# IMPROVING SCHOOL REFORM BY CHANGING CURRICULUM POLICY TOWARD CONTENT-AREA INSTRUCTION IN ELEMENTARY SCHOOLS: A RESEARCH-BASED MODEL [1,2]

Michael R. Vitale, *East Carolina University*
Nancy R. Romance, *Florida Atlantic University*
Michael Klentschy, *El Centro (CA) Elementary School District*

***Abstract***

An emerging trend involves linking and applying research-based advancements in content teaching and learning with systemic school reform. By integrating interdisciplinary research perspectives with systemic problems of school reform, this paper raises the awareness of the potential for increasing the allocation of instructional time for in-depth content-area instruction in science (and other content areas) as a research-validated, curricular approach for accelerating the achievement of all students in both reading comprehension and writing). Described are two research-validated models (*Valle Imperial Project in Science, Science IDEAS*) that exemplify such potential changes in curricular policy by replacing traditional reading/language arts instruction with in-depth science within which reading comprehension and writing are integrated. Presented is a reform-oriented rationale for changing curricular policy to increase the instructional time allocated to teaching science and other content areas at the elementary levels.

An emerging trend in education is the attempt to dynamically link ongoing research initiatives for advancing the quality of K-12 teaching and learning with the more generally evolving process of systemic school reform (e.g., Secretary's Summit on Science, 2004). In advocating an operational strategy that integrates and applies paradigmatically different interdisciplinary research perspectives (e.g., Bransford et al, 2000) to the persistent problems of school reform, the objective of this paper is to raise the awareness of educators and policy makers regarding the potential for in-depth science as a form of content area instruction to serve as a critical element in furthering school reform efforts that, to the present, have emphasized the improvement of achievement outcomes in literacy (e.g., reading comprehension, writing) as ends in themselves rather than as a vehicle for meaningful content-area learning. In doing so, this paper provides evidence in support of the related questions of how and why increasing the allocation of instructional time for in-depth science instruction at the upper elementary levels (grades 3-5) offers a research-validated means for significantly accelerating the achievement progress of all students in both science and literacy (e.g., reading comprehension, writing).

Despite a continuing national emphasis on educational reform for the past 20 years, student proficiency in content-area reading comprehension (and writing) and achievement in content areas such as science have remained systemic problems. When reaching high school, many students representative of all SES strata do not have sufficient academic preparation in prior knowledge or reading comprehension proficiency to perform successfully in content-oriented courses. In addition, there are indications that the lack of emphasis for in-depth teaching of science and other content areas in elementary schools is a systemic barrier to successful school reform (Hirsch, 1996; Vitale & Romance, 2006). Within a framework of school accountability, a predominant school reform strategy has been to increase the time allocated to school- or district-adopted basal reading programs by reducing the instructional time allocated to science and other content areas, especially for those at-risk students most dependent upon school to learn. However, allocating increased instructional time to prepare students for non-content-oriented reading tests

---

[1] *Paper Presented at the Annual Meeting of the American Educational Research Association, April 2006, San Francisco, CA*
[2] *Preparation of this paper was supported by IES Project R305G04089 and NSF/IERI Project REC 022835.*

effectively withholds opportunities for meaningful content learning for school-dependent children across grades 3-8. In turn, the resulting lack of curricular preparation of such students for high school content courses is likely a major contributor to the magnification of the “black-white” test gap from elementary to the secondary levels. Although the short-term pressures of accountability might be difficult for schools to overcome, of even greater importance are the negative long-term curricular implications for student general reading comprehension proficiency and preparation for high school science courses that ultimately become manifest at the high school level (NAEP, 2002, 2003; Rand Report, 2003).

In addressing the challenge of amplifying the role of science and other content-area instruction in school reform, this paper (a) overviews the research-based theoretical perspectives relevant to reform issues that provide the foundations for considering in-depth instruction in science and other content areas as a critical element in school reform, (b) summarizes research findings and presents implications for school reform of two multi-year developmental research initiatives (*Valle Imperial Project in Science*, *Science IDEAS*) that improve student reading comprehension and writing through in-depth science instruction in which reading comprehension and writing are embedded, and (c) presents a reform-oriented rationale educators can use to advocate for changes in curriculum policy that would result in the increase of instructional time allocated to science and other content areas as a reform strategy for improving student reading comprehension and writing. Emphasized as part of the rationale presented is how a curricular policy of improving achievement in reading comprehension and writing through increased in-depth content area instruction also would result in better preparation of all students for success in high school content-area courses in both the science and non-science areas (e.g., history, literature, geography). Finally, considered are specific opportunities associated with the school reform movement that would be facilitative of efforts by educators to change curricular policy to increase time for content area teaching and learning at the elementary level.

## *Consensus Research Perspectives and Findings Underlying the Importance of Meaningful Science Learning to Literacy in School Reform*

Recent appraisals of interdisciplinary research related to meaningful learning summarized in the recent report by the National Academy Press, *How People Learn*, (Bransford et al, 2000) provide a foundation of why and how in-depth science and content area instruction can serve as a core element in literacy development (e.g., reading comprehension, writing). In their overview, Bransford et al summarized the findings of established research studies of experts and expertise as a unifying concept for meaningful learning. Such studies have repeatedly established that in comparison to novices, experts demonstrate a highly-developed organization of knowledge that emphasizes 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 a perspective (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; Walsh, 2003). In this section, a combination of theoretical perspectives and empirical findings are presented to establish 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, a critical reform goal.

### *Cognitive Science Foundations of Knowledge-Based Instruction Models*

In considering the operational characteristics associated with disciplinary expertise as a foundational framework, the notion of knowledge-based instruction provides a methodological perspective for approaching curriculum and instruction. Implemented originally in computer-based intelligent tutoring systems (ITS), the distinguishing characteristic of knowledge-based instruction models is that all aspects of instruction (e.g., teaching strategies, student activities, assessment) are related explicitly to an overall design that represents the logical structure of the concepts in the subject-matter discipline to be taught, a curricular structure that optimally should parallel the knowledge organization of disciplinary experts.

In considering this design characteristic as a key focus for meaningful learning, knowledge-based instruction is best illustrated by the original ITS architecture developed in the early 1980's (e.g., Kearsley, 1987; Luger, 2002). As Figure 1 shows, in ITS systems the explicit representation of the knowledge to be learned serves

- - - Insert Figure 1 Here - - -

as an organizational framework for all elements of instruction, including the determination of learning sequences, the selection of teaching methods, the specific activities required of learners, and the evaluative assessment of student learning success. In considering the implications of knowledge-based instruction for education, it is important to recognize that one of the strongest areas of cognitive science methodology focuses on explicitly representing and accessing knowledge (e.g., Luger, 2002; Kolodner, 1993, 1997; Sowa, 2000).

The research foundations of knowledge-based instruction models are consistent with well-established findings from cognitive science. In particular, Bransford et al (2000), in the recent National Academy Press report, *How People Learn*, 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 & Fincham, 1994; Anderson & 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 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 to procedural knowledge.

In emphasizing the role of prior knowledge in learning, the consensus research findings presented by Bransford et al (2000) emphasized that both the conceptual understanding and use of knowledge by experts in application tasks (e.g., analyzing and solving problems) is primarily a matter of accessing and applying prior knowledge (see Kolodner, 1993, 1997) under conditions of automaticity. As characteristics of learning processes, the preceding emphasizes 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, Sidman (1994) and others (e.g., Artzen & Holth, 1997; Dougher & Markham, 1994) have explored the conditions under which extensive practice to automaticity focusing on one subset of relationships can result in additional subsets of relationships being learned without explicit instruction. In these studies, the additional relationships were not taught, but rather were implied by the original set of relationships that was taught (i.e., formed equivalence relationships). In related work, both Niedelman (1992) and Anderson and others (e.g., Anderson, 1996) have offered interpretations of research issues relating to transfer of learning that are consistent with the knowledge-based approach to learning and understanding. Considered together, these findings represent an emerging knowledge-based emphasis on the linkage between the logical structure of what is to be taught with the instructional means to accomplish meaningful learning.

***Considering Comprehension through Reading from a Knowledge-Based Perspective Emphasizing Content Area Instruction***

As noted in the RAND report (Snow, 2002) and others (e.g., National Reading Panel, 2000), there are a substantial number of studies in the fields of reading and instructional psychology that have investigated different aspects of reading comprehension instruction (e.g., Block & Pressley, 2002; Farstrup & Samuels, 2002; Gersten et al, 2001). 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 ultimately required for success in textbook-oriented high school courses. In a comprehensive interdisciplinary review of reading comprehension research, McNamara et al (in press) concluded that skilled comprehenders are more able to actively and efficiently use knowledge (and strategies) to help them comprehend text and, further, that individual differences in reading comprehension depend on the dynamics associated with such knowledge activation. Clearly, within the context of the present paper, such knowledge activation is an explicit component of any instructional environment that focuses on the development of in-depth content area understanding.

While education has addressed the role of knowledge in meaningful learning (i.e., comprehension) to a limited degree, (e.g., see Carnine, 1991; Glaser, 1984; Hirsch, 1996, 2001; Kintsch, 1998), such attention was minimal until the publication of the Bransford et al (2000) book (see Cavanagh (2004) interview with David Klahr). Consistent with McNamara et al’s (in press) conclusions, Bransford et al presented a clear conceptual overview of the role of knowledge in meaningful learning, showing that the core-concept frameworks that experts develop to organize their knowledge are highly facilitative of their gaining an accurate and in-depth understanding of the dynamics of the settings with which they interact. In contrast, novices commonly attend to irrelevant features using weak organization schemes that do not accurately represent the informational dynamics they face. A second emphasis in the Bransford et al book was on the crucial role of how such conceptual frameworks as a form of prior knowledge facilitate new meaningful learning (i.e., comprehension in learning tasks). Considered together, these cognitive science perspectives provide a dynamic means to understand important differences between what the reading comprehension literature has identified as proficient vs. struggling readers, particularly in settings requiring content area reading (see Snow, 2002).

An important implication from the Bransford et al (2000) book supported by a wide variety of sources (e.g., Carnine, 1991; Glaser, 1984, Kintsch, 1998; Vitale & Romance, 2000) is that curriculum mastery is best considered a form of expertise and that student conceptual mastery of academic content should reflect how experts perceive the discipline (see also Schmidt et al, 2001). In this regard, emphasizing the in-depth understanding of core concepts and concept relationships is a critical element of general comprehension and, by inference, of reading comprehension as well. In fact, a knowledge-based perspective of reading comprehension that is consistent with the broad idea of meaningful comprehension presented by Bransford et al (2000) would suggest the nature of comprehension in both general learning and reading settings is equivalent, with the exception that the specific learning experiences associated with reading comprehension are text-based.

***Toward a Rationale in Support of Content Area Instruction in Science as a Means for Enhancing Literacy Development at the Elementary Levels***

Given the preceding, a logical argument in support of the relevance of in-depth content area instruction to literacy development can be outlined. Because the disciplinary structure of science knowledge is highly coherent, cumulative in-depth instruction in science provides a learning environment that is well-suited for the development of understanding as expertise. As discussed in later sections, meaningful science learning naturally incorporates critical elements associated with the development of such curricular expertise by students (e.g., acquisition and organization of conceptual knowledge, experiencing a potentially wide range of application experiences that provide varied practice in learning). And, in turn, with the active development of such in-depth conceptual understanding serving as a foundation, the use of existing knowledge in the comprehension of new knowledge and in the communication of what knowledge has been learned provide the basis for key elements aspects of literacy development.

***Research trends recognizing the importance of informational texts in primary (K-2) grades***. Within the last several years, emerging trends consistent with the preceding have focused on the importance of informational text (and science content) as early literacy initiatives in the primary grades. In studying the lack of informational text to which young children are exposed in school settings, Duke and her colleagues (e.g., Pearson & Duke, 2002) noted that the terms “comprehension instruction” and “primary grades” seldom appear together. As advocates of increasing the involvement of primary students with informational material, Duke and her colleagues have implicitly recognized two interdependent cognitive science principles (see Bransford et al, 2000) about which school practitioners (and policy makers) seem unaware (see Hirsch, 2003) and which provide an important foundation for possible K-2 science instructional interventions. The first, as noted previously, is that comprehension is a far more general concept than reading comprehension, and, the second is that prior domain-specific knowledge is the most powerful factor influencing comprehension, whether or not learning is "text-based." In explaining the lack of informational text at the primary levels, Pearson and Duke reported that many teachers erroneously believe instruction that involves content area comprehension must wait until students develop decoding proficiency in reading. Although beyond the scope of this paper, Pearson and Duke list and refute major unsupported beliefs that serve as barriers to the use of informational text at the primary grades (e.g., young children cannot handle them and are uninterested, comprehension is best at upper elementary grades).

