Linking Meaningful Learning in Science with Reading Comprehension and Writing

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Science IDEAS as a Model

- As an extensively researched-based instructional model with meaningful learning (understanding) as its prime goal, Science IDEAS is designed around key perspectives emanating from several areas of research….
  - Cognitive science/learning sciences
  - Expert/novice literature
  - Science education
  - Literacy/Discourse processing

Points of Intersection Between the Science Education and Cognitive Science/Discourse Processing Communities

1. The goal of these communities is to advance student understanding (comprehension) in deep and meaningful ways
2. Each community addresses and benefits from both cognitive task analysis and studies of expertise that can be combined to develop a detailed definition of deep understanding (or a cognitive model) within and across a domain (s) of interest
3. Each community recognizes the importance of principles from learning sciences that underlie effective instruction:
   - Building/eliciting/representing prior knowledge
   - Making thinking explicit
   - Emphasizing conceptual links between big ideas (core concepts) of a domain and the component concepts that are subordinate to them
   - Providing opportunities for practice and cumulative review

Presentation Overview

- **Problems being addressed**
- Description of the knowledge-based instructional model used to address the problems
- Evidence of effectiveness of the model
- Multi-disciplinary theoretical perspective underlying the model
- Learning from science text: Broadening the conceptions of the nature of the discourse
- Implications for further research

- **Problem Areas: Achievement Trends**
  - Content-area reading comprehension; percent of all learners achieving at the advanced levels; performance of diverse populations especially in urban centers (Rand, 2002; NAEP 2000, 2005)
  - Achievement in science across grades 5,8,12 (NAEP 2005)
- **Problems Areas: Aspects of Comprehension**
  - Little use of expository text at K-5 levels (Hirsch, 2003; 2005; Duke et al, 2003; Walsh, 2003)
  - Recognition that comprehension is challenging when readers lack relevant prior knowledge (Alexander et al, 2003; Graesser, et al, 2003; Kintsch, 2003; Vitale, 2007)
  - Lack of early (Gr 3-5) strategy instruction emphasizing the cognitive processes associated with comprehension of expository text has implications for instruction at the secondary level and beyond

Presentation Overview

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- **Description of the knowledge-based instructional model used to address the problem of *meaningful understanding***
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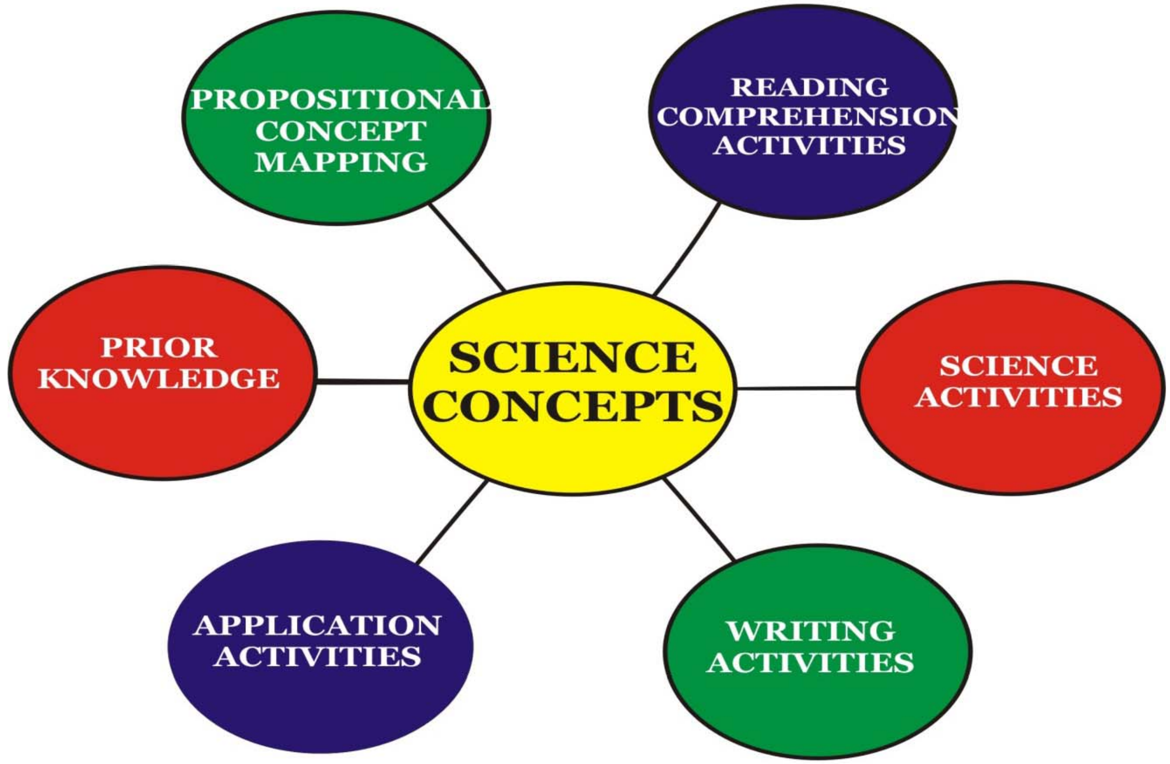
Description of Model: Science IDEAS

- Science IDEAS as an Instructional Model
  - Science **concepts** used as the basis for linking all aspects on instruction within the integrated instructional model used in grades 3-5
  - Meaningful **cumulative learning** serves as the context for development of reading comprehension proficiency
  - Magnifies the role of **relevant prior knowledge** as a primary factor in comprehension

