the discipline as the basis for a grade-articulated curricular framework.
2. Insure that the curricular framework provides students with a firm prior knowledge foundation essential for maximising comprehension of ‘new’ content to be taught.
3. Focus instruction on core disciplinary concepts (and relationships) of a domain and explicitly address prior knowledge and cumulative review.
4. Provide adequate amounts of initial and follow-up instructional time necessary to achieve cumulative conceptual understanding emphasising ‘students learning more about what they are learning’.
5. Guide meaningful student conceptual organisation 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.
6. Provide students with opportunities to represent the structure of conceptual knowledge across cumulative learning experiences as a basis for oral and written communication (e.g. propositional concept mapping, journaling/writing).

- 341 7. Reference a variety of conceptually oriented tasks for the purpose of assessment
342 in order to distinguish between students with and without in-depth understanding
343 (e.g. distinguishing positive vs. negative examples, using IF/THEN principles to
344 predict outcomes, applying abductive reasoning to explain phenomena that occur
345 in terms of science concepts).
- 346 8. Recognise how and why in-depth, meaningful, cumulative learning within a
347 content-oriented discipline provides a necessary foundation for developing
348 proficiency in reading comprehension and written communication.

349 **Research Into the Effect of Integrating Literacy** 350 **Within Knowledge-Based Science Instruction**

351 While the preceding studies involved the general linkage between science and
352 literacy, this section reviews in expanded fashion two different multi-year models
353 that have taken a broader approach by replacing (vs. enhancing) regular reading/
354 language arts instruction with in-depth science instruction in which reading com-
355 prehension and writing are integrated. These two models are the *Valle Imperial*
356 *Project in Science* (Klentschy 2003, 2006; Klentschy and Thompson 2008) and
357 *Science IDEAS* (Romance and Vitale 2001, 2008). Both models have demonstrated
358 that using in-depth science instruction as a means for improving student literacy
359 (reading comprehension, writing) is consistently more effective than the traditional
360 basal reading/language arts programs presently endorsed by the majority of elemen-
361 tary education practitioners, policy makers (see Reading First Impact Study Interim
362 Report, Gamse et al. 2008) and reading experts in academic settings. Moreover,
363 each of these comprehensive models incorporates the eight major instructional prin-
364 ciples based on interdisciplinary perspectives for integrating literacy within science
365 instruction and offers significant implications for curricular policy that would also
366 enhance time allocated to science in K–5 classrooms.

367 ***Valle Imperial Project in Science (VIPS)***

368 **VIPS Program Overview**

369 Working with primarily Hispanic students in Imperial County, located in the south-
370 east corner of California along the US border with Mexico where 50% of students
371 are ELL, the VIPS science instructional model emphasises five interrelated elements
372 necessary for effective systemic reform (National Academy of Science 1997): (a) a
373 high-quality curriculum; (b) sustained professional development and support for
374 teachers and school administrators; (c) materials support; (d) community and top
375 level administrative support; and (e) programme assessment and evaluation. Within
376 this framework, the design of the VIPS model links science and literacy through the

use of student science notebooks within an inquiry-based approach to science instruction in which students are provided with an opportunity to develop 'voice' in their personal construction of the meaning of science phenomena. In the VIPS model, the student 'voice' is represented through the science notebooks that students use during their science learning experiences as a repository for reflections and as a knowledge-transforming (vs. storytelling) tool for constructing meaning. As a means for engendering significant growth in student achievement in both reading, writing and science (Amaral et al. 2002; Jorgenson and Vanosdall 2002; Saul 2004; Klentschy 2003; Klentschy and Molina-De La Torre 2004), the extensive use of science notebooks linking science and literacy has been a major contributor to the success of the VIPS programme.

In order to construct models through the workings of written language, children must necessarily interact with people and objects in their environment. Within the instructional environment established by the VIPS model, students use writing (and drawing) as a means for simultaneously constructing and reflecting on their understanding of science phenomena. This general view of the dynamics of student learning establishes a foundation for teaching in which children learn science by doing science and then use writing as part of their science experiences. This suggests that – in the context of science activities – student-produced science notebooks promote the use of literacy while clarifying students' emerging theories about science phenomena (see also Hand et al. 2004; Norton-Meier et al. 2008). Student science notebooks provide not only stability and permanence to children's work, but also purpose and form.