It is not surprising that the work of Duke and others (e.g., Duke, Bennett-Armistead et al, 2003; Duke, Martineau et al, 2003; J. Pressley et al, 1996) have found that primary students have minimal opportunities for exposure to learning that involves cumulative meaningful comprehension, despite an extensive research base that provides guidance on how such instruction should be pursued effectively (see Engelmann & Carnine, 1991; Vitale & Romance, 2006). More specifically, Pearson and Duke (2002) list a series of research-based approaches involving teacher story reading (i.e., read alouds) that can build student content-area comprehension as early as kindergarten (e.g., asking meaningful questions about story elements, engaging students in retelling summarizations, using elaboration strategies such as theme identification, intensive text-study through elaborative discussion). All of these approaches are highly knowledge-focused, inquiry-oriented, and implicitly 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 a complementary analysis, Walsh (2003) reported that current basal reading series at the primary levels are unable to engender meaningful knowledge development from a logical basis because they do not contain such knowledge by design. As a result, Walsh noted, the problems subsequently evidenced by students in text comprehension are likely due to lack of prior knowledge rather than deficiencies in reading skills or strategies. Moreover, rather than committing the substantial instructional time required to build meaningful knowledge at the primary levels, students are passed to upper elementary grades and beyond which, in turn, exacerbate the problem by replacing content area instruction such as science with instruction in non-content-oriented reading (see Jones et al, 1999; Klentschy & Molina-De La Torre, 2004). Therefore, rather than reversing an expanding academic deficit at the primary levels (see Hart & Risley, 2003 for a related view), many students progress through the educational system while appearing to be successful until faced with high school content area courses for which deficiencies in content knowledge defects are paramount, particularly for low-SES students who depend on school to learn. In this regard, Thompson & O'Quinn (2001) have emphasized the importance of academically-focused early childhood education in addressing the black-white test gap in a preventative fashion (see also Fryer & Levitt, 2005; Hirsch, 1996; Joseph, 2004; Pretti-Frontczak et al, 2003). In general, K-2 instructional interventions which emphasize the development of meaningful knowledge in science and other content areas are consistent with emerging literacy trends (Palmer & Stewart, 2003) that emphasize the use of informational text for developing comprehension proficiency at the primary levels (see also Holliday, 2004; Klentschy & Molina-De La Torre, 2004; Ogle & Blachowicz, 2002; Gould, Weeks, & Evans, 2003, for related views).

***Research trends recognizing the importance of content area instruction in science in primary (K-2) grades***. Building on the research in the preceding sections, a major emphasis in support of any sound K-2 science instructional intervention is that science knowledge offers a meaningful context through which students at the primary levels are able to experience learning more about what is being learned in a fashion that enhances their capacity for comprehension, as outlined in a following section. As a focus for meaningful learning, science conceptual knowledge deals with everyday events that students experience on an ongoing basis. And, in developing science knowledge, students become 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 (Vitale & Romance, 2000; Vitale, Romance, & Dolan, 2003).

Considered as a knowledge-based model within which literacy as reading comprehension and writing are naturally embedded, K-2 science instruction is consistent with emerging research arguing for the importance of science at the primary levels. For example, 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 & Brenneman (2004) have shown from the standpoint of feasibility how a preschool science program 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. In working with 3 to 6 year olds, Smith (2001) described how the active involvement of young children in gaining science knowledge is naturally motivating (see also Conezio & French, 2002) if topics are approached with sufficient depth and time, a position consistent with the 1995 "National Science Education Standards" (see Rakow & Bell, 1998). In 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 students, Tytler and Peterson (2001) summarized the meaningful changes in 5-year-old's explanations of evaporation as a result of extended in-depth science instruction, Jones and Courtney (2002) addressed the processes of curricular planning for instruction and assessment in early science learning, Armga et al (2002) and Colker (2002) suggested guidelines for teaching science in early childhood settings, and Lee et al (2000) described the benefits of schoolwide thematically-oriented instruction in science.

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

***Research trends recognizing the importance of content area instruction in science for literacy development in upper elementary (grade 3-5) grades.*** Although the instructional models and research findings of the grade K-5 *Valle Imperial Project in Science* and the grade 3-5 *Science IDEAS Project* presented in the following sections are highly relevant to the preceding points, this section first considers evidence from other sources addressing the linkage of in-depth science instruction and literacy development that provide the general research foundations for both. In this regard, both the *Valle Imperial Project in Science (VIPS)* and *Science IDEAS* exemplify in-depth instructional approaches (e.g., Mintzes et al, 1998; Minstrell & van Zee, 2000) to science teaching and learning which emphasize students learning more about what is being learned in a cumulative and meaningful fashion. In doing so, classroom instruction for both projects attempts to engender an in-depth understanding of both science concepts and the nature of science that is consistent with national science standards (e.g., AAAS, NRC) and articulated across grade levels. The architecture of both instructional models involves sequencing different types of classroom activities consistent with recommendations in the literature (e.g., Bransford et al, 2000; Donovan et al 2003) that provide a means for an embedded approach to assessment (e.g., Kellough et al, 1996; Pellegrino et al, 2001). Finally, a major component of both projects are extensive professional development systems that focus on increasing teacher science understanding and on providing continuing teacher support in the form of apprenticeship and coaching (e.g., King & Newmann, 2001) through a professional staff proficient in the use of the interventions.

Consistent with the findings of both the *Valle Imperial Project in Science (VIPS)* and *Science IDEAS*, other significant research in reading comprehension (Guthrie et al, 2004; Guthrie & Ozgungor, 2002) has shown that replacing portions of basal reading materials with content-oriented reading materials in science (and social studies) significantly improves both general reading proficiency and student motivation to engage in reading. Armbruster and Osborn (2001) have summarized research findings demonstrating positive student achievement in reading comprehension resulting from integrating science content with reading/ language arts. Many of the instructional strategies incorporated within the *VIPS* and *Science IDEAS* (e.g., referencing prior knowledge, mental imagery, questioning, and summarization) were recognized by Block and Pressley (2002) in a cumulative review of research as effective in improving reading comprehension. In an overview of work investigating thinking and intelligence, Perkins and Grotzer (1997) reported the importance of content-oriented disciplinary study in the form of cognitive reorganization and disposition to think that is consistent with the instructional architecture of both models. Finally, a number of recent articles (Beane, 1995; Ellis, 2001; Hirsch, 2001; Schug & Cross, 1998; Yore, 2000) have discussed curricular issues and findings that support curriculum interventions represented by the *VIPS* and *Science IDEAS* in which a core curriculum content is used as a framework for embedding both reading and writing.

## *Considering Two Research-Validated Instructional Models for Enhancing Reading Comprehension and Writing through In-Depth Science Instruction*

In combination with the theoretical perspectives and research findings described above, the two science instructional models (*Valle Imperial Project in Science(VIPS), Science IDEAS*) have paradigmatic implications for changing elementary curricular policy to increase the time allocated to science instruction. In keeping with Kuhn's (1996) development of the idea of paradigmatic change within a discipline, the consistent research results obtained through these two in-depth science models are clearly anomalous from the standpoint of commonly accepted elementary (K-5) curricular policy and practice (see Hirsch, 1996). This is true for three important reasons. First, the implementation of each of the two models *replaces* traditional reading/language arts instruction with in-depth instruction in science within which reading comprehension and writing are embedded. Second, in the absence of traditional reading/language arts curriculum instruction, both models consistently have obtained greater achievement outcomes in reading comprehension and/or writing in addition to increased achievement in science. And, third, while the operational characteristics of the two models differ, both demonstrate the effectiveness of in-depth science learning with low SES and/or limited English proficiency (LEP) at-risk student populations. The paradigmatic implications of both models with regard to improving school reform are that both models have demonstrated that using in-depth science instruction as a means for improving student literacy (reading comprehension, writing) is consistently more effective than the accepted reading/language arts curricular approaches presently endorsed by the majority of elementary education practitioners, policy makers, and reading experts in academic settings. With the preceding in mind, this section first describes each of the two in-depth science models and then summarizes the empirical research findings and implementation requirements for each. Then, in the following section, the paradigmatic implications of each for curricular policy and school reform are considered.

## Valle Imperial Project in Science

The *Valle Imperial Project in Science* (*VIPS*) is located in Imperial County, CA, the southeast corner of California along the U.S. border with Mexico, approximately 120 miles from San Diego. Most Imperial County residents have a strong cultural and linguistic ties to Mexico and Imperial County ranks highest in poverty of all counties in California. The population of the school system is predominately Hispanic (81%), with approximately 11% Caucasian, 5% African American, and 1% Native American. More than 50% of students in the county are limited English proficient (LEP).

### *Description of the VIPS Model*

The *VIPS* science instructional model implemented in the Imperial County, CA is based on the National Science Resources Center – LASER Model which emphases five critical interrelated elements necessary for effective systemic reform (National Academy of Science, 1997). These elements are: (a) a high quality curriculum; (b) sustained professional development and support for teachers and school administrators; (c) materials support; (d) community and top level administrative support; and (e) program assessment and evaluation. Within 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 based upon the belief that students should be provided with an opportunity to develop "voice" in their personal construction of the meaning of science phenomena.

***Writing about science as a constructivist learning process.*** In the *VIPS* model, the student "voice" comes in the form of science notebooks that students utilize during their science experiences, in social interactions, as a tool for reflection, and as a knowledge-transforming (vs. story telling ) 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 & Molina-De La Torre, 2004), science notebooks serve as an important vehicle for extending student literacy and have an important part in the documented success of this program.

The use of writing in the *VIPS* model as a vehicle to promote learning is consistent with the belief that writers must engage in active reprocessing at the level of concepts and central ideas (Scardamalia and Bereiter, 1986). As a result, writing serves as a heuristic device with which students can achieve powerful insights and understandings about content (VanDeWeghe, 1987). Writing enables students to express their current ideas about science content in a form in which supports examination and thinking in learning. The writing process, therefore, serves as an activity for constructing and representing meaning and as tool for understanding and communication. Because the first goal of writing is to communicate understanding. writing is an effective instrument to motivate student thinking about what is understood. As a result, student achievement in science and the ability to use language are highly reciprocal (Fellows, 1994).

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 (White and Gundstone, 1992). This general view of the dynamics of student learning establishes a foundation for teaching wherein 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 Hand et al, 2004)..

***Operational perspectives on variants of student writing in the VIPS model.*** The *VIPS* model reflects the belief that the science notebooks which students construct are a very special, essential means of communication. Student science notebooks provide not only stability and permanence to children's work, but also purpose and form. This form of "knowledge-focused" writing also helps students link new information with prior knowledge (Rivard, 1994). Such cumulatively constructed science notebooks can also contain drawings, tables or graphs that are essential in forming meaning for children from their science experiences. The earlier young children are able to learn to keep records of observations, the better prepared are they to make this process a natural part of their science activities (Hapgood et al, 2004; Harlen, 1988). In the *VIPS* model, children at all levels, as early as kindergarten, participate in experiences that require them to collect and interpret times and distances or data on other measurements in their science notebooks. The subsequent use of science notebooks in class discussions helps students construct meaning of the science phenomena (Harlen, 2001). Student science notebooks then become more than a record of data that students collect, facts they learn, and procedures they conduct. Rather, science notebooks also become a record of students' reflections, questions, speculations, decisions and conclusions, all of which focus on science phenomena to be understood. As such, science notebooks are a central place where language, data, and experience operate jointly to form meaning for students while providing teachers with a window into student thinking processes.