Science



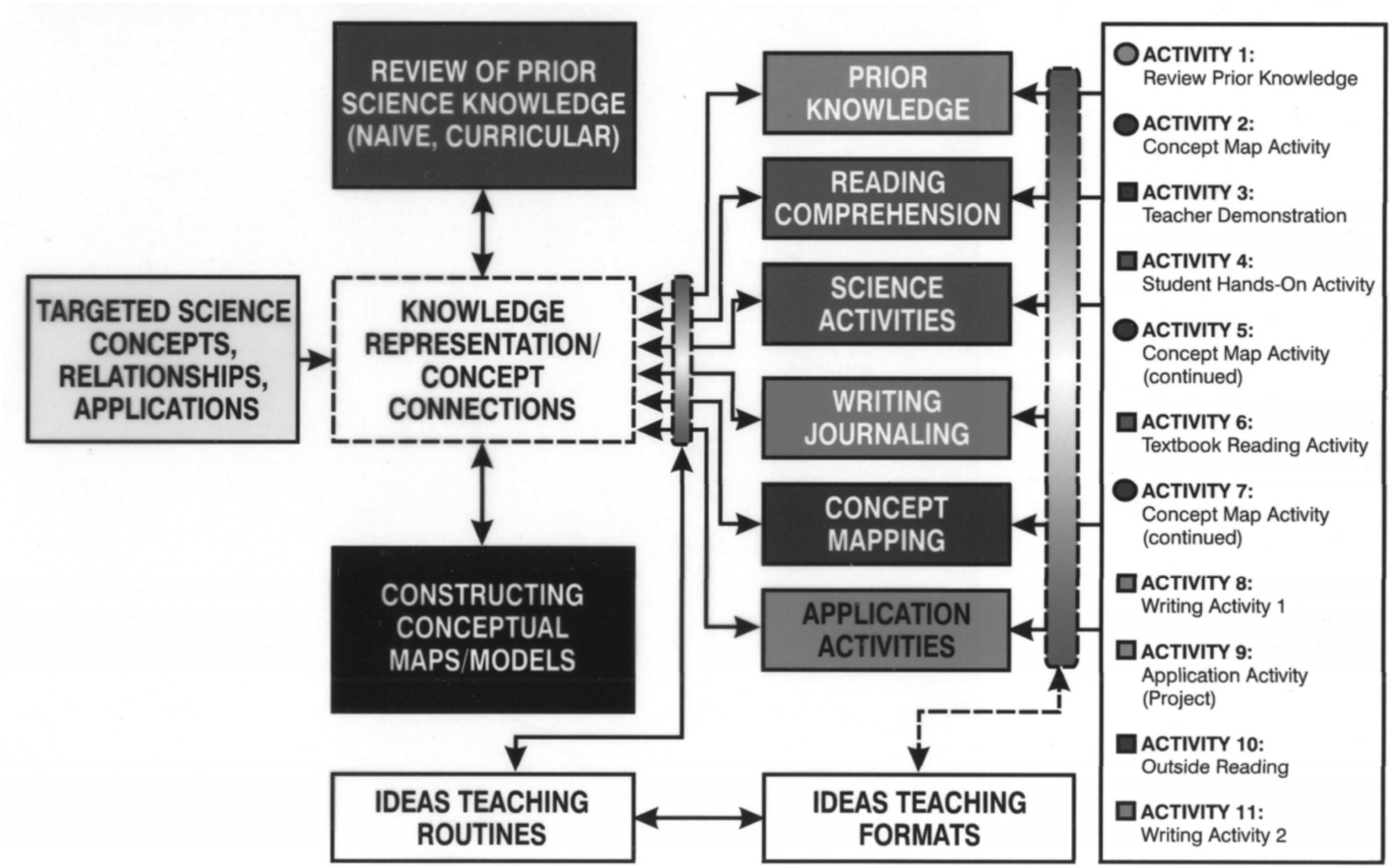
IDEAS

6 Elements of Science IDEAS Model

A daily two-hour integrated instructional model used in grades 3-5 that includes…

- **Hands-on Science**: Guided inquiry and open-ended inquiry
- **Reading Comprehension**: Routine for reading expository text along with the use of multiple non-fiction sources to engender deep understanding (comprehension)
- **Writing and Journaling**: Represent understanding through use of science journals and notebook activities
- **Propositional Concept Mapping**: A routine for eliciting, analyzing and representing knowledge
- **Prior Knowledge**: Use of Science IDEAS elements for accessing and/or building prior knowledge to promote deep understanding
- **Application Tasks**: Applying concepts across varied contexts

Architecture of Science IDEAS Model



How Science IDEAS Addresses Comprehension

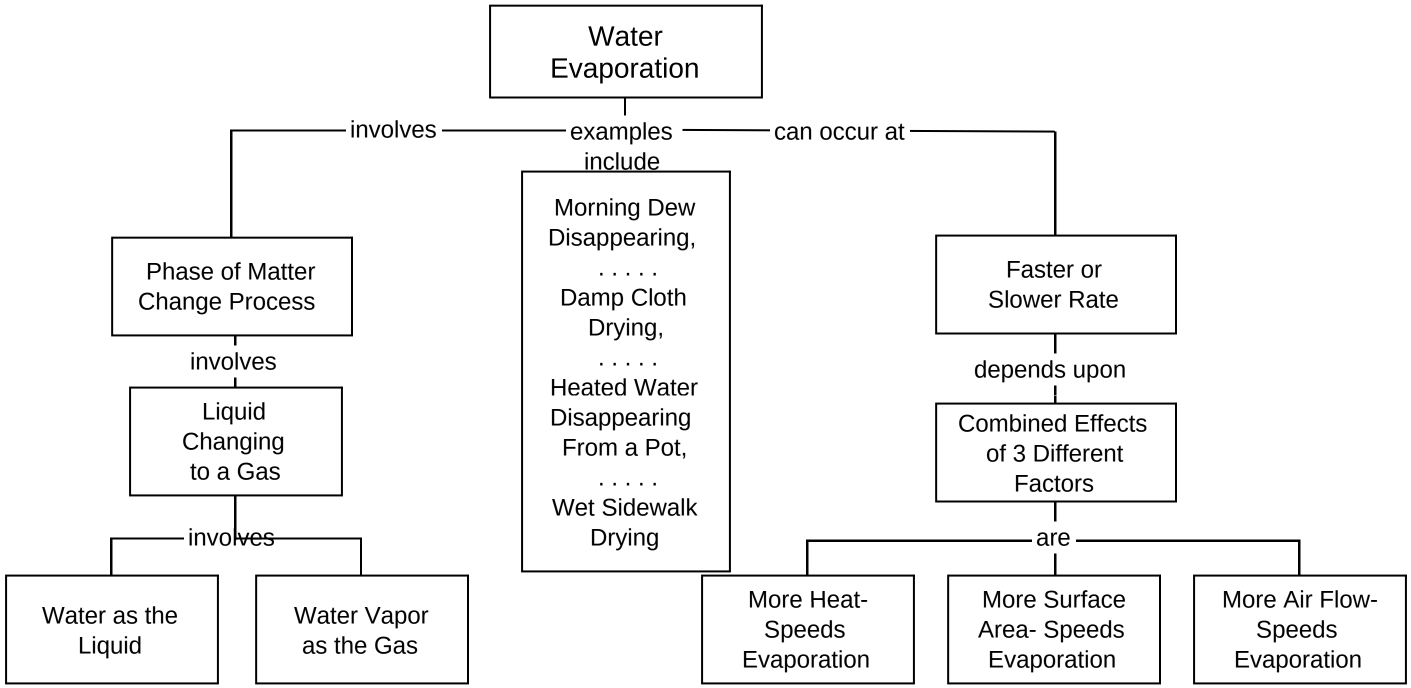
Meaningful Cumulative Learning in Science