VIPS Research Findings

A major research focus of the VIPS science model has been documenting the relationship between the levels of student achievement (reading, writing, science) and the number of years of student participation in the VIPS science model. Recent studies reported by Klentschy (2003, 2006) involved students who had been enrolled in the El Centro School District for a 4 year period. Students in grade 4 and grade 6 were formed into groups based on the number of years (0–4) during which they experienced VIPS science instruction from project-trained teachers using the VIPS standards-based instructional science materials. The reading and science achievement measures used in the study were obtained from a district-wide administration of the Stanford Achievement Test (SAT) in Reading and Science. Student achievement in writing (only in grade 6) was assessed through a District-developed Writing Proficiency Test that used prompts requiring specific types of writing.

For reading, Stanford Achievement Test (SAT) reading achievement scores increased linearly over years of VIPS participation (from 0 to 4 years) for grades 4 and 6 students. Contrary to the achievement drop that is commonly found at the fourth-grade level (Chall and Jacobs 2003; Hirsch 2003), students in the VIPS model for 4 years (i.e. grades 1–4, grades 3–6) displayed levels of SAT Reading achievement that were above grade level (grade 4 mean NPR = 57, grade 6 mean

419 NPR = 67) based on national norms. For science, the results showed that Stanford
420 Achievement Test (SAT) science achievement scores also increased linearly over
421 the years of VIPS participation (from 0 to 4 years) for grade 4 and grade 6 students.
422 Again, contrary to the achievement drop that is commonly found at the fourth-grade
423 level, students in the VIPS model for 4 years (i.e. grades 1–4, grades 3–6) displayed
424 levels of SAT Science achievement that were above grade level (grade 4 mean NPR
425 = 53, grade 6 mean NPR = 64) based on national norms. Finally, for writing achieve-
426 ment, assessed through a district-developed test, proficiency for students in grade 6
427 also increased linearly with the number of years of VIPS participation. Students in
428 the VIPS science model for 3 or for 4 years displayed a high degree of writing pro-
429 ficiency (91% and 89% pass-rates, respectively), reflecting the VIPS emphasis on
430 meaningful writing.

431 **Conclusions and Related Findings: VIPS**

432 Overall, the results suggest a substantial relationship between the number of years
433 of participation in the VIPS science model and achievement in reading, writing and
434 science. These findings are consistent with those reported by Ted Bredderman
435 (1983) in an analysis of 57 research studies of the learning effects of science pro-
436 grammes that emphasise in-depth learning relative to traditional textbook pro-
437 grammes. In that study, Bredderman reported a 14-percentile point difference in
438 favour of in-depth (inquiry-based) programmes, along with consistent positive
439 effects for females, economically disadvantaged students and minority students. In
440 the VIP studies, students who did not participate in VIPS science during the years
441 covered by this study (i.e. students with 0 years of participation) typically received
442 instruction from science textbooks or from individually developed teacher units.
443 The results of the VIPS studies also are consistent with a meta-analysis of 81
444 research studies by James Shymansky and others (1990), which contrasted the per-
445 formance of students in hands-on, activity-based programmes with that of students
446 in traditional textbook-based programmes.

447 At the same time, in interpreting the results of these meta-analyses, it is impor-
448 tant to note that more recent complementary research findings (e.g. Magnusson and
449 Palincsar 2003; Palincsar and Magnusson 2001; Swan and Guthrie 1999) have
450 emphasised that the integration of hands-on science activities with reading and writ-
451 ing, rather than hands-on science alone, was associated with increased student
452 achievement. In fact, as a major characteristic of the VIPS (and Science IDEAS)
453 model, the integration of literacy within science (vs. use of basal reading/language
454 arts programmes) explains the combined overall impact of programme participa-
455 tion, resulting in both improved science achievement and the transfer of the VIPS
456 science experiences by students to an overall improvement in reading and writing.