Using writing tasks that engage students in reflecting upon their own alternate conceptions and in reconciling them with available evidence (and current conceptions) is an effective classroom strategy for enhancing conceptual change (Fellows, 1994). It is in this context that the *VIPS* science program views the role of student science notebooks as a powerful tool in the learning process of each student. Rather than focusing on discrete knowledge learned for its own sake, students are challenged to apply their knowledge in solving meaningful problems. In this context, student science notebooks serve as the medium for working-out responses to complex problems requiring higher order reasoning. Thus, the way that writing is employed and evaluated in the classroom is critical in determining students' own perceptions of their potential for the meaningful learning of content (Rivard, 1994). By cumulatively creating their own science notebook pages, students are able to describe and reflect on their ways of seeing and thinking about the science phenomena, constructing and reconstructing meaning through their own lens of experience (Shepardson & Britsch, 2001). And, using science notebooks as a vehicle, construction of meaning is done in the "voice" of the student, not the teacher.

The Imperial County *VIPS* science program has an established belief that students need time to develop the skill of self-expression in recording their observations. In the earliest stages, young children may use their notebooks only to draw what they see and what they think is going on. This early use of drawings is an important beginning because if students are expected to record their observations in some way, they are likely to observe more closely and shed their preconceptions to see what is really there (Harlen, 2001). Later, as students develop, science notebooks become useful instruments for recording what they do in their investigations and the results they achieve. The professional development program for teachers in Imperial County schools is designed to develop as a "best practice" teacher guidance of students recording of what they actually see and do, not what they think teachers expects them to see or do.

The nature of students' contextualization of the science phenomena and their writing activities on science notebook pages are dependent on the student's familiarity with the phenomena and equipment and with the length of exposure to the program of instruction (Amaral et al, 2002). In unfamiliar situations, student entries reflect only immediately observed phenomena associated with a science investigation, whereas, in familiar situations, children's entries are based on their knowledge gained from prior experiences with phenomena, placing the science investigation into a real-world context (Shepardson & Britsch, 1997). In fact, an analysis of the initial use of student science notebooks in the *VIPS* model confirmed that students' first science notebooks took on the form of a narrative or procedural recount (Amaral et al, 2002). One caveat about the use of science notebooks, however, is that while they may engage students in solving problems, they less frequently engage students in finding problems (Reddy et al., 1998). While students may be quite interested in and excited about carrying out science activities, they may not be willing to spend time interpreting their results. Students' self-produced science notebook pages may themselves be viewed as a story that unfolds over time that fits children's way of seeing. Therefore, while such stories may be distorted from the perspective of a scientist or a teacher (Shepardson & Britsch, 1997), because this action is developmental, teachers must continually guide students to be reflective about their work. In summary, student science notebooks when used appropriately have the potential to move students beyond simply completing assigned tasks to engaging students to make sense of the tasks. In this way, science notebooks (and student writing) can simultaneously support the development of student scientific knowledge, general thinking, and literacy.

***Overview of Research Findings for the VIPS Model***

***Effect of the VIPS model on achievement in reading, writing, and science.*** A major focus of the research studying the effects of the *VIPS* science model has focused on 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 in the El Centro School District, the largest district in Imperial County, CA. The study reported here (Klentschy, 2003) consisted of students who had been enrolled in the El Centro School District for a four year period, regardless of school attendance (or project involvement) within the district. Over the four-year period, there was a 92% student stability rate and students not enrolled in the District for the full four year period were excluded since the type of science instruction they would have received in other districts was not determinable. The resulting sample consisted of 615 students in 4th grade and 634 students in 6th grade.

Students in grade 4 and grade 6 were formed into groups based on the number of years (0-4) they had received *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 districtwide administration of the Reading (state-mandated) and Science Subtests (state-optional) of the Stanford Achievement Test, 9th Edition, Form T. 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. The writing assessment was administered districtwide by classroom teachers and scored by a District team of trained evaluators using a four point holistic rubric (a score of 3 was passing) covering the content and conventions of writing. Because the focus of the writing test in grade 6 was on reporting information to help the reader understand a procedure or process, the prompt presented to grade 6 students presented a problem about which students were to propose solutions in their writing task (e.g. Dana et al, 1991; McColskey & O'Sullivan, 1993). This task was considered an appropriate measure for assessing the effect of the *VIPS* model because of the extensive student involvement in science notebook writing and process of inquiry students experienced during *VIPS* classroom instruction.

Table 1 shows the mean Stanford Achievement Test (SAT) reading achievement score by years of *VIPS* participation for grades 4 and 6. A two-way ANOVA performed on the NPR means ( $N = 1$ per cell) indicated a significant linear relationship ( $F(1, 7) = 82.47$, $p < .001$) between years of *VIPS* participation and reading achievement across the two grade levels. The adjusted mean NPR cross-sectional growth between grade 4 and grade 6 of +3.4 was not significant, indicating no difference in student reading performance as they progressed through grade levels, contrary to the achievement drop that is commonly found (see Chall & Jacobs, 2003; Hirsch, 2003). As Table 1 also shows, students who were in the *VIPS* model for 4 years (i.e., grades 1 through 4, grades 3 through 6) displayed levels of SAT Reading achievement that were well above grade level (Grade 4 mean NPR = 57, Grade 6 mean NPR = 67) on SAT national norms.

- - - Insert Table 1 Here - - -

Table 2 shows the writing proficiency pass-rate by years of *VIPS* participation for students in grade 6. A regression analysis confirmed that the linear increase in percentage of pass scores as a function of years of participation in the *VIPS* model was statistically significant ( $F(1, 3 = 3.45$, $p < .05$). As Table 2 also shows, the grade 6 students who participated in the *VIPS* science model for 3 or for 4 years displayed a high degree of writing proficiency (91 and 89 percent pass-rate, respectively), reflecting the *VIPS* emphasis on meaningful writing.

- - - Insert Table 2 Here - - -

Table 3 shows the mean Stanford Achievement Test (SAT) science achievement score by years of *VIPS* participation for grades 4 and 6. A two-way ANOVA performed on the NPR means ($N = 1$ per cell) indicated a significant linear relationship ( $F(1, 7) = 278.49$, $p < .001$) between years of *VIPS* participation and science achievement across grade levels. In addition, the adjusted mean cross-sectional NPR growth between grade 4 and grade 6 of +4.8) also was significant ( $F(1,7) = 10.97$, $p < .05$), indicating a consistent increase in student performance as they progressed through grade levels (again, contrary to the achievement drop that is commonly found). As Table 3 also shows, as with reading (Table 1) and writing (Table 2), students who in the *VIPS* model for 4 years displayed levels of SAT science achievement that were well above grade level (Grade 4 mean NPR = 53, Grade 6 mean NPR = 64) on SAT national norms.

- - - Insert Table 3 Here - - -

***Conclusions and related findings***. Overall, the results reported here indicated a substantial effect of years of participation in the *VIPS* science model and achievement in reading, writing, and science. These findings are consistent with those reported by Bredderman (1983) in an analysis of 57 research studies comparing the learning effects of science programs that emphasize in-depth learning to traditional textbook programs. In that study, Bredderman reported a 14-percentile point difference in favor of in-depth (inquiry-based) programs, along with consistent positive effects for females, economically disadvantaged, and minority students. In the present study, students who did not participate in the district *VIPS* science model during the years covered by this study (i.e., students with zero (0) years of participation) typically received instruction from textbooks or from an individually developed teacher units. The results of the present study are also consistent with a meta-analysis of 81 research studies by Shymansky and others (1990) which contrasted the performance of students in hands-on, activity-based programs with that of students in traditional textbook-based programs.

At the same time, in interpreting the results of these meta-analyses, it is important to note that more recent complementary research findings (e.g., Magnusson & Palincsar, in press; Palincsar & Magnusson, 2001; Swan & Guthrie, 1999) have emphasized that the integration of hands-on science activities with reading and writing rather than hands-on science alone resulted in increased student achievement outcomes. In fact, as a major characteristic of the *VIPS* (and *Science IDEAS*) model, such integration explains the combined overall impact of program participation resulting in both improved science achievement and the transfer of the *VIPS* science experiences by students to an overall improvement in reading and writing.

As students have advanced through the grade levels in recent years, participation in *VIPS* science instruction has had other cumulative effects. For example, in 2004, Klentschy & Molina-De La Torre (2004) found that more students in the District were enrolled in high school chemistry and physics classes than in any previous year, and that reading achievement at the high school level had improved incrementally with each succeeding high school freshman class over the past three years. In addition, they found that the cohort of students graduating from high school in 2004 had the highest graduation rate in a decade.

***Practical Guidelines for Implementing the VIPS Model***

The most difficult part of any journey is the first step. As such the embedding of expository writing strategies into teacher professional development programs is an essential beginning stage. The implementation of the *VIPS* Imperial County model is based upon the notion that six elements are integral to the *VIPS* model if students are to gain meaningful understanding from their science classroom experiences. These six research-based science notebook components and associated criteria have been identified and utilized with teachers in Imperial County since 1996 (Klentschy and Molina-De La Torre, 2004). While these six components will be found in student science notebook entries associated with most lessons, they are not necessarily found in student entries across all lessons. These six components are: (a) Question, Problem, Purpose, (b) Prediction, (c) Planning, (d) Observations/Claims-Evidence, (e) What Have You Learned?, and (e) Next Steps/New Questions.

There are several ways for teachers to begin using student science notebooks. One approach is to have teachers work with students with the following stems: (a) Today I (or we) want to find out_________________, (b) I think ________ will happen because _________, (c) I noticed (or observed) ___________ , (d) I wonder ________________, (e) Today I learned ____________, and (f) Questions I have now are ________ . Once the preceding stems are introduced, they can be gradually withdrawn as students gain experience in using their science notebooks. (For more ideas for getting started visit the Imperial County science program website at http://www.*VIPS*cience.com).

Since the development of the capacity for teachers and school principals is a critical issue related to implementation, a sustained program of professional development for classroom teachers and principals is critical to the success of any reform effort in science or any other subject. In the past, the application of consensus research findings has not always been applied to professional development plans associated with teacher and principal capacity building. In this regard, the capacity development of teachers, policy makers and professional development planners should consider ten critical elements or design principles drawn from an application of the consensus research in the formulation of policy and professional development design models (National Academy of Science, 1997; Stigler & Hiebert, 1999; Klentschy & Molina–De La Torre, 2004). These ten elements include: (a) Linkage of preservice and actual classroom practice, (b) Institutes to deepen content understanding, (c) Opportunities to deepen pedagogical skills, (d) In-classroom support and coaching, (e) Leadership development, (f) Materials support, (g) Time for collaboration and networking, (h) Applications of technology, (i) Workshops focusing on student work as the centerpiece, and (j) Opportunities to refine and reflect on instructional delivery through lesson study. In a supporting analysis, Berlinger (1994) stated that teachers move along three separate and distinct pathways in their development from novice to expert. The first dimension, content, relates to the depth and use of the content understanding of the teacher. The second dimension, pedagogy, relates to the teaching strategies associated with best practice. The final dimension, student learning, refers to the ability of the teacher to determine the degree to which students understand what has been taught.

The application of the ten professional development design principles coupled with individual teacher capacity development in content, pedagogy and, student learning have been critical in the formulation of policy and professional development design for the *VIPS* model. And, just as teachers need a program of sustained professional development carefully crafted, so do school principals. For school principals, the *VIPS* professional development emphasizes deepened content understanding, science standards alignment to materials, analysis of best classroom practices, analysis of student work, and experience with the process of coaching and feedback.

In approaching the implementation of the *VIPS* model, the key to effective science teaching is to enable students to develop ideas about the world around them that fit evidence they have collected and about which they have developed personal meaning. Learning science is relevant to literacy because it involves both the processes of thinking and action and the ability to communicate about science phenomena. Because communication has a central role in the process of inquiry (see Hand et al, 2004), there is a centrality in the power of language in shaping our constructions of the world about us. Words and language are used as a way of trying out a framework for understanding, and students need to have time and space to reflect on ideas. Vygotsky (1978) stated “the three most important aspects of a teacher’s role in elementary science are providing materials for students to observe and investigate, asking the right kinds of questions, and helping students to communicate their thinking and developing ideas.” The *VIPS* model is a valuable tool for addressing these three important elements.

## Science IDEAS Model

The research on *Science IDEAS* model was conducted in a large urban school setting (N = 262,027) in southeastern Florida. The population of the school system was highly diverse (African American = 36%, Caucasian = 38%, Hispanic = 21%, Other: 5%, Free Lunch: 37%).