……requires a ***curricular structure*** with opportunities for students to be able to:

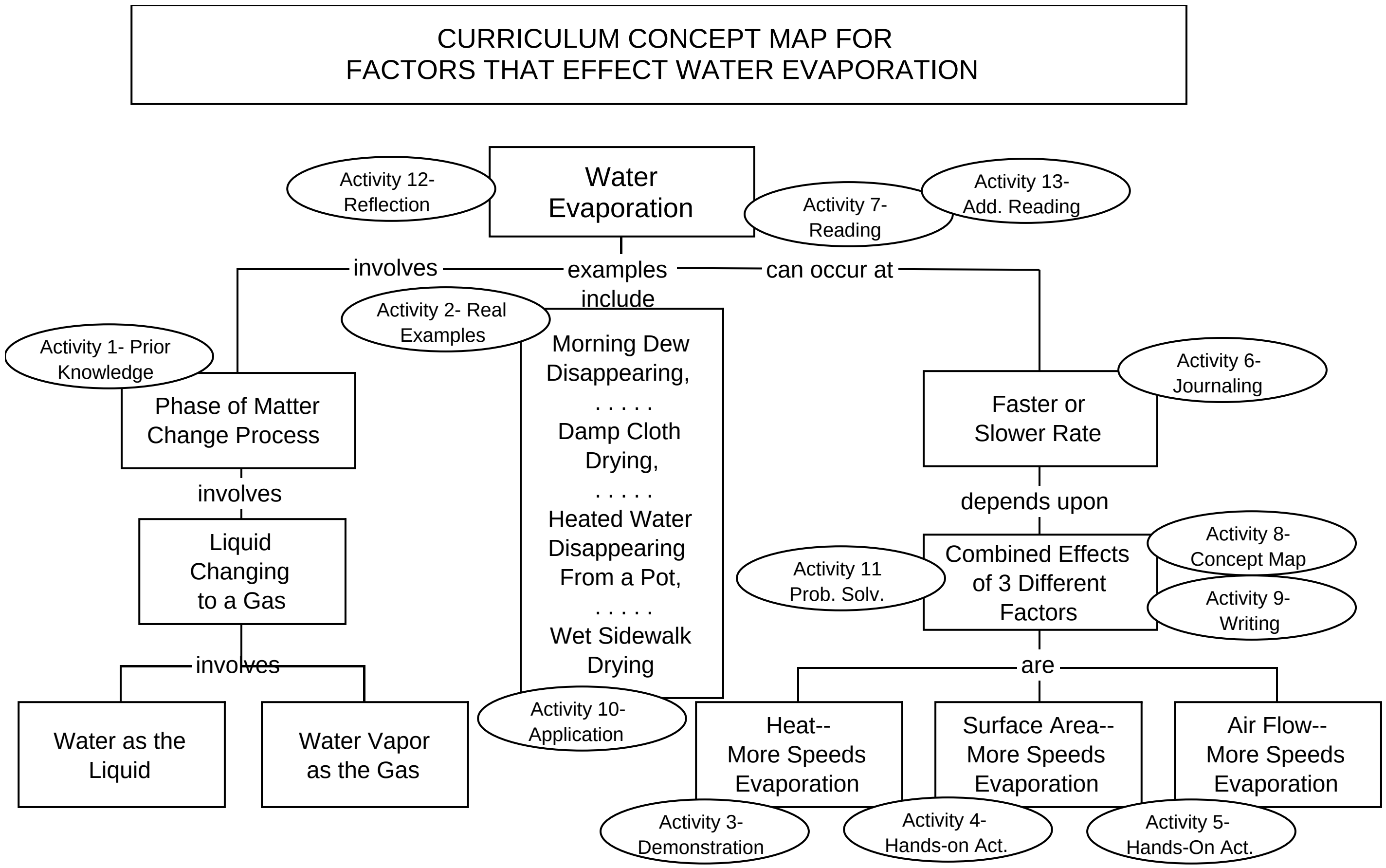
- organize their knowledge around core concepts (big ideas) and concept relationships
- easily access and integrate their prior conceptual knowledge with new knowledge
- learn more about what is being learned (expertise model)

Propositional Curriculum Concept Map

CURRICULUM CONCEPT MAP FOR
FACTORS THAT EFFECT WATER EVAPORATION



Propositional Instructional Concept Map



Constructing Propositional Curriculum Maps …..

First-Hand Investigations: Building/Amplifying Prior Knowledge

Students are actively engaged in motivating hands-on science activities with emphasis on Matter and Energy