457 As VIPS students advanced through the grade levels, participation in VIPS sci-
458 ence instruction has had other cumulative effects. For example, Klentschy and
459 Molina-De La Torre (2004) found that more students in the district were enrolled in
460 high school chemistry and physics classes than in any previous year, and that read-

ing achievement at the high school level had improved incrementally with each 461
succeeding high school freshman class over a 3-year period. In addition, they found 462
that the cohort of students in high school in 2004 had the highest graduation rate in 463
a decade. 464

Science IDEAS Model 465

Science IDEAS Programme Overview 466

The research on Science IDEAS model was conducted in large, highly diverse, 467
urban school settings in south-eastern Florida (e.g. African American = 36%, 468
Caucasian = 38%, Hispanic = 21%, other = 5%, free lunch = 37%). Science 469
IDEAS is a cognitive-science-oriented instructional intervention that was initially 470
validated within a grade 4 upper elementary setting (Romance and Vitale 1992). 471
Implemented through a daily 2-h block of time which replaces regular reading/ 472
language arts instruction, Science IDEAS is an integrated instructional model that 473
embeds reading and writing within science instruction. In Science IDEAS, multi- 474
day science lessons engage students in a variety of instructional activities (e.g. 475
inquiry-based/hands-on science, reading text/trade/Internet science materials, 476
writing about science, science projects, journaling, propositional concept map- 477
ping as a knowledge representation tool), all of which focus on enhancing science 478
conceptual understanding. As an instructional intervention implemented within a 479
broad inquiry-oriented framework (e.g. all aspects of teaching and learning 480
emphasise learning more about what is being learned through text and non-text 481
modalities), teachers use core science concepts and concept relationships (which 482
students master to develop in-depth science understanding) as curricular guide- 483
lines for identifying, organising, and sequencing all instructional activities. From 484
a curriculum integration standpoint, as students engage in science-based reading 485
activities, teachers guide and support reading comprehension (and writing) in an 486
authentic fashion. 487

As a simplified illustration of how Science IDEAS functions as a strong knowl- 488
edge-based instruction model, Figure 87.2 shows how a propositional concept map 489
(see Romance and Vitale 2001) representing the concept of evaporation could serve 490
as a knowledge-based framework for organising and sequencing complementary 491
instructional activities. Within the knowledge-based curricular framework repre- 492
senting the concept of evaporation, teachers identify additional reading, hands-on 493
projects and writing activities to expand in-depth science knowledge. 494

The foundations of the Science IDEAS model are well-grounded in cognitive 495
science (see Romance and Vitale 2001, 2008). Curricular mastery is considered as 496
equivalent to knowledge-based expertise, and the cumulative development (and 497
subsequent access) of curricular prior knowledge is considered to be the most 498
critical determinant of success in meaningful learning across all varieties of 499
instructional tasks, including reading comprehension. 500

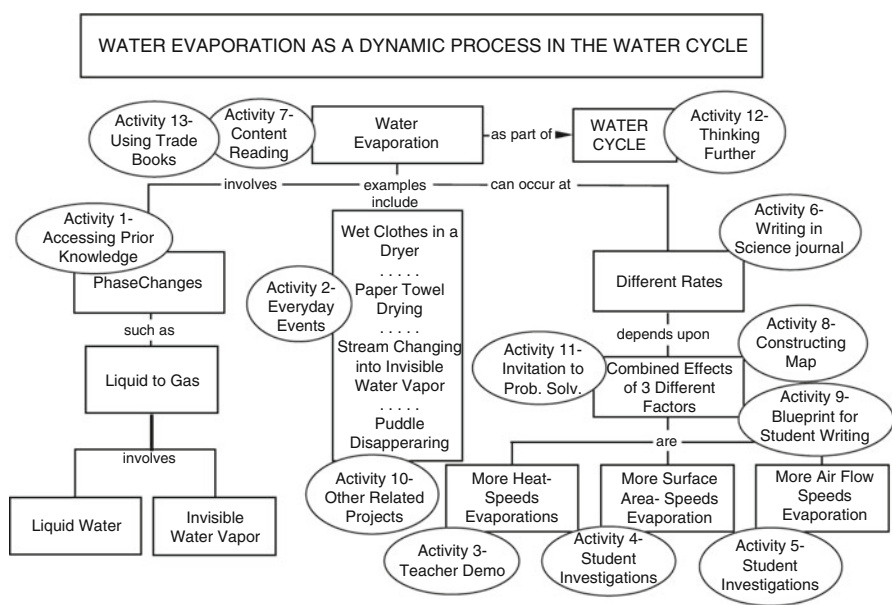


Fig. 87.2 Simplified illustration of a propositional curriculum concept map used as a guide by grade 4 Science IDEAS teachers to plan a sequence of knowledge-based instruction activities

