Synthesis of Research from
How Students Learn: Science in the Classroom

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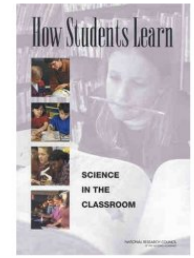

KEY FINDINGS ABOUT HOW STUDENTS LEARN SCIENCE		**STeLLA STRATEGIES**
1. Students' prior knowledge must be engaged.	A fundamental insight about learning is that *new understandings are constructed on a foundation of existing understandings and experiences*. Students come to the classroom with preconceptions about how the world works. The understandings they carry with them into the classroom will shape significantly how they make sense of what they are taught (see "A Fish Story" and imagine your students as the fish and the frog as you, the teacher). If students' initial knowledge is not engaged, the students might fail to grasp the new concepts and information that are taught; they might distort the new information to make it fit with their prior experience (as the fish did), or they might memorize facts for purposes of a test but revert to their preconceptions outside the classroom. NOTE: It is not just inattentive students who misinterpret science instruction; students who are trying hard to make sense of the science ideas will want to make the new science ideas fit with their own experience which can lead to misinterpretations of the science ideas. With respect to science, everyday experiences often reinforce the very conceptions that scientists have shown to be limited or false, and everyday modes of reasoning are often contrary to scientific reasoning. Research shows that many high school and college students still hold the same misconceptions as young students, despite having studied the scientific explanations in high school and college. Students also have misconceptions about how scientists think and work, often failing to appreciate the centrality of conceptual knowledge in the scientific inquiry process. **Implications for Teaching** Draw out and work with the preexisting understandings that students bring with them. • Abandon the model of the child as an empty vessel to be filled with knowledge and instead think of students' heads as filled with a myriad of wonderful ideas and experiences relevant to the science you are teaching. Actively inquire into students' thinking, creating classroom tasks that will reveal student thinking. Then plan ways to help students find the scientific conceptions useful and meaningful so they can change their initial conceptions to accommodate the new ideas. Students need opportunities to explore their own ideas, to appreciate the limitations of their ideas, to understand how scientific explanations are different from their own, to make sense of scientific explanations, and to use this learning process to change their everyday conceptions to ones that are more scientifically accurate and that make sense to the learner. • The use of frequent formative assessment helps make student thinking visible to themselves, their peers, and their teacher. Given the goal of learning with understanding, assessments of all types must tap students' understanding and develop their ability to use and apply knowledge rather than merely repeating facts or performing isolated skills.	***Student Thinking Lens*** Ask questions to elicit student ideas and predictions Ask questions to probe student ideas and predictions Ask questions to challenge student thinking

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2. Organizing science knowledge into conceptual frameworks is essential in developing scientific understanding.	To develop understandings that truly change the way students think about the world around them, students need a deep foundation of usable knowledge that is organized in their minds as a connected, conceptual framework that they know how to use to make predictions, solve problems, explain new situations, and so forth. This kind of deep understanding contrasts with the kind of learning so commonly tested in science classrooms—memorization of lists of science terms and facts. This idea of learning with understanding has two parts: (1) To be meaningful beyond passing a test, factual knowledge MUST be placed in a conceptual framework (a set of connected "big ideas"), and (2) Concepts are given meaning through experiences with multiple representations that are rich in science ideas and details and through experiences with multiple phenomena that the ideas help explain. The scientific concepts take on meaning as students see their usefulness in explaining a variety of real-world situations and phenomena. Students can be supported in building conceptual understandings by actively engaging in processes of scientific inquiry. Opportunities to learn science as a process of inquiry involve drawing from first-hand data and observations and using knowledge of the data and science ideas to reason about the phenomena under study. This process can be used to challenge and build on students' initial ideas and everyday experiences of the world. It can also provide evidence to help students see a need for different explanations and why scientific explanations make sense. **Implications for Teaching** Teach science in depth, providing many examples in which the same concept is at work and providing a firm foundation of knowledge of science ideas. • Superficial coverage of all topics in science should be replaced with in-depth study of fewer topics that allows key science concepts to be understood. • Teachers need in-depth knowledge of the science content they will teach, the nature of scientific inquiry and the terms of scientific discourse, and the relationship between science concepts and real-world phenomena. • Assessments for purposes of accountability (e.g., statewide assessments) must test deep understanding rather than surface knowledge. A teacher is put in a bind if she or he is asked to teach for deep conceptual understanding, but in doing so produces students who perform poorly on standardized tests. Much work needs to be done to minimize the trade-off between assessing depth and assessing objectively (e.g., multiple choice tests).	***Student Thinking Lens*** Engage students in using and applying new science ideas in a variety of ways and contexts Engage students in interpreting and reasoning about data and observations Engage students in making connections by synthesizing and summarizing key ideas Engage students in communicating in scientific ways ***Science Content Storyline Lens*** Identify one main learning goal Set the purpose with a focus question or goal statement Select activities that are matched to the learning goal Select content representations matched to the learning goal and engage students in their use Sequence key science ideas and activities appropriately Make explicit links between science ideas and activities Link science ideas to other science ideas Highlight key science ideas and focus question throughout Summarize key science ideas

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3. Learning to monitor one's own thinking is essential in learning to think like a scientist.	A "metacognitive" approach ("thinking about thinking") to instruction can help students learn to take control of their own learning by engaging them in understanding learning goals and monitoring their progress in achieving them. A metacognitive, or self-monitoring, approach can help students develop the ability to reflect on their own thinking and learning processes. In science, we can help students think like scientists by using metacognitive approaches that make scientific thinking processes visible and engage students in reflecting on how their own thinking is similar to and different from scientific ways of thinking. For example, students can examine the tendency of us all to attempt to confirm rather than rigorously test (and possibly refute) our current ideas. The approach is deepened when you help students learn why and how to create models of phenomena that can be put to an empirical test. Through metacognition, students reflect on their role in inquiry and on the monitoring and critiquing of their own claims, as well as those of others. Applying a metacognitive habit of mind helps students compare their personal ways of knowing with those developed through centuries of scientific inquiry. Being metacognitive about science is different from simply asking whether we comprehend what we read or hear; it requires taking up the particular critical lens through which scientists view the world. **Implications for Teaching** The teaching of metacognitive thinking should be integrated into the science curriculum. • Help students understand the discourse that scientists use as they make sense of their data and observations—both their internal dialogue and external communication with a community of scientists. It is not enough to give students tasks that require them to think and reason. In addition, students need to learn how scientists think and reason and how that might contrast with their own ways of thinking and making sense. For example, students should learn to ask questions such as: *How do we know that? What's your evidence?* • To help students monitor their developing understandings, engage them in reflecting on their learning, their changing ideas, and their remaining questions and wonderings. A lesson summarizing activity, for example, might prompt students to reflect on how their ideas have changed and why. Alternatively, the class might pause after a science discussion to reflect on ways they did and did not think and communicate in scientific ways during the discussion.	***Science Content Storyline Lens*** Set the purpose with a focus question or goal statement ***Student Thinking Lens*** *NOTE: All the Student Thinking Lens strategies can be used to provide opportunities for students to think about their thinking and learning processes. But one Student Thinking Lens strategy explicitly addresses the need to compare student ways of thinking to scientific ways of thinking:* Engage students in communicating in scientific ways