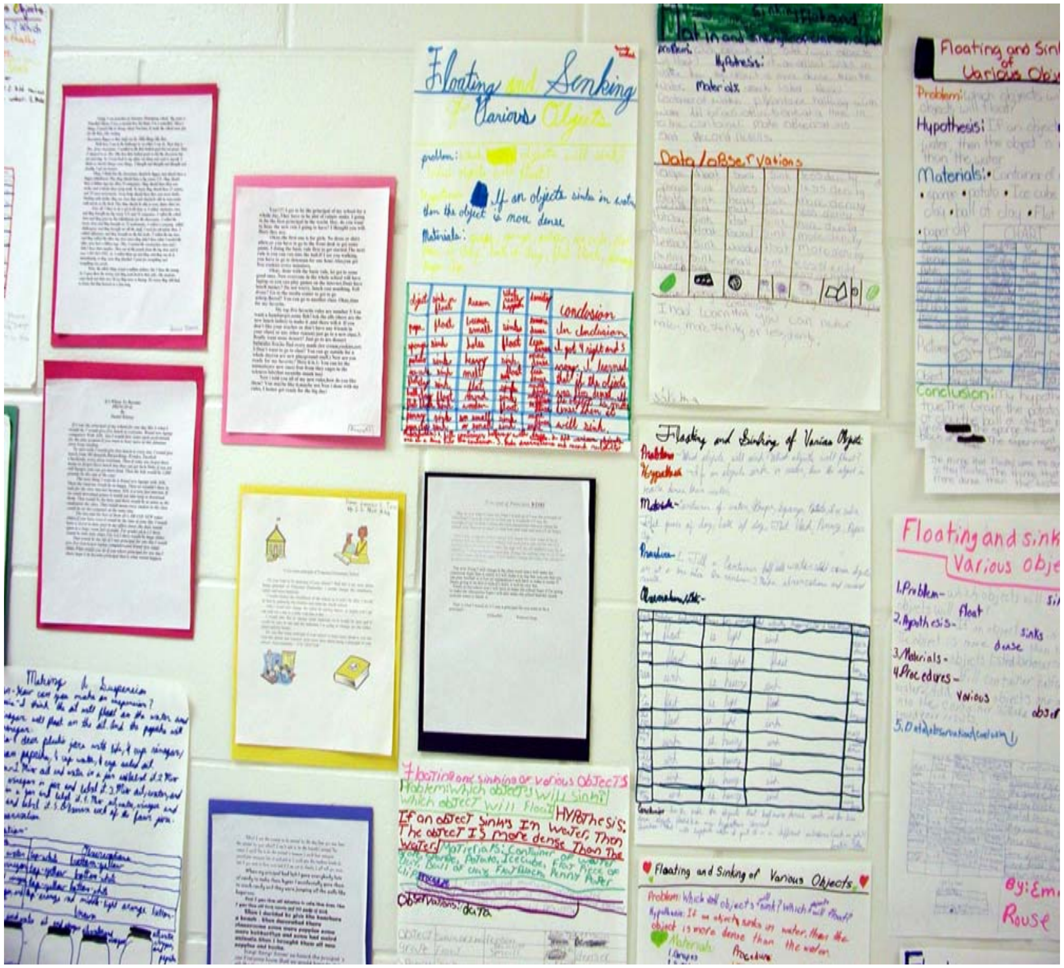
Meaningful Learning Supported by Investigations, Classroom Interaction and Discussion

Students collect and analyze data and record their observations (meaningful writing about science)

Discussions help to extend, re-organize and summarize concepts and concept relationships resulting from multiple sources

Anchors learning in the present using real world scenarios

Writing to Learn

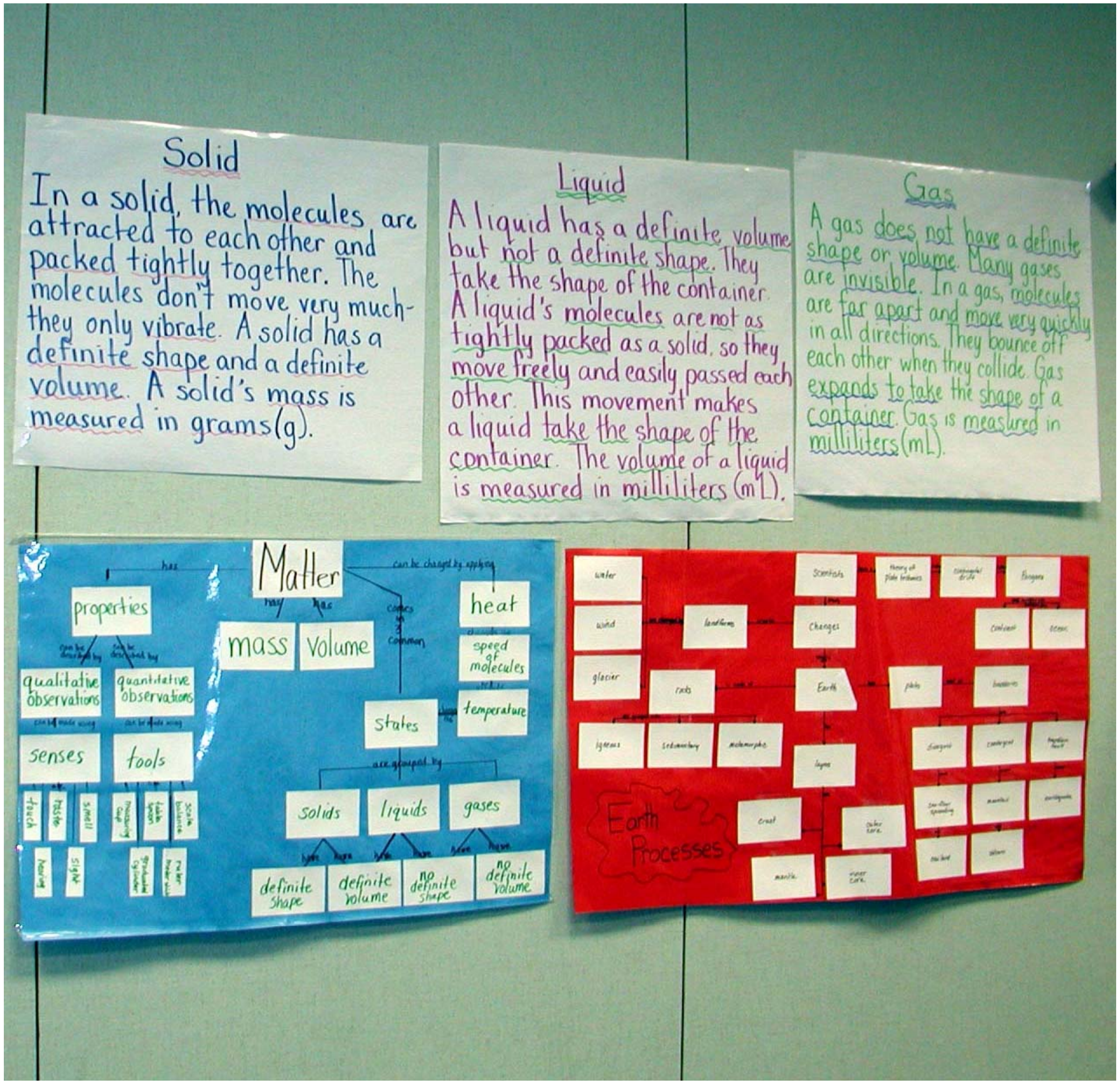


Key cognitive processes:

1. **Eliciting knowledge**
2. **Analyzing and representing knowledge**

Strategy for Anchoring Activities and Discussion and Making Thinking Visible

Propositional Concept Maps: Situates Learning in Terms of Core Concepts and Concept Relationships