### *Description of the Science IDEAS Model*

*Science IDEAS* is a research-based, cognitive-science-oriented instructional intervention that was initially validated within a grade 3-5 upper elementary setting (Romance & Vitale, 1992). Implemented through a daily 2-hour block of time which replaces regular reading/language arts instruction, *Science IDEAS* is an integrated instructional model that embeds reading and writing within science instruction. In *Science IDEAS*, multi-day science lessons engage students in a variety of instructional activities (e.g., hands-on science experiments, reading text/trade/internet science materials, writing about science, science projects, journaling, propositional concept mapping as a knowledge representation tool), all of which focus on enhancing science conceptual understanding. As an instructional intervention implemented within a broad inquiry-oriented framework (e.g., all aspects of teaching and learning emphasize learning more about what is being learned through text and non-text modalities), teachers use core science concepts and concept relationships (which students master to develop in-depth science understanding) as curricular guidelines for identifying, organizing, and sequencing all instructional activities. From a curriculum integration standpoint, as students engage in science-based reading activities, teachers guide and support reading comprehension (and writing) in an authentic fashion.

As a simplified illustration of how *Science IDEAS* functions as a strong knowledge-based instructional model, Figure 2 shows how a propositional concept map (see Romance & Vitale, 2001) representing the concept of evaporation could serve as a knowledge-based framework for organizing and sequencing complementary instructional activities. Within the knowledge-based curricular framework representing the concept of evaporation, teachers identify additional reading, hands-on projects, and writing activities to expand in-depth science knowledge.

- - - Insert Figure 2 Here - - -

***Research Results of the Effect of Science IDEAS as a Knowledge-Based Model for In-Depth Comprehension***

***Effect of Science IDEAS model on achievement in reading and science.*** The foundations of the *Science IDEAS* model are well established (see Romance & Vitale, 2001). These consider curricular mastery as equivalent to knowledge-based expertise and the development (and subsequent access) of cumulatively developed curricular prior knowledge as the most critical determinant of success in meaningful learning across all varieties of instructional tasks, including reading comprehension. The empirical results of the initial research investigation implemented in grade 4 classrooms reported by Romance and Vitale (1992) were very positive (e.g., the study was recognized with national awards from the *National Association for Research in Science Teaching*). In comparison to demographically similar controls, *Science IDEAS* instruction not only resulted in significantly higher levels of student achievement on nationally-normed tests in science (adj. mean difference in MAT science = .95 GE); but also on reading comprehension (adj. mean difference in ITBS reading comprehension = .32 GE). In addition, *Science IDEAS* students displayed significantly more positive attitudes toward science learning, more positive self-confidence in learning science, and more positive attitudes toward reading.

Using the initial findings as a foundation, the *Science IDEAS* model subsequently was extended to a greater number of classrooms across grades 3-5 which included ethnically diverse student populations and a variety of academic levels ranging from above average to severely at-risk. As summarized in Figures 3 and 4 (see Romance & Vitale, 2001), the expansion of the *Science IDEAS* model during that time period to over 50 teachers and over

- - - Insert Figures 3 and 4 Here - - -

1200 students revealed a similar and consistent pattern of findings in terms of the magnitude of positive effects in both reading comprehension and science learning (along with similar positive affective outcomes). In addition, the year 4 study addressed an important equity issue by showing that the differences in rate of achievement growth and affective outcomes in favor of the *Science IDEAS* participants were related only to program participation and not to student demographic characteristics (e.g., at-risk, gender, race). However, the finding most important to questions of curricular policy and school reform is not that *Science IDEAS* students displayed consistently higher achievement in science. Rather, it is that a knowledge-based, conceptually-oriented intervention that did not explicitly emphasize reading instruction obtained better results in reading comprehension than an alternative (basal) reading curriculum specifically adopted by schools to teach reading comprehension.

At the present time, the Science IDEAS research group is engaged in a five-year project funded by the National Science Foundation (NSF) to develop, implement, and study the process of scaling up both the elementary (grades 3-5) and a middle school (grades 6-8) variant of the model. Through the 2005-2006 school year, the *Science IDEAS* model is being implemented in grades 3-5 on a schoolwide basis in 12 elementary schools and in grades 6-8 for science instruction in 5 middle schools. With the completion of year 4 this spring, the project will be able to begin to analyze cumulative achievement trends for participating students (vs. comparable controls) and develop initial (for the project) achievement projections across grades as a function of years of participation by students and fidelity of teacher implementation of the Science IDEAS model by teachers. Through the present, the project implementation model has become increasingly effective in engendering increased teaching fidelity in the initial year of school participation while successfully sustaining (or improving) the implementation fidelity in continuing elementary schools. Although a comprehensive analysis of the data cannot occur until all longitudinal achievement data through 2005 are received from cooperating districts and integrated within a comprehensive database, project elementary schools evidencing effective fidelity through the present (4 of 4 in 2003-2004, 9 of 11 in 2004-2005) have all either maintained or improved to an "A" status on the Florida State Accountability System after replacing their regular basal reading program with in-depth science instruction. In addition, a controlled mini-study conducted within the project at grade 5 in Spring, 2004, found that *Science IDEAS* schools significantly outperformed comparable traditional schools using basal reading programs on both the ITBS Reading Comprehension and Science tests (Vitale & Romance, 2005).

***Science IDEAS and reading comprehension: A knowledge-based interpretation reading comprehension transfer.*** The important research finding (Romance & Vitale, 2001) that *Science IDEAS* had a consistently positive effect on student reading comprehension requires further interpretation. First, because the specific (mostly non-science) content of the reading materials used in the nationally-normed reading comprehension tests (ITBS, SAT) was different than the specific science content students learned and read about in their classrooms, the positive effects of *Science IDEAS* on reading comprehension clearly represented a general transfer of learning outcome in reading comprehension (see Niedelman, 1992). Second, *Science IDEAS* teachers did not explicitly instruct students in reading skills (e.g., main idea, cause-effect, sequencing) or, up to 2003-2004, did not incorporate into instruction reading comprehension strategies that research (e.g., Gersten et al, 2001, Trabasso & Bouchard, 2002) has recognized as important in content area reading comprehension (see Romance & Vitale, 2005), although some of these occurred naturally within the context of teaching in-depth science (e.g., cause-effect relationships are a fundamental form of science knowledge.)

One possible interpretation of the consistent transfer effects from *Science IDEAS* to reading comprehension is knowledge-based in perspective and follows points made by Bransford et al (2000) that emphasize the importance of the development of prior knowledge in meaningful learning and the work of Kolodner and her colleagues (e.g., Kolodner, 1993, 1997) on case-based knowledge representation and reasoning. More directly relevant, however, are the factors relating to the development of expertise summarized by Bransford et al and Anderson (1996) and the general ontological functions of knowledge representation offered by Sowa (2000).

From a knowledge-based perspective, this working view is that the progressive experiences in gaining cumulative in-depth science understanding within *Science IDEAS* resulted in the developmental refinement of a general ontological framework (see Vitale & Medland, 2002) of fundamental core concepts and concept relationships within which additional knowledge could first be assimilated and then used as an organizational framework that resulted in a form of expertise-based new learning. As noted earlier, within a knowledge-based framework, Sowa's (2000) analysis of the ontological functions of knowledge representation and the complementary work of both Anderson (1996) and Sidman (1994) emphasize the importance of extensive and varied practice in the development of concepts and concept relationships. One possible working hypothesis is that students in *Science IDEAS* refine (at some level of automaticity) their ontological proficiency in a fashion that facilitates their representation, assimilation, and access of information as a form of expertise. Such ontological expertise could facilitate students acquiring, organizing, and thinking about new information that is embedded in reading comprehension tests, even if their domain-specific prior knowledge is minimal. From this general constructivist perspective (Mintzes et al, 1998), it is reasonable that students with such prior comprehension experience and expertise would be far better prepared to assimilate new information through reading and then to be able to access and think about such information in answering questions about it. However, this important research question has yet to be addressed systematically.

***Research in reading and educational psychology focusing on reading comprehension that complements the cognitive science literature in support of Science IDEAS.*** There also is a substantial body of literature in the area of reading comprehension that supports the effectiveness of the *Science IDEAS* model. In a comprehensive summary of text comprehension strategy instruction, Trabasso and Bouchard (2002) examined 205 empirically-based studies involving 12 distinct cognitive strategies for improving reading comprehension (e.g., comprehension monitoring, graphic organizers, prior knowledge, question generation, story structure, summarization, vocabulary instruction) that were conducted from 1980 through the date of their review. In their conclusions, they emphasized the importance of episodic content knowledge as a basis for reader-constructed deeper understanding, the related use of graphically-oriented story mapping (see also Williams, 2002) as a basis for guiding student explication of narrative understanding, and the related role of student summarization involving identification and organization of core concepts and themes in material that is read.

Among the most important finding reported by Trabasso and Bouchard (2002) was that the use of multiple strategy instruction taught through dialogue-rich teacher modeling/guidance was a powerful approach for improving student reading proficiency. In identifying directions for future research, they emphasized the importance of conducting reading comprehension strategy research within content area instructional settings and in focusing on the issue of enhancing the transferability of reading comprehension strategies. In a complementary review, Gersten et al (2001) reported similar conclusions (see also Farstrup & Samuels, 2002).

In another review focusing on children's searching and using informational text, Dreher (2002) stressed the importance of substantially expanding the instructional experiences of upper elementary students with informational (content-oriented) text. Similar concerns relating to the need to emphasize informational text at the elementary levels have been presented by Ogle and Blachowicz (2002). In a review of research designed to improve the comprehension of expository text, Pearson and Fielding (1995) found that organizational enhancements summarizing text structure (e.g., hierarchical elaboration summaries, visual organizers) were powerful in facilitating overall comprehension and learning. Finally, within a context of discourse analysis, Weaver and Kintsch (1995) noted the importance of the structure of domain specific prior knowledge in affecting how text is understood and remembered in general, and how the interactive nature of domain specific knowledge (along with text cohesion) impacts the effectiveness of reading comprehension strategies in particular (see also Perkins & Grotzer, 1997)

***Conclusions and related findings.*** The research findings associated with the *Science IDEAS* model have demonstrated that replacing traditional reading/language arts with in-depth science instruction within which reading comprehension and writing are embedded consistently results in higher achievement outcomes in both reading comprehension and science. Although referenced in earlier sections, it is important to again recognize the extensive work by Guthrie and his colleagues (e.g., Guthrie et al, 2004; Guthrie & Ozgundor, 2002) with upper elementary students that also repeatedly shown that adding authentic content-oriented reading materials (e.g., science, social studies) to traditional reading/language arts instruction has a positive effect on both reading proficiency and student motivation to engage in reading. In this regard, Armbruster and Osborn (2001) summarized research findings demonstrating positive student achievement in reading comprehension resulting from integrating science content with reading/language arts. Finally, other sources (Beane, 1995; Ellis, 2001; Hirsch, 1996, 2001; Schug & Cross, 1998; Yore, 2000) discussed issues and findings that support interventions in which core curriculum content is used as a framework for embedding reading comprehension strategies.

### *Practical Guidelines for Implementing the Science IDEAS Model*

The present research initiative involving *Science IDEAS* is a multi-year effort focusing on the question of implementation scalability. The specific goal of the present NSF-funded research initiative is to study the systemic development of how school districts are able to gain the capacity and organizational infrastructure necessary to sustain the implementation of *Science IDEAS* while concomitantly expanding it to new school sites. Within the context of this scale up project, there are two complementary perspectives: one that addresses what is required to implement the *Science IDEAS* model itself on a large scale, and one that addresses the scale-up processes that would insure the sustainability and expansion of it by participating school districts (see Vitale & Romance, 2004).