501 Using the initial findings (Romance and Vitale 1992) as a foundation, the Science
 502 IDEAS model subsequently was extended to over 50 classrooms and 1,200 students
 503 across grades 3–5, which included ethnically diverse student populations and a variety
 504 of academic levels ranging from above average to severely at-risk. Most recently,
 505 the Science IDEAS research group is engaged in a multi-year project funded by the
 506 National Science Foundation (NSF) to develop, implement and study the process of
 507 scaling up the model both at the upper elementary level and, in a complementary
 508 fashion, adapt the grade 3–5 model to the primary level (grades K–2). Currently, the
 509 Science IDEAS model is being implemented in grades K–5 on a school-wide basis
 510 in 12 elementary schools.

511 **Science IDEAS Research Findings**

512 The research completed from 1992 to 2001 consisted of a series of studies conducted
 513 in authentic school settings, typically over a school year. In the first study (Romance
 514 and Vitale 1992), three average-performing grade 4 classrooms implemented the
 515 Science IDEAS model over the school year with their end-of-year achievement being
 516 measured by the ITBS Reading and the MAT Science. Results showed that Science
 517 IDEAS students outperformed comparison students by approximately 1 year’s grade
 518 equivalent (GE) in science achievement (+0.93 GE) and one-third of a GE in reading
 519 achievement (+0.33 GE). In the second study conducted the following school year,

Science IDEAS was again implemented with the same three teachers/classrooms in grade 4. In this replication, similar levels of achievement were found, with Science IDEAS students outperforming comparison students by +1.5 GE in science and +0.41 GE in reading (Romance and Vitale 2001).

In the third and fourth studies that followed (Romance and Vitale 2001), the robustness of the model was tested by (a) increasing the number of participating schools, (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 and Vitale 2001) were 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 +0.51 GE in reading over a 5-month (vs. school year) intervention. However, in contrast with earlier findings, no significant effect was found for the younger grade 4 at-risk students for the 5-month intervention.

In the fourth study, the number of participating schools and teachers/classrooms was increased to 15 school sites and 45 classroom teachers. The fourth study revealed that Science IDEAS students displayed greater overall achievement on both science (+1.11 GE) and reading (+0.37 GE). In addition, grade 5 students outperformed grade 4 students while, in a similar fashion, regular students outperformed at-risk students. But, unlike year 3, no interactions were found, indicating that the year-long Science IDEAS intervention was consistent across both grade levels (grade 4 and grade 5) and with both regular and at-risk students. In addition, in the final year of the expansion, the study addressed an important equity issue by showing that the differences in rate of achievement growth and affective outcomes in favour of the Science IDEAS participants were related only to programme participation and not to student demographic characteristics (e.g. at-risk, gender, race).

All of the preceding reported studies (1992–2001) focused on individual teachers/classrooms located in a variety of different school sites. However, beginning with 2002, the Science IDEAS research framework (supported by an IERI/NSF grant) was composed of two different initiatives. The primary initiative (Romance and Vitale 2008) involved implementing Science IDEAS on a school-wide basis in grades 3, 4 and 5 in an increased number of participating schools (from 2 to 12). The increased number of such school-wide interventions provided a framework for studying issues relating to scale-up of the Science IDEAS model (Romance and Vitale 2007; Vitale and Romance 2005; Vitale et al. 2006). The second initiative consisted of two smaller studies embedded within the overall scale-up project that explored extrapolations of the Science IDEAS model to grades K–2 (Vitale and Romance 2007a) and as a setting for reading comprehension strategy effectiveness (Romance and Vitale 2006).

Figure 87.3 shows the cross-sectional effect across grades 3–8 of the Science IDEAS model implemented school-wide in grades 3–8 on ITBS science and reading achievement across 12 participating and 12 comparison schools in 2006–2007 (Romance and Vitale 2008). Both groups of schools were comparable demographically (approximately 60% minority, 45% of students receiving free or reduced-cost lunch). In interpreting these figures, it should be noted that students in grades 6, 7