Teacher Use

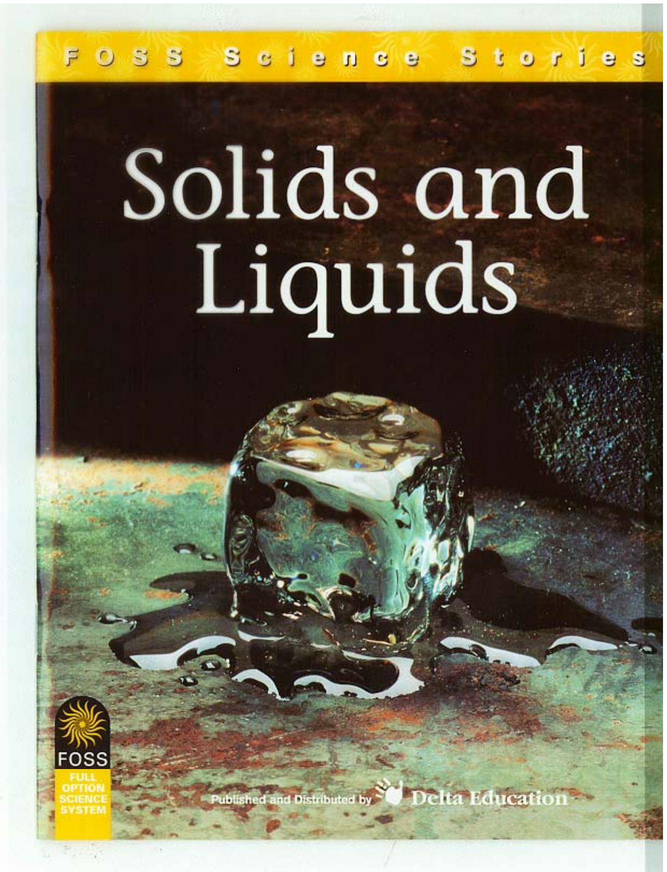
1. Planning a unit of study
2. Blueprint for instruction
3. Guide for Assessment

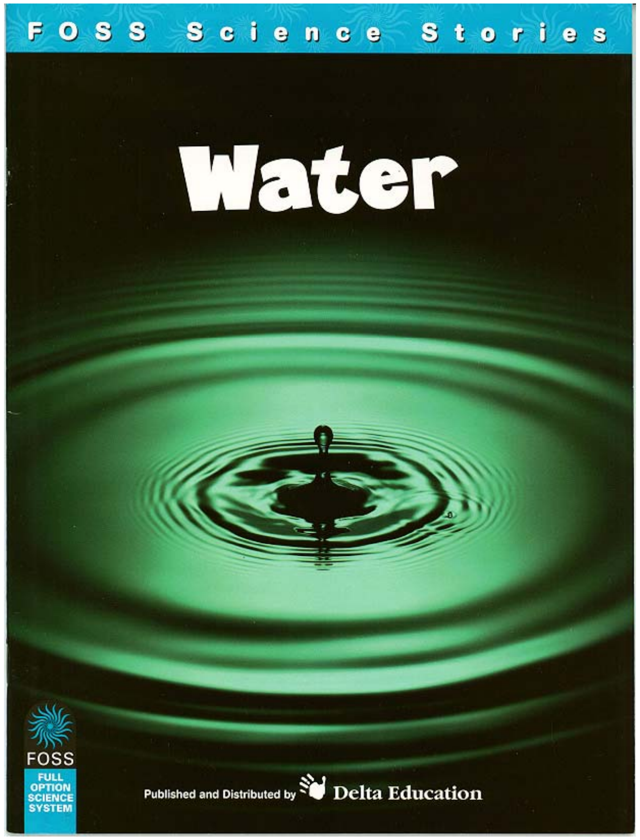
Student Use

1. Studying
2. Guide for Writing
3. Tool for Comprehension

Expertise Model: Learning more about what one already knows broadens and deepens knowledge…

(Guthrie, 2003; Glaser, Chi & Farr, 1988; Feltovich, 1998)





Rule of 10..;For each major topic area students will read 10 varied sources on the topic…

Knowledge-Focused / Multi-Part Reading Comprehension Strategy Used in Science IDEAS

- Explicit focus on access and organization of the knowledge required for comprehension (Hirsch, 2003; Alexander, 2003; Graesser, 2003, 2007)
- **Consists of complementary set of three sub-strategies:**
  - **Text-analysis sub-strategy**
  - **Propositional concept mapping sub-strategy**
  - **Summarization/writing sub-strategy**
- Sub-strategies have consensus research base
- Sub-strategies are "expertise-based" and engineered for application by teachers
- For detail, see Vitale & Romance (in McNamara (Ed.), 2007)

Affordances of the SI Model

Integrated nature of the SI model offers affordances for all learners:

1. Conceptual relatedness among all aspects of instruction minimizes the deficits associated with emphasizing one instructional approach over another
2. Opportunities for interaction across varied instructional formats
3. Curriculum focus, coherence and articulation
4. Motivational aspects associated with interest in science, giving student choices and how success engenders further success

Presentation Overview

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- Description of the knowledge-based instructional model used to address the problems
- **Evidence of effectiveness of the Science IDEAS Model**
- Multi-disciplinary theoretical perspective underlying the model
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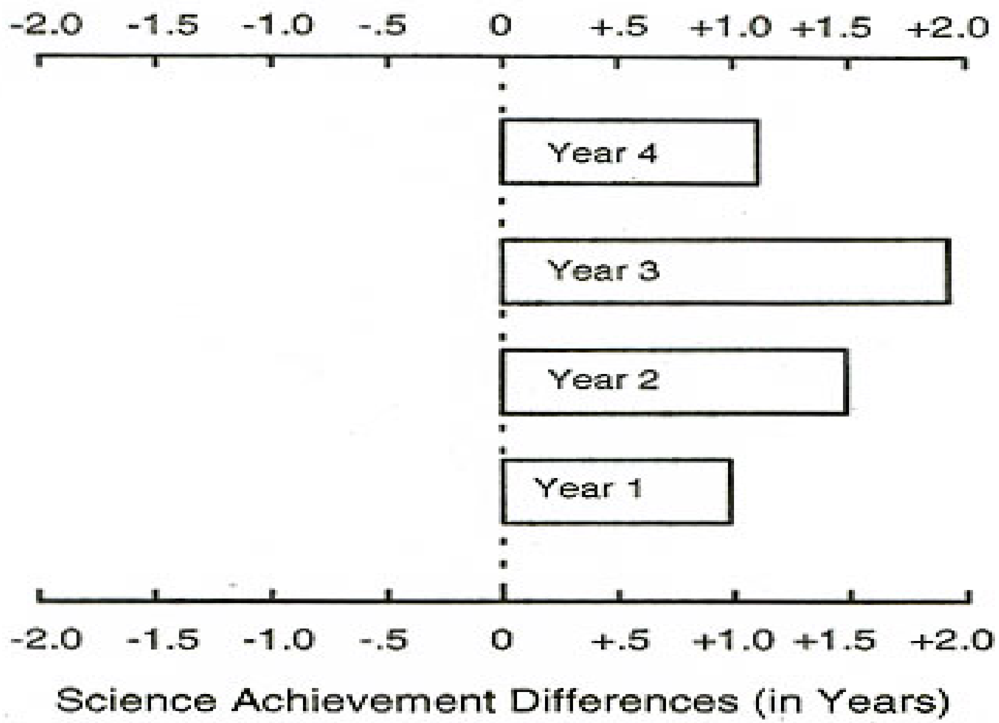
Research History…Initial Implementation and Findings