The major component for initial implementation of *Science IDEAS* is a two-week professional development institute for teachers described by Romance & Vitale (2001) and Romance and Vitale (2006) that consists of the three interdependent elements needed by teachers to teach the daily 2-hour *Science IDEAS* instructional blocks: (a) gaining the science content knowledge necessary to teach in-depth science, including proficiency with hands-on science activities (b) understanding how to use the elements of the *Science IDEAS* model itself as a guide for in-depth science teaching, and (c) learning how to integrate reading comprehension, writing activities (with language arts skill development) within in-depth science instruction. Following initial two-week sessions, teacher professional development and support (for grade level planning, classroom implementation) are continued during the school year. Then, over the following two years, summer and school-year professional development and in-school support are reduced to a maintenance level. Other elements required to implement the model on a schoolwide basis include (a) scheduling of the 2-hour science block (replacing basal reading/language arts instruction and minimizing student pull-outs on a schoolwide basis), (b) acquiring the classroom resources necessary for hands-on activities and extra science reading materials, (c) allocating time for and involving the principal in grade-level unit planning, and (d) involving the principal in the monitoring of fidelity of implementation at the classroom level.

The successful scale-up of *Science IDEAS* would mean that schools themselves have gained the capacity to sustain the level of implementation fidelity that results in the performance outcomes in reading comprehension and science established by prior research. Within the project scale up model (Vitale & Romance, 2004), this is accomplished through several interdependent operations that involve a three-step phasing process. In phase one, project staff are responsible for initiating and supporting all aspects of the implementation. In phase two, project staff work collaboratively with appropriate school and district personnel to develop the capacity of the district and schools to assume responsibility for all facets of *Science IDEAS* implementation. In phase three, the project staff withdraws and turns the responsibility for implementation over to appropriate district and school personnel.

Within the multi-phase scale up process itself, a number of focal points are crucial. The first is that the district develops sufficient capacity (and infrastructure) to sustain the implementation in schools presently using *Science IDEAS* before attempting large scale expansion. The second is that the district establishes sufficient capacity to support expansion to new sites before attempting to do so. In this regard, a major component of the present scale up model is the development of teacher and principal leadership cadres within model sites who will eventually provide the long-term resource capacity needed for sustainability and expansion. And, finally, the scale up model recognizes that in order for the implementation to be sustained on an ongoing basis, some means for the integration of both the positive classroom characteristics of instruction and student performance outcomes resulting from the *Science IDEAS* model must be established as part of whatever accountability system or processes that establish the “institutional value” of the school District. This latter "value added" element is of critical importance because if such implementation characteristics and performance outcomes of *Science IDEAS* are not represented in a valid form within the institutional value structure that is used for decisionmaking, then it is unlikely to be sustained or expanded on a long-term basis.

## Toward a Reform-Oriented Rationale for Improving School Reform by Expanding Instructional Time for Science in Elementary Schools

### *Reconsidering the Status of School Reform*

Within the context of school reform, a disturbing characteristic identified in the literature has to do with the curricular impact of State- and Nationally-mandated reading assessment programs implemented within a framework of school accountability that has reduced the instructional time allocated to in-depth science instruction. Complementing and extending previous research on the lack of adequate instructional time to teach science (e.g., Mullis & Jenkins, 1988; Schoenberger & Russell, 1986), Jones et al (1999) reported how a State-mandated school reform initiative emphasizing improved reading achievement resulted in elementary schools decreasing the amount of time science was taught. Specifically, in order to improve achievement on State-developed standards-based reading tests, schools (particularly low-achieving schools whose students are dependent on schools to learn) devoted an increased amount of instructional time to reading test preparation by re-allocating time from other curricular content areas, including science. Although conducted in North Carolina (NC), Jones et al and the other studies cited above are consistent with the experiences reported informally by many science educators. Replacing science and other content area instruction with reading instruction (or test-specific reading preparation) is a widespread curricular phenomenon in elementary schools.

It is easy to understand under pressures of accountability why elementary schools reduce or eliminate the time for teaching science with the hope of improving reading achievement. However, at the same time, it is difficult to accept such a policy as effective when there is good reason to believe its ultimate curricular effect (i.e., besides possibly spuriously raising reading test scores) is highly negative insofar as it affects the lack of preparation of students for science and other content-oriented (e.g., history, economics, government, literature) courses that becomes evident at the high school level. For example, in NC, reading achievement as measured by State tests has increased substantially across grades 3-8, while, at the same time, performance on State mastery tests in key high school courses (e.g., science, history, government, literature) has not. In particular, the achievement gap on high school course-specific tests between white and minority students (often representing low SES students more dependent upon school to learn) has continued to be substantial (see NC End-of-Course Test Report, 2005).

Overall, even after a 20 year initiative, the pervasiveness of the systemic factors noted above do not bode well either for successful school reform or for strengthening the curricular emphasis on content area teaching and learning in elementary schools. Reflecting a limited substantive framework for making evidence-based decisions, schools repeatedly tend (a) to adopt new initiatives which are not research-validated under the guise of pursuing adaptive strategies for obtaining educational reform goals (e.g., Carnine, 1995; Ellis, 2001) or (b) to continue institutional commitments in the face of poor effectiveness to those preciously adopted (e.g., Dade County Schools, 2000). Insofar as the present dominant curricular policy involving science and other content area instruction is concerned, the prevailing tactic used by elementary schools after over 20 years of school reform is to enhance student achievement on state-mandated reading assessments by replacing content area instruction with practice on reading test preparation materials. And, at the same time, the combined instructional time allocated to traditional reading instruction and to reading test preparation seems a stable curricular commitment to reform while the substantive content (e.g., science, social studies) of classroom instruction receives minimal policy attention and is allowed to vary greatly from school to school (see Hirsch, 1996).

### *Research-Based Perspectives in Support of the Potential Role of Science as a Key Element in School Reform Emphasizing Content-Area Learning*

Within the context of standards-based school reform (e.g., AFT, 1997; Feldman, 2000), an apparent logical contradiction is that states demonstrating cumulative improvement in reading achievement in grades 3-8 as measured by state reading tests have experienced no corresponding improvement at the high school levels (e.g., Florida, North Carolina). However, a number of complementary perspectives suggest that the substantial lack of success in high school reform can be readily understood. First, in content-oriented high school courses, student prior knowledge is a major determinant of successful learning (see Bransford et al, 2000; Hirsch, 1996). In this sense, when students do not have the prior levels of understanding required for success, teachers are faced with the problem of replacing portions of high school courses with remedial instruction on the prerequisite knowledge students have not acquired in the preceding grades (K-8).

Second, the reason as to why students have not developed adequate prior knowledge in the elementary and middle school levels is that instruction at those levels emphasizes process (or affective outcomes) rather than meaningful understanding of academic content (e.g., teaching strategies vs. core curriculum content). Although this perspective will be developed more fully below, it is consistent with the fact that “teaching reading comprehension” per se is a major curricular emphasis in grades 3-8, despite the fact that reading itself cannot logically function as a curriculum because content comprehension is based upon disciplinary knowledge. In this context, a representative inspection of how reading presently is defined for assessment purposes is instructive. In the case of the well-established NAEP testing program (Dougher et al, 1994; NAEP, 2005), the framework for reading assessment is of only minimal relevance to the comprehension requirements students face when they read content-area textbooks and other content-oriented materials. Rather, NAEP reading skills emphasize affectively-oriented judgments, some of which are relevant to understanding literature and some of which are not. Further, because NAEP skills are consistent with popular reading standards, all NAEP skills can be addressed superficially through non-content oriented basal reading materials sold as “literature” or, for older students, through supplementary remedial reading materials that are “content-free.”

In this regard, the problem is not with the concept of literature per se. Rather the problem is that the materials labeled as literature that schools use have minimal opportunities for developing meaningful understanding beyond referencing common student life experiences because they have no meaningful academic content by design (see Walsh, 2003). To the detriment of long-term educational reform, the “opportunity cost” of allocating student instructional time to reading programs that emphasize non-academic, non-content materials is that such time replaces the opportunities for students to interact with the very forms of content-oriented instruction and reading materials that are necessary to provide them with the knowledgeable foundation necessary for future success in high school courses and to develop a potentially transferable proficiency in content-area reading comprehension. With this in mind, it is easy to understand why low-SES students who depend on schools to learn would be expected to perform poorly at the high school level if they did not receive adequate, content-rich, learning opportunities (e.g., Coleman, 1966). This illustrates the importance of Hirsch’s (1996) views on why the lack of emphasis in the curriculum policy of elementary schools on the development of the prior knowledge of low-SES students has the effect of systemically withholding the exact form of intellectual capital they need for future academic success.

***Toward a Rationale for Improving School Reform by Expanding Time for Science and Other Content Area Teaching in Elementary Schools***

Overall, the implications of the preceding perspectives for school reform are as follows: (a) the preparation of students for successful meaningful learning in high school should be considered a major reform goal on which minimal progress has yet to be met, (b) the systemic problem explaining the lack of success achieving this goal is the popular misconception that reading is a curriculum in grades 3-8 (i.e., beyond the development of decoding and fluency in grades K-2), and (c) the replacement of academically-oriented instruction (such as science, social studies) that emphasize the meaningful development and subsequent utilization of conceptual prior knowledge with the non-academic “literature” materials common to “reading curricula” is a major barrier to successful educational reform. In this sense, given the research presented in this paper, if increasing time for in-depth instruction in science and other content areas is a remedy for addressing the above problem, then changing curriculum policy to increase the instructional time for in-depth science and other content area instruction at the elementary levels has the potential to result in significant improvement in systemic educational reform.

In contrast to the common scenario in which reading displaces science and other content area instruction, the research presented here is supportive of why increasing the time allocated for teaching science (and, by inference other content areas) could help solve recognized school reform problems associated with reading comprehension while better preparing students for future high school success. In doing so, the fundamental theoretical perspective comes from knowledge-based instruction models from cognitive science and artificial intelligence whose structure is, in fact, highly curricular (see Vitale & Romance, 1999, 2000, 2006). As discussed here, these models require the specification of the conceptual content to be learned as a logical basis for providing a sound curricular context for both the instructional strategies and assessment methodologies used. In curriculum planning, the logical structure of the discipline (i.e., core concepts and core concept relationships) should be used to provide an organizational framework for specifying the sequence of the content to be taught and, therefore, for instructional strategies and assessment as well. Additionally, in knowledge-based instruction, all teaching activities should require students to relate what they are learning to previously learned core concepts or core concept relationships. As a result, knowledge-based instruction emphasizes the cumulative development of the forms of prior knowledge that enhance student success in new learning tasks.

In adaptations of knowledge-based instruction to science education, both the *VIPS* and *Science IDEAS* models for teaching in-depth science within which literacy goals were integrated concomitantly improved the reading comprehension, writing, and science achievement of highly diverse student populations by replacing traditional reading/language arts instruction with in-depth science instruction. Considered in a schematic form, the preceding provides educators with a rationale for how expanding the time for in-depth science (and content area) teaching can improve high priority student achievement goals within a school reform/accountability framework through a dual focus: (a) the improvement of student general reading comprehension (and writing) and (b) the development of the prior knowledge students need to be successful in high school science and other content courses. At the present time, this rationale has been applied successfully as a foundation for initiating *VIPS* and *Science IDEAS* in an increasingly larger number of elementary schools. In a complementary fashion, as part of an NSF-funded multiyear project to scale up *Science IDEAS*, the participating school districts have linked elementary project feeder schools to middle schools in which science courses would be taught using knowledge-based approaches for in-depth science teaching to further accelerate student preparation for high school science courses. Considered together as successful applications of the rationale presented here, these initiatives should offer educators encouragement for advocating that increasing the time for in-depth science and other content area instruction would have significant implications for improving the success of educational reform in reading comprehension and high school achievement that are not likely to occur without a strong emphasis on content-oriented instruction at the elementary level.

In pursuing such a systemic change in curricular policy, educators should consider two other related factors. First, as a matter of timing, a number of reform-oriented states (e.g., Florida, North Carolina) are in the process of introducing or have introduced state-mandated science testing in elementary grades. These initiatives reflect the fact that policymakers (e.g., No Child Left Behind) have begun to recognize that in-depth science understanding at elementary grade levels is an important reform priority that has been ignored to this point. In particular, in states that plan to test science at the elementary levels, schools are unlikely to have sufficient instructional time to address comprehension instruction in both science and reading separately. Under these conditions, addressing reading comprehension within science instruction could become an attractive curricular alternative.