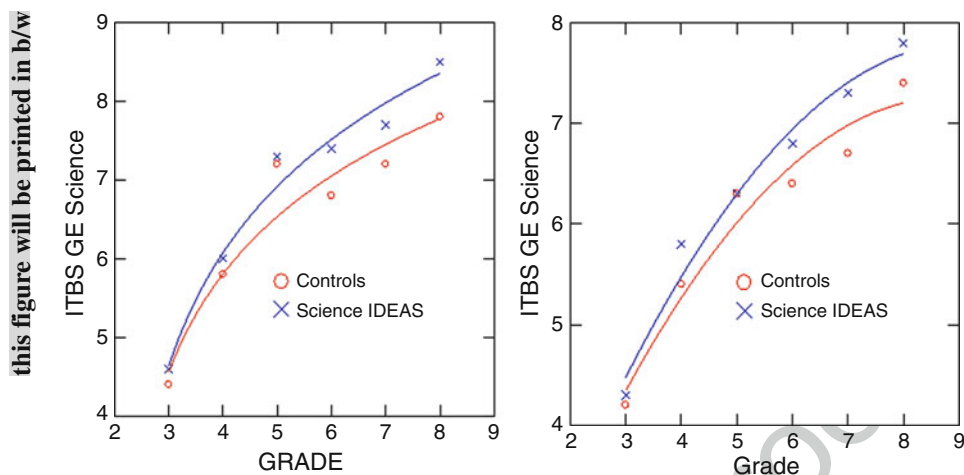


Fig. 87.3 2006–2007 ITBS achievement trajectories for Science IDEAS and control schools in science and reading across grades 3–8

565 and 8 (who had previously attended Science IDEAS or comparison schools) were
 566 categorised as extensions of the Science IDEAS or comparison school they attended
 567 in grade 5).

568 In interpreting achievement trajectories in science in Figure 87.3, linear models
 569 analysis revealed that Science IDEAS students obtained higher overall ITBS
 570 science achievement scores than comparison students (adjusted mean difference =
 571 +0.38 GE in science with grade-level differences ranging from +0.1 GE to +0.7
 572 GE). Both the treatment main effect and the treatment-by-grade interaction were
 573 significant, indicating that the magnitude of the treatment effect increased with
 574 grade level. Co-variates were gender and at-risk status. In interpreting the achieve-
 575 ment trajectories in reading shown in Figure 87.3, linear models analysis revealed
 576 that Science IDEAS students obtained higher overall ITBS reading achievement
 577 than comparison students (adjusted mean difference = +0.32 GE in reading, with
 578 grade-level differences ranging from 0.0 GE to +0.6 GE). While the overall treat-
 579 ment main effect was significant, the treatment-by-grade level interaction was not.
 580 Co-variates were gender and at-risk status. Other results of the analyses were that
 581 (a) the treatment effect was consistent across at-risk and non-at-risk students for
 582 both ITBS science and reading and (b) girls outperformed boys on ITBS Reading
 583 (there was no gender effect for science).

584 The second research initiative consisted of two small-scale studies embedded
 585 within the overall NSF scale-up project that explored extrapolations of the Science
 586 IDEAS model to grades K–2 and explored the effectiveness of in-depth science
 587 instruction as a setting for reading comprehension strategies. The objective of the
 588 K–2 mini-study (Vitale and Romance 2007a) was to adapt the grade 3–5 Science
 589 IDEAS model to grades K–2 in two Science IDEAS schools (vs. two comparison
 590 schools). Within the context of scale-up, the involvement of K–2 teachers/classrooms

was designed to transform the implementation of the grade 3–5 model into a more comprehensive, school-wide instructional model. Unlike the grade 3–5 model, however, in grades K–2, teachers only incorporated 45 min of science instruction into their daily schedules while continuing their regular daily reading instruction. A year-long study revealed an overall main effect in favour of Science IDEAS students on ITBS science (+0.28 GE). However, for ITBS reading achievement, a significant treatment-by-grade level was found, and subsequent simple effects analysis showed a significant difference of 0.72 GE in grade 2 on ITBS reading, but no effect in grade 1. There was a significant effect of white vs. non-white (+0.38 GE), but no treatment-by-ethnicity interaction.