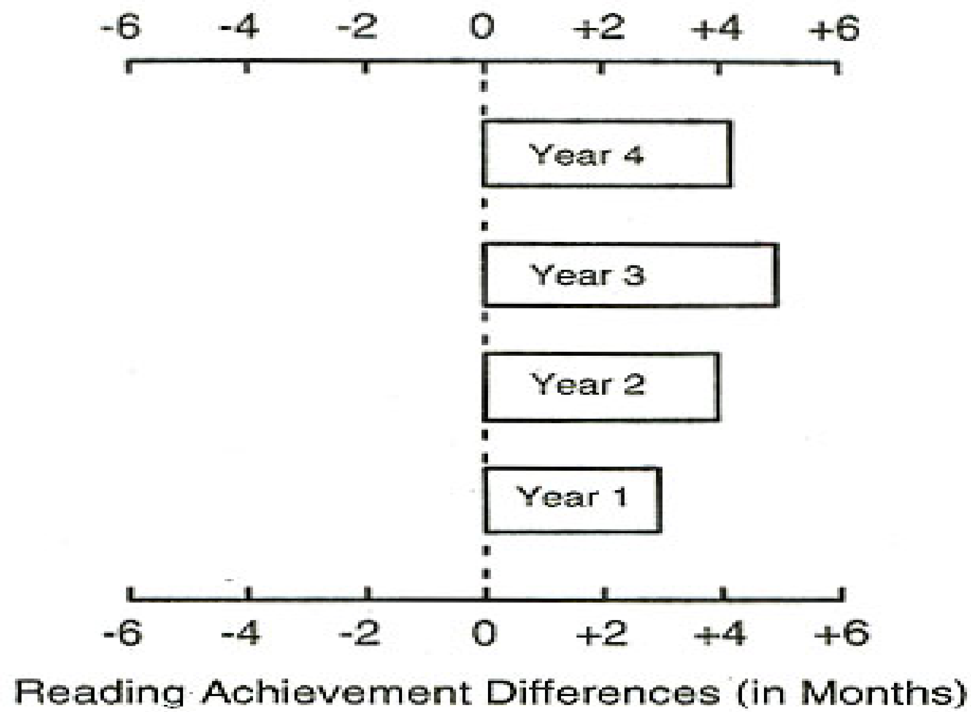
- **Context: (Over a Five Year period)**
  - Applied school settings in grades 3-5
  - Comparison groups used; previous achievement served as co-variate
- **Instructional Intervention (Treatment) described previously**
  - *Replacement* of Reading/Language Arts instruction with daily 2-hour science instruction (*Science IDEAS*)…
  - *Focus* on teaching/learning science concepts
  - *Use concepts as a framework* for reading/writing as well as for hands-on activities and projects
  - *Use of propositional concept mapping* as a tool for teacher/student organization of conceptual knowledge

Science IDEAS: Multi-Year Findings (Science)



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

Science IDEAS: Multi-Year Findings (Reading)



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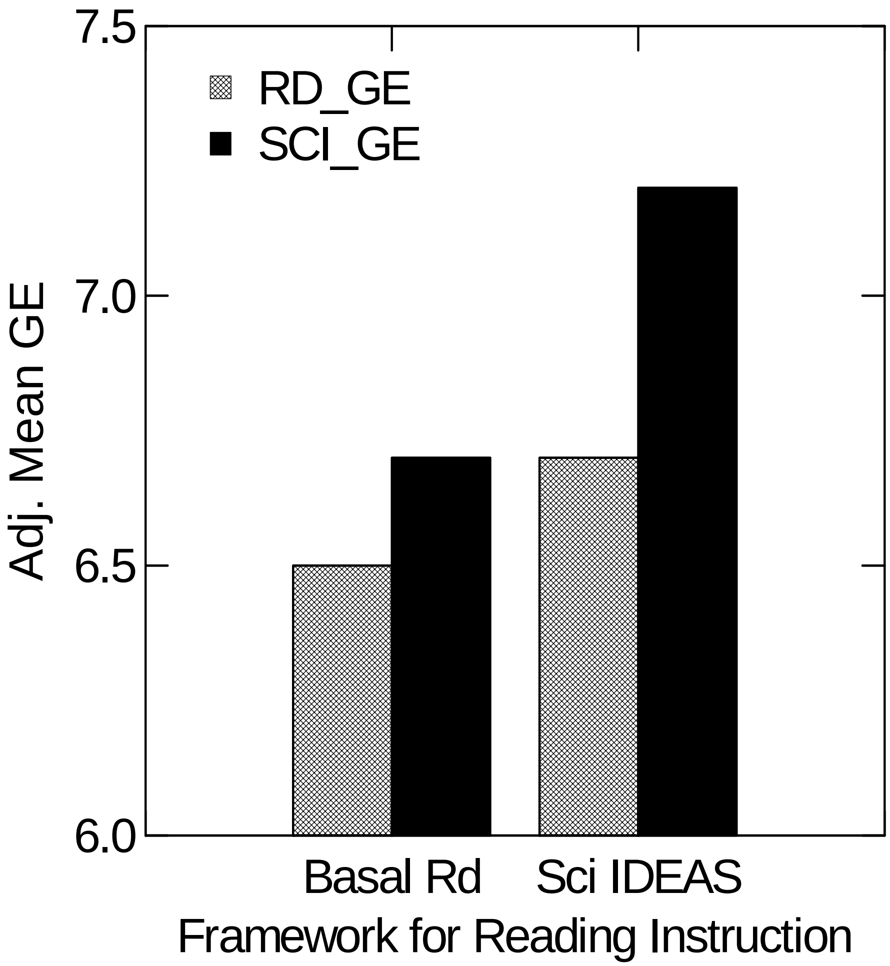
Science IDEAS – Current NSF/IERI Funded Project