Second, it is critically important that educational policy does not allow the simple adding of materials with some form of science content or content from other disciplines (see Carnine, 2004) to existing reading programs to be equated with the form of knowledge-based in-depth science instruction represented by the *VIPS* model and *Science IDEAS*. In fact, research suggests that reading any materials containing coherent academic content that engages students in cumulative understanding is preferable to non-content oriented basal reading materials (e.g., Guthrie and Ozgundor, 2002). However, in advocating the present rationale, education policy makers should firmly keep in mind that simply obtaining better results than basal (or "literature-oriented") reading programs in grades 3-5 does not imply the development of the level of proficiency in reading comprehension that is required for success in high school or the development of the in-depth prior knowledge in a content discipline that will facilitate student success in high school content courses. Rather, following the present rationale, it is in-depth content-area instruction that provides the prior knowledge and understanding that facilitates student success in high school courses and, as an interpretation of research findings, helps develop the forms of student expertise that could enhance their general proficiency in the meaningful comprehension of new knowledge in different high school content courses.

A final matter to be considered here has to do with the tactics for gathering evaluative evidence in support of pursuing a change in curricular policy in advance of initiating such advocacy. In this regard, the most direct form of supporting data are cross-sectional student achievement trends (including reading comprehension) by grade level, from grade 3 (or earlier) through high school (at least grade 10). In addition to presenting achievement data in aggregate form articulated across grade levels, such data also should be disaggregated in terms of (a) different levels of initial student achievement in grades K, 1, 2 or 3, (b) student SES levels, (c) race, and/or possibly (d) gender. Presentation of such achievement trends provides an empirical means to link existing curricular policy at the elementary levels with the eventual problems in high school as a logical framework for supporting the rationale to increase the instructional time allocated to science and other content area instruction in grades 3-5. In this sense, curricular policy should consider high school achievement outcomes in grades 9-12 as reflecting the cumulative curricular effect of student learning throughout K-12, not just high-school specific instruction at grades 9-12. Then, complimenting student achievement trends, additional evaluative information in the form of surveys (or testimonials) should be obtained from high school teachers of key academic courses offered in grade 9 regarding the extent to which their students begin high school with substantial deficiencies in prior knowledge that should have been addressed in earlier grades. Together, these two forms of information provide explicit support for the rationale for improving school reform by increasing the instructional time allocated for in-depth science and other content area instruction. Although the short-term effect of educational reform initiatives may have temporarily diminished the role of content area instruction at the K-5 elementary level, reflections on the present curricular policy that underlie persistent problems in educational reform may well provide educators with the opportunity to expand the role of content area instruction at the elementary levels on a long-term basis.

**References**

Amaral, O., Garrison, L., & Klentschy, M. (Summer, 2002). Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal*, 26:2, 213-239.

American Federation of Teachers. (1997). *Making standards matter 1997. An annual fifty state report on efforts to raise academic standards.* Washington, DC: AFT.

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought.* Mahwah, NJ: Erlbaum.

Anderson, J. R. (1996). ACT: A simple theory of complex cognition. *American Psychologist, 51,* 335-365.

Anderson, J. R., & Fincham, J. M. (1994). Acquisition of procedural skills from examples. *Journal of Experimental Psychology, 20*, 1322-1340.

Anderson, J. R. (1993). Problem solving and learning. *American Psychologist*, *48,* 35-44.

Anderson, J. R. (1992). Automaticity and the ACT theory. *American Journal of Psychology, 105,* 15-180.

Armbruster, B. B., & Osborn, J. H. (2001). *Reading instruction and assessment: Understanding IRA standards.* New York: Wiley.

Armga, C., Dillon, S., Jamsek, M., Morgan, E.L., Peyton, D., & Speranza, H. (2002). Tips for helping children do science. *Texas Child Care, 26*(3), 2-7.

Artzen, E., & Holth, P. (1997). Probability of stimulus equivalence as a function of training design. *Psychological Record, 47,* 309-320.

Asoko, H. (2002). Developing conceptual understanding in primary science. *Cambridge Journal of Education, 32*(2), 153-164.

Beane, J. A. (1995). Curriculum integration and the disciplines of knowledge. *Phi Delta Kappan, 76,* 646-622.

Berlinger, D.C. (1994). Expertise: the wonder of exemplary performances. In J. Mangieri and C. Block (Eds) *Creating Powerful Thinking in Teachers and Students: Diverse Perspectives.* Fort Worth, TX: Harcourt Brace College.

Block, C. C. & Pressley, M. (Eds.). (2002). *Comprehension instruction: Research-based best practices.* New York: Guilford Press.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn.* Washington, DC: National Academy Press.

Bredderman, Ted, (1983), Effects of activity-based elementary science on student outcomes: A quantitative synthesis, Review of Educational Research, 53(4), 499-518.

Carnine, D. (1991). Curricular interventions for teaching higher order thinking to all students: Introduction to a special series. *Journal of Learning Disabilities, 24 (5),* 261-269.

Carnine, D. (1995). Standards for educational leaders: Could California's reading results show the way? *Education Week, 42.*

Carnine, D. (2004). Avoiding science 'lite.' *Education Week*, 23(10), 30-44.

Cavanagh, S. (November 10, 2004). NCLB could alter science teaching. *Education Week,* 24(11), 1, 12-13.

Chall, J. S., & Jacobs, V. A. (2003). The classic study on poor children's fourth grade slump. *American Educator, 27*(1), 14-16.

Coleman, J. S. (1966). *Equality of educational opportunity*. Washington, DC: USDOE.

Colker, L. J. (2002). Teaching and learning about science. *Young Children, 57*(5), 10-11, 47.

Conezio, K. & French, L. (2002). Science in the preschool classroom: Capitalizing on children's fascination with the everyday world to foster language and literacy development. *Young Children, 57*(5), 12-18.

Dana, T. M., Lorsbach, A. W., Hook, K., & Briscoe, C., (1991). Students showing what they know: A look at alternative assessments. In G. Kulm and S. M. Malcolm (Eds.), *Science assessment in the service of reform.* (pp. 331-337). Washington, D.C.: American Association for the Advancement of Science.

Donovan, M. S., Bransford, J. D., & Pellegrino (Eds.) (2003). *How people learn: Bridging research and practice*. Washington, DC: National Academy Press

Dougher, M. J., & Markham, M. R. (1994). Stimulus equivalence, functional equivalence and the transfer of function. In S.C. Hays, L.J. Hays, M. Santo, & O. Koichi (Eds.), *Behavior analysis of language and cognition* (pp. 71-90). Reno, NV: Context Press.

Dreher, M. J. (2002). Children searching and using information text: A critical part of comprehension. In Block, C. C. & Pressley, M. (Eds.), *Comprehension instruction*.(pp. 247-258). NY: Guilford Press.

Duke, N. K., Bennett-Armistead, V. S., & Roberts, E. M. (2003). Filling the nonfiction void. *American Educator, 27*(1), 30-35.

Duke, N. K., Martineau, J. A., Frank, K. A., Bennett-Armistead, V. S. (2003). *33.6 minutes per day: The impact of including more information text in first grade*. Unpublished manuscript, Michigan State University.

Duke, N. & Pearson, P. D. (2002). Effective practices for developing reading comprehension. In Farstrup, A. E. & Samuels, S. J. (Eds.), *What research has to say about reading instruction.* (pp.205-242). Newark, DE: International Reading Association.

Ellis, A. K. (2001). *Research on educational innovations.* Larchmount, NY: Eye on Education.

Engelmann, S, & Carnine, D. (1991). *Theory of instruction: Principles and applications.* Eugene, Oregon: ADI Press.

Farstrup, A. E. & Samuels, S. J. (2002). *What research has to say about reading instruction*. Newark, DE: International Reading Association.

Feldman, S. (2000). Standards are working: But states and districts need to make some mid-course corrections. *American Educator, 24*(3), 5-7.

Fellows, N. (1994). A window into thinking: Using student writing to understand conceptual change in science learning. Journal *of Research in Science Teaching*. 31(9), 985-1001.

French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly, 19*, 138-149.

Fryer, R. G., & Levitt, S. D. (2005). Falling behind. Hoover Institution. www.educationnext.org/20044/64.html.

Fuhrman, S. H., & Massell, D. (1992). *Issues and strategies in systemic reform.* New Brunswick, NJ: Rutgers University, Consortium for Policy Research in Education.

Gelman, R. & Brenneman, K. (2004). Science learning pathways for young children. *Early Childhood Research Quarterly, 19*, 150-158.

Gersten, R., Fuchs, L. S., Williams, J.P. & Baker, S. (2001). Teaching reading comprehension strategies to students with learning disabilities: A review of research. *Review of Educational Research, 71*, 279-320.

Ginsburg, H. P. & Golbeck, S. L. (2004). Thoughts on the future of research on mathematics and science learning and education. *Early Childhood Research Quarterly, 19*, 190-200.

Glaser, R. (1984) Education and thinking: The role of knowledge. *American Psychologist, 39(2)* 93-104.

Gould, C. J., Weeks, V., & Evans, S. (2003). Science starts early. *Gifted Child Today Magazine*, Summer 2003. 26, 38-43.

Guthrie, J. T., & Ozgungor, S. (2002). Instructional contexts for reading engagement. In C.C. Block & M. Pressley (Eds.). *Comprehension instruction: Research-based best practices* (pp. 275-288). New York: The Guilford Press.

Guthrie, J. T., Wigfield, & Perencevich, K. C. (Eds.). (2004). *Motivating reading comprehension: Concept-oriented reading instruction.* Mahwah, NJ: Earlbaum.

Hand, B., Hohenshell, & Prain, V. (2004). Exploring students' responses to conceptual questions when engaged with planned writing experiences. *Journal of Research in Science Teaching*, 41(2), 186-210.

Hapgood, S., Magnusson, S. J., & Palincsar, A. S. (2004). Teacher, text, and experience: A case of young children's scientific inquiry. *The Journal of the Learning Sciences*, 13(4), 455-505.

Harlen, W. (1988). *The teaching of science*. London: David Fulton.

Harlen, W. (2001). *Primary science, taking the plunge*. (2nd ed.) Portsmouth, NH: Heinemann.

Hart, B. H., & Risley, T. R. (2003). The early catastrophe: The 30 million word gap. *American Educator, 27*(1), 4-9.

Hirsch, E. D. (2003). Reading comprehension requires knowledge – of words and the world: Scientific insights into the fourth-grade slump and stagnant reading comprehension. *American Educator, 27*(1), 10-29.

Hirsch, E. D. (2001). Seeking breadth and depth in the curriculum. *Educational Leadership, 59* (2), 21-25.

Hirsch, E. D. (1996). *Schools we need. And why we don't have them.* NY: Doubleday.

Holliday, W. G. (2004). Choosing science textbooks: Connecting science research to common sense. In W. Saul (Ed.). *Crossing borders in literacy and science instruction*.(383-394). Newark, DE: International Reading Association and NSTA Press.

Jones, J. & Courtney, R. (2002). Documenting early science learning. *Young Children*, *57*(5), 34-38, 40.

Jones, M. G., Jones, B.D., Hardin, B., Chapman, L., Yarbrough, T., & Davis, M. (1999). The impact of high-stakes testing on teachers and students in North Carolina. *Phi Delta Kappan*, *81*, 199-203.

Jorgenson, O., & Vanosdall, R. (2002). The death of science? What are we risking in our rush toward standardized testing and the three r's. Phi Delta Kappan, 83(8), 601- 605.

Joseph, B. L. (2004). *Teacher expectations of low-SES preschool and elementary children: Implications of a research-validated instructional intervention for curriculum policy and school reform.* Unpublished Doctoral Dissertation, Greenville, N.C: College of Education.

Kearsley, G. P. (Ed.). (1987). *Artificial intelligence and instruction: Applications and methods.* New York: Addison-Wesley.

Kellough, R. D., Cangelosi, J. S., Collette, A. T., Chiapetta, E. L., Souviney, R. J., Trowbridge, L. W., et al. (1996). *Integrating mathematics and science.* Englewood Cliffs, NJ: Merrill.

King, M. B. & Newman, F. M. (2001). Building school capacity through professional development: Conceptual and empirical considerations. *The International Journal of Education Management, 15*(2), 86-93.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge, U.K.: Cambridge University Press.