The objective of the grade 5 mini-study (Vitale and Romance 2006b) was to explore whether research-validated reading comprehension strategies (see Vitale and Romance 2007b) would be differentially effective in the cumulative meaningful learning setting established by Science IDEAS classrooms in comparison to a basal reading classrooms emphasising narrative, non-fiction reading. After a 7-week intervention in which reading comprehension strategies were implemented in Science IDEAS classrooms and basal reading classrooms in accordance with a 2×2 factorial design (with prior state-administered reading test scores as a covariate), the results showed that Science IDEAS students performed significantly higher than basal students on both ITBS science (+0.38 GE) and reading (+0.34 GE). Although the main effect of reading comprehension strategy use was not significant, the instructional setting-by-strategy use interaction was significant. Specifically, simple effects analysis showed the use of the reading comprehension strategy by Science IDEAS students improved their overall performance in both science (+0.17 GE) and reading (+0.53 GE), but strategy use had no effect in basal classrooms.

Conclusions and Related findings: Science IDEAS 616

The major conclusion from the multi-year pattern of findings is that Science IDEAS, as an integrated instructional model, was effective in accelerating student achievement in both science and reading in grades 3, 4 and 5. More importantly, the magnitude of the effects expressed in grade equivalents on nationally-normed tests (ITBS, SAT, MAT) was educationally meaningful. Because, in grades 3, 4 and 5, Science IDEAS replaces regular basal reading instruction, the effectiveness of the Science IDEAS model which emphasises in-depth, cumulative, conceptual learning offers major implications for curricular policy at the elementary levels (see Vitale et al. 2006). Of parallel importance is the finding that the effects of Science IDEAS in grades 3, 4 and 5 were transferable to grades 6, 7 and 8. Although this finding is presently being replicated, it has important implications for elementary curricular policy.

Complementing the preceding are other supportive findings that (a) the effect of Science IDEAS is consistent for both regular and at-risk students, (b) the adaptation of the model for use in grades K–2 is feasible and (c) Science IDEAS, in emphasising in-depth, conceptual learning, provides a more effective context for reading comprehension enhancement strategies than narrative-oriented basal reading

633 materials. Overall, the multi-year research initiative involving Science IDEAS
634 provides a strong pattern of evidence supporting the effectiveness of the Science
635 IDEAS model, as well as the natural linkage of science and literacy (Romance and
636 Vitale 2006, 2008).

637 **Towards an Interdisciplinary Rationale** 638 **for Expanding the Role of In-Depth Science Instruction** 639 **in Elementary Schools**

640 The preceding discussion suggests implications for policy and practice concerning
641 the role of in-depth science instruction in elementary schools. These implications
642 are counter to those of present school reform initiatives which, despite their limited
643 success (e.g. Gonzales et al. 2008; Lee et al. 2007; Lutkus et al. 2006), continue to
644 emphasise increased instructional time for traditional reading/language arts at the
645 expense of science instruction (Dillon 2006; Jones et al. 1999). As noted in this
646 chapter, there is an expanding consensus research base from science and literacy
647 educators that linking in-depth science and traditional reading/language arts instruc-
648 tion jointly improves student achievement in both literacy and science. As also
649 presented here, the interdisciplinary research foundations for such combined
650 achievement results are well-established. Yet, despite consistent positive outcomes,
651 the impact of interventions which only augment reading/language arts instruction
652 with in-depth science are necessarily limited. Rather, consistent with interdisciplin-
653 ary research foundations, comprehensive knowledge-based models which develop-
654 mentally integrate reading/language arts within in-depth science instruction would
655 promise to provide an instructional environment that is far more powerful.

656 In fact, the VIPS and Science IDEAS models overviewed here have accom-
657 plished such integration, as well as demonstrating both immediate and long-term
658 achievement effects. In terms of immediate findings, both models have shown con-
659 sistent results that replacing traditional reading/language arts with in-depth science learn-
660 ing results in substantial student achievement acceleration in science, reading
661 comprehension and writing. Moreover, both have reported positive transfer effects
662 of in-depth science instruction from the elementary to secondary levels. Specifically,
663 studies of Science IDEAS revealed that grade 3–5 students displayed greater
664 achievement in science and reading comprehension in grades 6–8. And, VIPS stud-
665 ies demonstrated increased enrolment of students in high school science courses
666 and subsequent graduation rates. In fact, such positive transfer effects from elemen-
667 tary-level instruction to secondary-level performance are contrary to findings
668 reported in the literature (e.g. Dolan 2005). Building on a foundation of interdisci-
669 plinary research perspectives and findings, science education researchers and prac-
670 titioners alike could have an opportunity to argue for systemic changes in present
671 curricular policy to increase substantially the instructional emphasis on in-depth
672 science instruction in grades K–5.

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