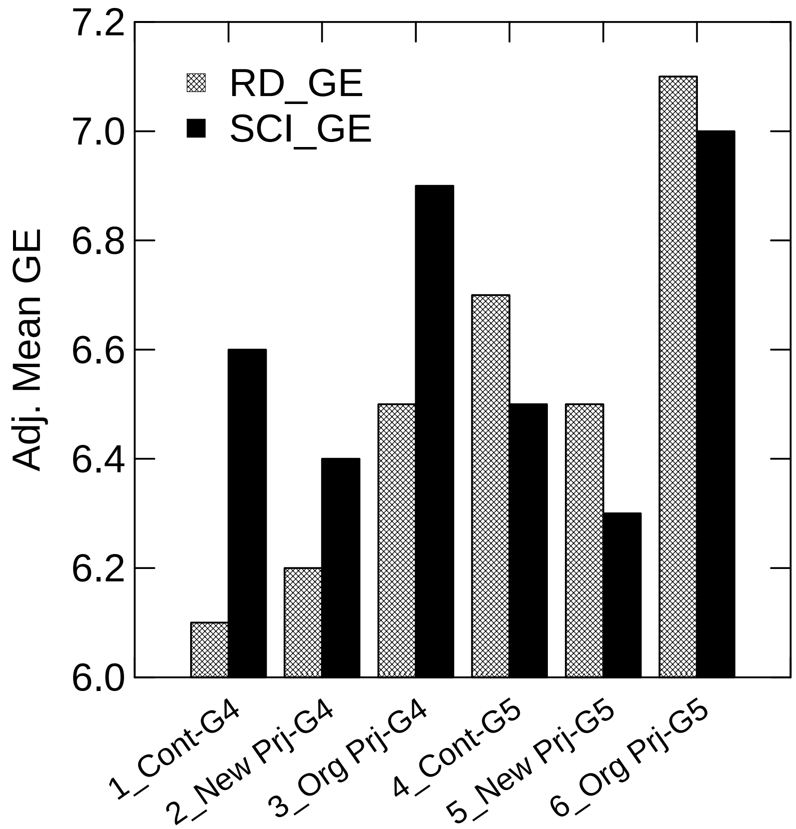
- On-going research initiative to replicate the findings of previous research
- Establishing a longitudinal database to assess the impact of the knowledge-focused reading comprehension strategy
  - Direct measure of general reading comprehension proficiency
  - Transfer measures across grades 3-8
  - Downward extension to grades K-2
- Project is also addressing the degree to which
  - fidelity of implementation predicts student achievement outcomes in science and general reading comprehension, and…
  - how multiple years in the project influence cumulative learning outcomes

Science IDEAS
2003-2004 ITBS Achievement Outcomes



Note- Shown are differences in adjusted grade equivalent means on the ITBS Reading and Science for grade 4-5 Science IDEAS and Basal Reading classrooms. After statistically equating students for differences on the preceding years FCAT Reading achievement, Science IDEAS students displayed significantly higher ITBS achievement on both Reading and Science.

Science IDEAS
2004-2005 ITBS Achievement Outcomes



Proj. = Science IDEAS Schools by Experience (1, 3 Yrs)

Note-
After statistically equating students for differences on the preceding years FCAT Reading achievement, Science IDEAS students in schools with 3 years experience displayed significantly higher ITBS achievement than Basal Reading schools on both Reading and Science.

Results for Science IDEAS schools in their initial year were varied, suggesting that more than 1 year for implementation experience is required before the Science IDEAS model is implemented with consistency.

Further Work-in-Progress: USDOE/IES Study

- Study compared traditional basal reading classrooms with classrooms using the knowledge-based reading comprehension strategy within the context of
    - (a) a narrative instructional environment, and
    - (b) the Science IDEAS environment
- Student achievement in Grades 3-4-5 (follow-up in grades 6-7)
    - Instruments
        - FCAT/ITBS Reading Comprehension, Science
        - High- vs. low- inference understanding (high- vs. low- cohesion)
        - Cumulative “learning through reading” transfer task
        - Student-reported use of reading comprehension strategy elements
        - Student attitude/self-confidence re: Reading (and Science)
- Preliminary results
    - Knowledge-based strategy use in both contexts (a and b) resulted in significant achievement in reading comprehension in comparison to non-strategy traditional basal reading control classrooms

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Multi-Disciplinary Framework Underlying the Design of the Intervention – Science IDEAS

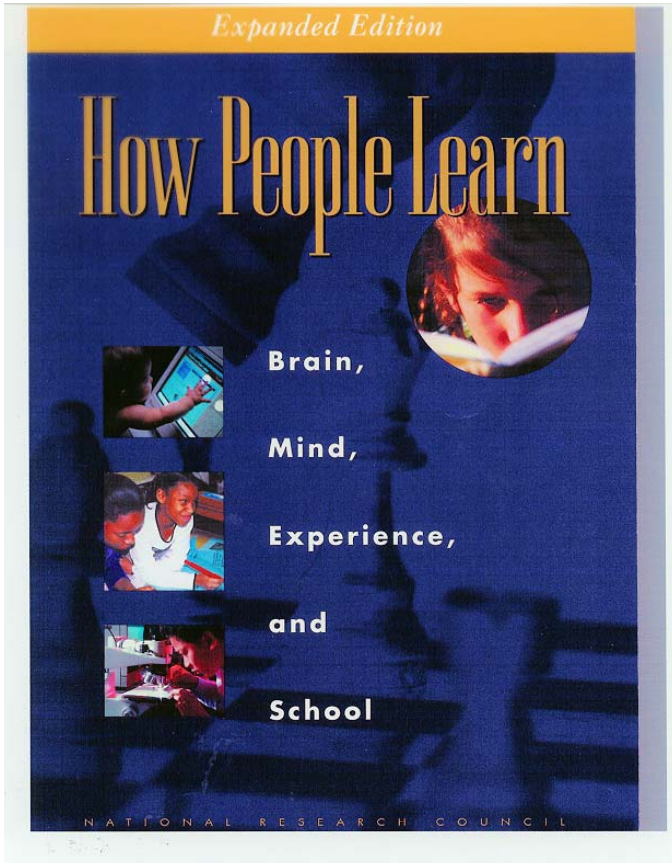
- Major Theoretical Framework
  - Expertise-oriented view of comprehension (with emphasis on role of knowledge) (Bransford, 2000; Glaser et al, 1998; Hoffman & Feltovich, 2006)
  - Aspects of the Construction-Integration model (Kintsch, 1994, 1998, 2002, 2004)
  - Multi-disciplinary perspectives supporting the Knowledge-Based Comprehension Model (KBC) used in Science IDEAS classrooms
    - Cognitive science perspective
    - Case-based reasoning
    - Direct instruction
    - Stimulus equivalence