Klentschy, M. P., & Molina-De La Torre, E. (2004). Students' science notebooks and the inquiry process. In E.W. Saul (Ed.), *Crossing borders in literacy and science instruction: Perspectives on theory and practice* (pp.340-354). Newark, DE: International Reading Association.

Kolodner, J. L. (1997). Educational implications of analogy: A view from case-based reasoning. *American Psychologist, 82*, 57-66.

Kolodner, J. L. (1993*). Case-based reasoning.* San Mateo, CA: Morgan Kaufmann.

Kuhn, T. (1996). *The structure of scientific revolution*. Chicago: University of Chicago Press.

Lee, M., Lostoski, M., & Williams, K. (2000). Diving into a school wide science theme. *Science and Children, 38*(1), 31-35.

Luger, G. F. (2002). *Artificial intelligence: Structures and strategies for complex problem-solving.* Reading, MA: Addison Wesley.

Magnusson, S. J., & Palincsar, A. S. (in press). Teaching and learning inquiry-based science in the elementary school. In J. Bransford & S. Donovan (Eds.) *Visions of teaching subject matter guided by the principles of how people learn.* Washington, DC: National Academy Press.

McNamara, D. S., de Vega, M., & O'Reilly, T. (in press). Comprehension skill, inference making, and the role of knowledge. In F. Schmalhofer & C. A. Perfetti (Eds.), *Higher level language processes in the brain: Inference and comprehension processe*s. Mahwah, NJ: Erlbaum.

McCloskey, W. & O'Sullivan, R. (1993). *How to assess student performance in science: Going beyond multiple choice tests.* Tallahassee, FL: Southeastern Regional Vision for Education (SERVE).

Minstrell, J., & van Zee, E. H. (2000). *Inquiring into inquiry learning and teaching in science*. Washington, DC: American Association for the Advancement of Science.

Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (1998). *Teaching science for understanding: A human constructivist view*. Englewood Cliffs, NJ: Academic Press.

Mullis, I.V. S., & Jenkins, L. B. (1988). *The science report card*. (Report No. 17-5-01). Princeton, NJ: Educational

NAEP (2005). What does the NAEP Reading Assessment measure? http://nces.ed.gov/nationsreportcard/reading/whatmeasure.asp

National Academy of Sciences. (1997). *Science for all children: A guide for improving elementary science education in your school district.* Washington, DC: National Sciences Resources Center, Smithsonian Institution.

National Reading Panel (2000). *Teaching children to read: An evidence-based assessment of scientific research literature on reading and its implications for reading instruction*. Jessup, MD: National Institute for Literacy.

Newton, L. D. (2001). Teaching for understanding in primary science. *Evaluation and Research in Education, 15*(3), 143-153.

Niedelman, M. (1992). Problem solving and transfer. In D. Carnine & E. J. Kameenui (Eds.). *Higher order thinking.* Austin, TX: Pro-Ed.

Ogle, D. & Blachowicz, C. L. Z. (2002). Beyond literature circles: Helping students comprehend informational texts. In Block, C. C. & Pressley, M. (Eds.), *Comprehension instruction*.(pp. 247-258). NY: Guilford Press.

Palincsar, A. S., & Magnusson, S. J. (2001). The interplay of first-hand and second-hand investigations to model and support the development of scientific knowledge and reasoning. In S. M. Carver & D. Klahr (Eds.) *Cognition and instruction: Twenty-five years of progress.* Mahwah, NJ: Erlbaum.

Palmer, R.G., & Stewart, R. (2003). Nonfiction trade book use in primary grades. *The Reading Teacher*, 57, 38-48.

Pearson, P. D. & Duke, N. (2002). Comprehension instruction in the primary grades. In Block, C. C. & Pressley, M. (Eds.), *Comprehension instruction*. (pp. 247-258). NY: Guilford Press.

Pearson, P. D. & Fielding, L. (1995). Comprehension instruction. In R. Barr, M. L. Kamil, P. B. Mosenthal, P. B., & P. D. Pearson. (Eds.) *Handbook of reading research, Volume II*: Mahwah, NJ: Lawrence Erlbaum Associates (p. 815-860).

Pellegrino, J. W., Chudowsky, N., & Glaser, R. (Eds.). (2001). *Knowing what students know.* Washington, DC: National Academy Press.

Perkins, D. N., & Grotzer, T. A. (1997). Teaching intelligence. *American Psychologist*, *52*, 1125-1133.

Pressley, M., Rankin, J., & Yokoi, L. (1996). A survey of instructional practices of primary teaches nominated as effective in promoting literacy. *Elementary School Journal*, 96, 363-384.

Pretti-Frontczak, K. L., Barr, D.M., Macy, M., & Carter, A. (2003). Research and resources related to activity-based intervention, embedded learning opportunities, and routines-based instruction: An annotated bibliography. *Topics in Early Childhood Special Education, 23*(1), 29-39.

Rakow, S. J. & Bell, M. J. (1998). Science and young children: The message from the National Science Education Standards. *Childhood Education, 74*(3), 164-167.

Reddy, M., Jacobs, P., McCrohon, C., & Herrenkohl, L. (1998). Creating scientific communities in the elementary classroom. Portsmouth, NH: Heinemann.

Revelle, G., Druin, A., Platner, M., Bederson, B., Hourcade, J. P., & Sherman, L. (2002). A visual search tool for early elementary science students. *Journal of Science Education and Technology, 11*(1), 49-57.

Rivard, L. (1994). A review of writing to learn in science: Implications for practice and research. *Journal of Research in Science Teaching*. 31(9), 969-983.

Romance, N. R. & Vitale, M. R. (2004). *Embedding knowledge-focused reading comprehension strategies in integrated science instruction: Effects on achievement in science and reading comprehension in grade 5.* Technical Report No. 104, NSF/IERI Project, College of Education, Boca Raton, FL: Florida Atlantic University.

Romance, N. R., & Vitale, M. R. (2001). Implementing an in-depth expanded science model in elementary schools: Multi-year findings, research issues, and policy implications. *International Journal of Science Education, 23,* 373-404.

Romance, N. R., Vitale, M. R., & Haky, J. (2000). Concept mapping as a knowledge-based strategy for enhancing student understanding. *The NSF Workshop Project Newsletter, 2,* 5-8.

Romance, N. R. & Vitale, M. R. (1999). Broadening the framework for student-centered instruction: Using concept mapping as a tool for knowledge-based learning. *College Teaching, 47,* 74-79.

Romance, N. R., & Vitale, M. R. (1992). A curriculum strategy that expands time for in-depth elementary science instruction by using science-based reading strategies: Effects of a year-long study in grade 4. *Journal of Research in Science Teaching, 29,* 545-554.

Sandall, B. R. (2003). Elementary science: Where are we now? *Journal of Elementary Science Education, 15*(2), 13-30.

Saul, W. (Ed.). (2004). *Crossing borders in literacy and science instruction*. Newark, DE: International Reading Association and NSTA Press.

Scardamalia, M. and Bereiter, C. (1986). Research on written composition. In Merlin C. Wittrock (Ed.), *Handbook on research on teaching*. (3rd ed.). New York: MacMillan.

Schmidt, W. H., McKnight, C. C., Houang, R. T., Wang, H. C., Wiley, D. E., Cogan, L. S., et al. (2001). *Why schools matter: A cross-national comparison of curriculum and learning*. San Francisco: Jossey-Bass.

Schoenberger, L., & Russell, T. (1986). Elementary science as a little added frill: A report of two recent case studies. *Science Education,* 70, 519-538.

Schug, M.C., & Cross, B. (1998). The dark side of curriculum integration. *Social Studies, 89,* 54-57.

Secretary's Summit on Science. (March 16, 2004). http://www.ed.gov.rschstat/research/progs/mathscience/science summit04.html.

Shepardson, D., & Britsch, S. (2001). The role of children's journals in elementary school science activities. *Journal of Research in Science Teaching,* 38(1), 43-69.

Shymansky, J .A., Hedges, L. V., & Woodworth, G. (1990). A Reassessment of the effects of inquiry-based science curricula of the 60's on student performance, *Journal of Research on Science Teaching,* 27(2), 127-144.

Sidman, M. (1994). *Stimulus equivalence.* Boston, MA: Author's Cooperative.

Siegler, R. S. (2000). The rebirth of children's learning. *Child Development, 71*(1), 26-35.

Smith, A. (2001). Early childhood – a wonderful time for science learning. *Investigating: Australian Primary & Junior Science Journal, 17*(2), 18-21.

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

Sowa, J. F. (2000). *Knowledge representation: Logical, philosophical, and computational foundations.* New York: Brooks Cole.

Stigler, J. W, & Hiebert, J. (1999). *The teaching gap*. New York, NY: The Free Press.

Swan, E., & Guthrie, J. T. (1999, April). *Influences of science observation and science trade books on reading comprehension and motivation*. Paper presented at the Annual Meeting of the American Educational Research Association, Quebec, CA

Thompson, C. L., & O'Quinn, S. D. (2001). *Eliminating the Black-White Achievement Gap: A Summary of Research.* North Carolina Educational Research CouncilChapel Hill, NC:

Trabasso, T., & Bouchard, E. (2002). Teaching readers how to comprehend text strategically. In Block, C. C. & Pressley, M. (Eds.), *Comprehension instruction*. (pp. 176-200). NY: Guilford Press.

Tytler, R., & Peterson, S. (2001). Deconstructing learning in science – young children's responses to a classroom sequence on evaporation. *Research in Science Education, 30*(4), 339-355.

VanDeWeghe, R. (1987). Making and remaking meaning: Developing literary responses through purposeful informal writing. *English Quarterly,* 20, 38-51.

Vitale, M. R., & Medland, M. B. (2002) *Knowledge structure development: A developmental framework for children's understanding of knowledge.* Boca Raton, FL: Center for School Development, Inc.

Vitale, M. R., & Romance, N. R. (2006). Research in science education: An interdisciplinary perspective. In J. Rhoten (Ed.). *Issues and trends in science teaching and learning for the 21st century.* NSLEA/NSTA.

Vitale, M. R., & Romance, N. R. (2004). *Using an instructional systems development model as a framework for research on scale up.* Technical Report No. 201, NSF/IERI Project, College of Education, Boca Raton, FL: Florida Atlantic University.

Vitale, M.R., Romance, N.R., & Dolan, M.F. (April, 2003). *A knowledge-based framework for the classroom assessment of student science understanding.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Vitale, M. R., & Romance, N. R. (2000). Portfolios in science assessment: A knowledge-based model for classroom practice. In J. J. Mintzes, J.H. Wandersee, & J.D. Novak (Eds.), *Assessing science understanding: A human constructivist view* (pp. 168-197). San Diego, CA: Academic Press.

Vitale, M. R. & Romance, N. R. (1999). *A knowledge-based approach to content area comprehension.* Region V Center for Educational Enhancement, Boca Raton, FL: Florida Atlantic University.

Vygotsky, L.S. (1978). Language *and thought*. Cambridge: MIT Press.

Walsh, K. (2003). Lost opportunity. *American Educator, 27*(1), 24-27.

Weaver, C. A., & Kintsch, W. (1995). Expository text. In Barr, R., Kamil, M. L., Mosenthal, P. B. and Pearson, P. D. (Eds.) *Handbook of reading research, Volume II*: Mahwah, NJ: Lawrence Erlbaum Associates (p. 230-245)

White, R., & Gundstone, R. (1992). *Constructing knowledge together: Classrooms as centers of inquiry and literacy*. Portsmouth, NH: Heinemann.

Williams, J. P. (2002). Using the theme scheme to improve story comprehension. In C.C. Block & M. Pressley (Eds.), *Comprehension instruction: Research-based best practices*. New York: The Guilford Press.

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*(1) 105-122.