Consensus Research: Conclusions About the Role of Knowledge in Meaningful Learning

Recent Research Related to Learning with Understanding…

3 Major Findings…

- Prior Knowledge is a major determinant of future learning
- In-depth understanding involves conceptually organizing knowledge which, in turn, makes it accessible for later use
- To be of value, curriculum must build cumulative knowledge used in future learning



Differentiating between Experts and Novices with Regard to Meaningful Learning (Understanding)

Bransford et al (2000) emphasized consensus research findings comparing experts and novices. The findings included:

- Experts display more organized knowledge that facilitates access and application to better understand the dynamics of the settings in which they interact
- Novices only attend to surface features using weak organization schemes

Related Research Findings

- Weaver & Kintsch (1995) noted the importance of *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 impacts the effectiveness of reading comprehension strategies in particular.
- Alexander & Jetton (2003) noted how prior knowledge is foundational to the learning process; how it enables learners to judge what is important; how it influences willingness to engage in text-based learning; how movement toward expertise requires a shift in learners' strategic profiles

Related Research Findings

- Guthrie et al (1997, 1998, 2002)
  - Results have shown repeatedly that engaging upper elementary students in content-area materials (science, social studies) significantly impacted reading proficiency and motivation
- Klentschy et al (2004)
  - Results have shown that using science improves writing proficiency, reading and advances language acquisition for ELL students

Related Research Findings

- Pearson & Fielding (1995) found that organizational enhancements such as summarization of text structure were powerful in facilitating overall comprehension and learning.
- Pearson and Duke (2002) debunked teachers' beliefs that use of informational text must wait until students develop decoding; or that young children cannot handle informational books; or that comprehension instruction must wait until students are efficient decoders

Related Research Supporting the Role of Knowledge in Meaningful Learning

- **Expert-Novice Literature** (Bransford, 2000; Glaser, 1984; Chi, Glaser & Farr, 1988; Chi, Feltovich & Glaser, 1981 – physics; Feltovich et al, 1984 – medical knowledge necessary for diagnostic expertise)
- **Cognitive Science** (Knowledge-Representation) and Instructional Design (J. R. Anderson, 1992, 1993, 1996; Sowa, 2000; Kolodner, 1997; Alexander, 1996)

Reading Comprehension within Science IDEAS

- Science IDEAS employs a knowledge-based model of comprehension ……….. a form of cognitive processing of information…....
- Consider how the Rand Report (Snow, 2000) defined comprehension….
  - The process of simultaneously extracting and constructing understanding from print or oral discourse

Examples:

1. Jones sacrificed and knocked in a run.
2. Woods was caught out of his crease on the first over after lunch.

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  - Text-analysis sub-strategy
  - Concept mapping sub-strategy
  - Summarization/writing sub-strategy
  - Supporting knowledge fluency development activity
- Sub-strategies (and multiple strategy use)
  - have consensus research base
  - are “expertise-based” and engineered for application by teachers
  - are applied in a complementary fashion

How the Elements of Multi-Part Reading Comprehension Strategy Operate

- Sub-strategies are
  - Combined to provide processes whose *application as reading occurs* enhances understanding of the knowledge to be gained re:
    - Accessing prior knowledge
    - Representing new knowledge to be learned
    - Generating expressions (oral, written) that summarize understanding of knowledge in a coherent fashion
  - Applied across cumulative, meaningful learning environments (the potential result is the integration of new and existing knowledge)
  - Engineered in their design to be learned and applied by students (and teachers) as a form of expertise

Cognitive Processes Used in Concept Mapping to Support Reading Comprehension

- Crandall, Klein & Hoffman (2006) provide a framework for thinking about the role of concept mapping for engendering deep understanding (i.e., comprehension)
  - Need to know what people do when they are engaged in complex tasks (e.g., comprehension)
  - This includes
    - How they think
    - What they know
    - How they organize and structure information
    - How they seek to understand better

Summary
Some Research-Oriented Perspectives Resulting from Our Work…..

- IF < students are not involved in cumulative meaningful learning within discipline >
  THEN < comprehension cannot occur (i.e., no knowledge to be learned) >
- AND
- IF < students are not involved in cumulative meaningful learning across disciplines (or ranges of different topics) >
- THEN < unlikely to develop “proficiency” in comprehension that is transferable (i.e., no broad experience in comprehension to be transferred) >

Current Perspective on Comprehension as a Form of Meaningful Learning

- In-depth meaningful learning implies performance characteristics exhibited by experts (i.e., performance mastery under specific conditions across the scope of a domain)

- In school learning settings, the requirements for <u>meaningful learning and comprehension are equivalent</u> in that both.......
  - Involve instructional experiences that require *cumulative understanding* (i.e., something to be learned)
  - Are *maximally efficient* when what is to be learned can be assimilated into prior knowledge
  - Require *reorganization of prior knowledge* when new learning cannot be assimilated
  - May involve combinations of “trial-and-error,” “effective instruction/teaching,” or “self-instructional strategies”

Elements of the Reading Comprehension Problem in Applied School Settings: Grades 3-4-5

- Current context of instruction does not support comprehension as meaningful cumulative learning
  - Narrative stories (“literature”) in the reading curriculum do not require meaningful learning
  - Content area texts (e.g., science) typically are incoherent, fragmented, and/or non-conceptual
- Reading “skills” and “comprehension strategies” emphasized by schools are problematic, re: confusing comprehension “causes” with comprehension “effects”
  - “Skill” demonstrations require comprehension
  - Majority of comprehension “strategies” require prior comprehension to use or are “unfocused”

Issues in Reading Comprehension Strategy Research Design

- Ecological validity of reading comprehension strategy research
- Use of model-oriented (vs. variable-oriented) research in applied school settings (Slavin, 1990, 2002)
- Emphasis on demonstration of replicability of research findings vs. singular emphasis on intra-study design
- Explication of curricular knowledge as central methodological condition in any learning research that addresses meaningful learning (and comprehension) within applied school settings
- Further research is needed to understand comprehension in complex domains