Table 1

*Mean Stanford Achievement Test (SAT) National Percentile Rank Reading Achievement for Students in Grades 4 and 6 by Years of Participation in the VIPS Science Program*

| Years of Participation | Grade 4 | | Grade 6 | |
|---|---|---|---|---|
| | N | Pct. Rank | N | Pct. Rank |
| 0 | 137 | 23 | 174 | 25 |
| 1 | 149 | 27 | 121 | 28 |
| 2 | 142 | 44 | 132 | 41 |
| 3 | 111 | 42 | 107 | 49 |
| 4 | 91 | 57 | 104 | 67 |

Table 2

*Writing Proficiency Pass Rate for Students in Grade 6 by Years of Participation in the VIPS Science Program.*

| Years of Participation | N Tested | N Passed | Pct. Passed |
|---|---|---|---|
| 0 | 173 | 39 | 23 |
| 1 | 119 | 81 | 68 |
| 2 | 132 | 95 | 72 |
| 3 | 107 | 97 | 91 |
| 4 | 104 | 93 | 89 |

Table 3

*Mean National Stanford Achievement Test (SAT) Percentile Rank Science Achievement for Students in Grades 4 and 6 by Years of Participation in the VIPS Science Program*

| Years of Participation | Grade 4 | | Grade 6 | |
|---|---|---|---|---|
| | N | Pct. Rank | N | Pct. Rank |
| 0 | 137 | 21 | 174 | 27 |
| 1 | 149 | 32 | 121 | 32 |
| 2 | 142 | 38 | 132 | 42 |
| 3 | 111 | 47 | 107 | 50 |
| 4 | 91 | 53 | 104 | 64 |

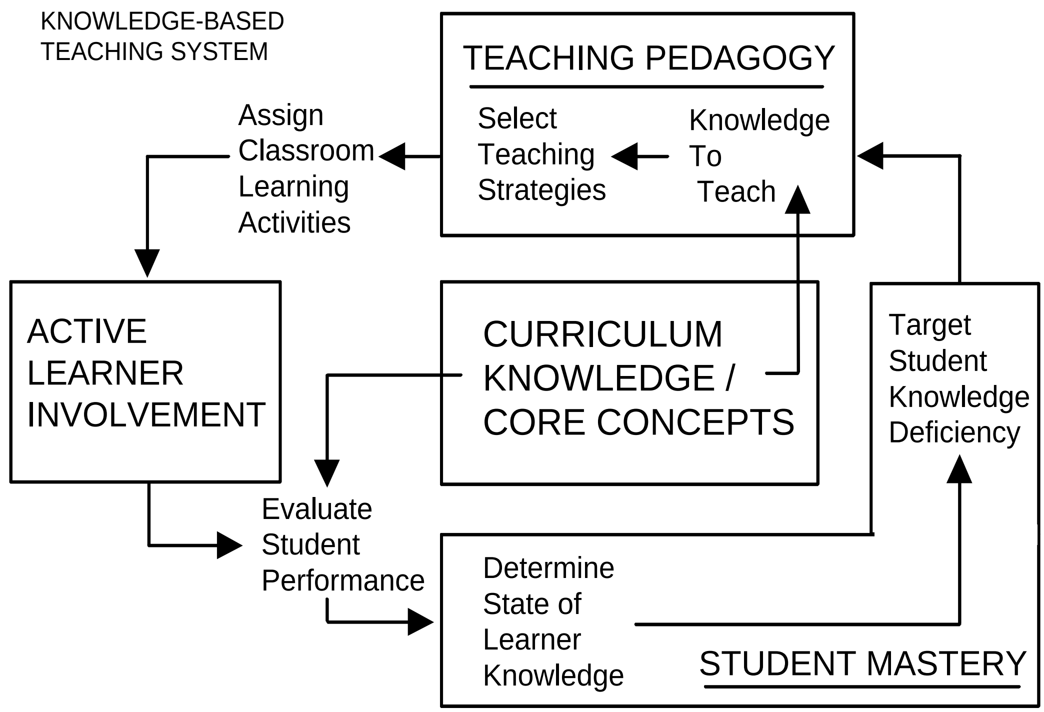
**Figure Captions**

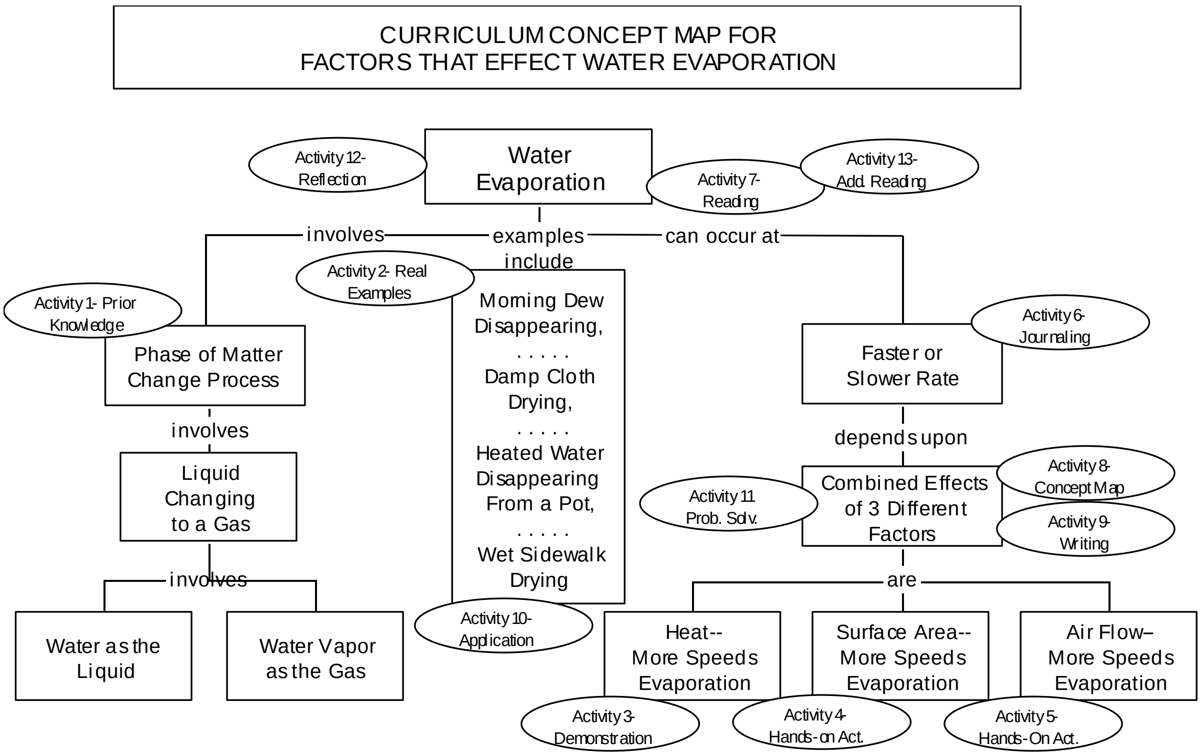
Figure 1. Architecture for a knowledge-based intelligent tutoring system.

Figure 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 instructional activities.

Figure 3. Summary of adjusted mean difference scores in grade-equivalent months showing higher reading achievement of IDEAS vs. comparison classrooms on ITBS-Reading (years 1, 2, 3) and SAT-Reading (year 4).

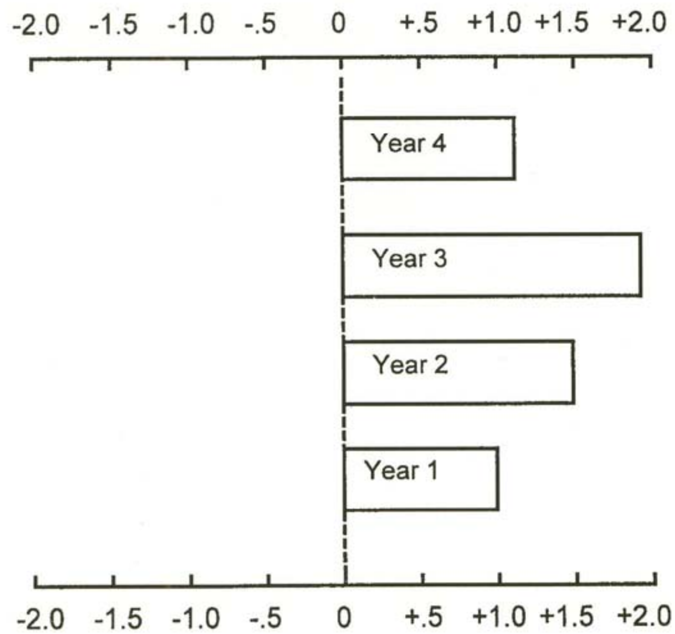
Figure 4. Summary of adjusted mean difference scores in grade-equivalent months showing higher reading achievement of IDEAS vs. comparison classrooms on ITBS-Reading (years 1, 2, 3) and SAT-Reading (year 4).


KNOWLEDGE-BASED
TEACHING SYSTEM
TEACHING PEDAGOGY
Select
Teaching
Strategies
Knowledge
To
Teach
Assign
Classroom
Learning
Activities
ACTIVE
LEARNER
INVOLVEMENT
CURRICULUM
KNOWLEDGE /
CORE CONCEPTS
Target
Student
Knowledge
Deficiency
Evaluate
Student
Performance
Determine
State of
Learner
Knowledge
STUDENT MASTERY


CURRICULUM CONCEPT MAP FOR
FACTORS THAT EFFECT WATER EVAPORATION
Water Evaporation
Activity 12- Reflection
Activity 7- Reading
Activity 13- Add. Reading
involves
examples include
can occur at
Activity 2- Real Examples
Activity 1- Prior Knowledge
Phase of Matter Change Process
involves
Liquid Changing to a Gas
involves
Water as the Liquid
Water Vapor as the Gas
Morning Dew Disappearing,
. . . . .
Damp Cloth Drying,
. . . . .
Heated Water Disappearing From a Pot,
. . . . .
Wet Sidewalk Drying
Activity 10- Application
Faster or Slower Rate
Activity 6- Journaling
depends upon
Combined Effects of 3 Different Factors
Activity 11 Prob. Solv.
Activity 8- Concept Map
Activity 9- Writing
are
Heat-- More Speeds Evaporation
Surface Area-- More Speeds Evaporation
Air Flow– More Speeds Evaporation
Activity 3- Demonstration
Activity 4- Hands-on Act.
Activity 5- Hands-On Act.

SCIENCE ACHIEVEMENT OF IDEAS VS COMPARISON CLASSROOMS

(Positive values indicate IDEAS classrooms performed better than comparison classrooms.)

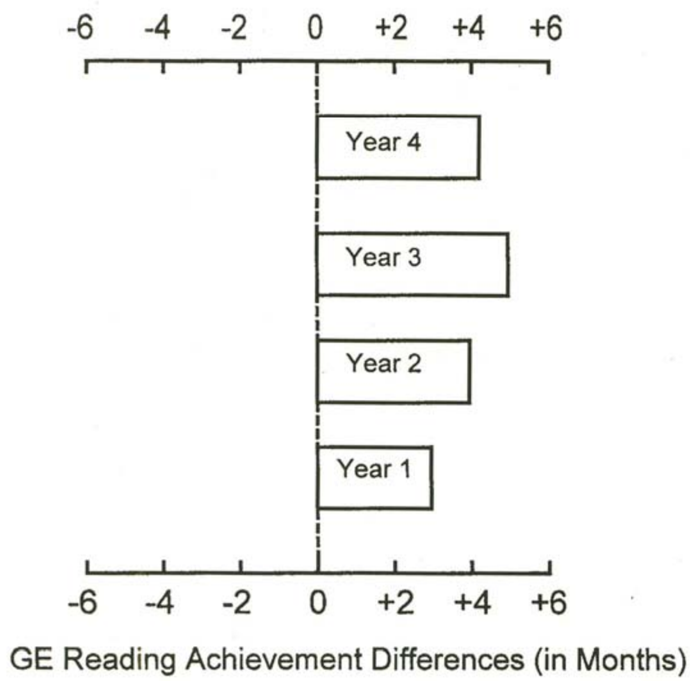



GE Science Achievement Differences (in Years)

Note: Year 1 students = grade 4; average/above average
Year 2 students = grade 4; average/above average
Year 3 students = grades 4,5; at-risk
Year 4 students = grades 4,5; average/above average/at-risk

## READING ACHIEVEMENT OF IDEAS VS COMPARISON CLASSROOMS

(Positive values indicate IDEAS classrooms performed better than comparison classrooms.)




Note : Year 1 students = grade 4; average/above average
Year 2 students = grade 4; average/above average
Year 3 students = grades 4,5; at-risk
Year 4 students = grades 4,5; average/above average/at-risk