Are We On the Right Track?

Is education on a race to no where?
Are we still a mile wide and an inch deep in science content?

Prompt: What inspired you to become a science educator and/or scientist? What role, if any, did a teacher and/or school play? When did this occur? What else sparked your interest in science?

Ask for some responses from the group
Are there any patterns in the group?

Some Key Questions
What do our group responses about what inspired us in science tell us about learning and teaching science?
What would you want to see going on in science classrooms?
What is the role of inquiry? Science practices?
What role does informal science play in learning science?
What's new in science education and education in general?

Evolution of Science Education
Let's look at some terms that are frequently used in science education.
Let's also include some historical events.
Let's cluster these in a historical sequence? Make timeline
Are historical aspects still being used? What were pitfalls with the early science programs?
Historical Education Events:

- Sputnik (Oct. 4, 1957)
- Federal funding for "alphabet soup" curriculum projects (late 1950's & '60s)
- ESEA (1st enacted 1965)
- A Nation At Risk (1983) "rising tide of mediocrity"
- First national standards (mathematics 1989; AAAS Project 2061 Science for All Americans 1993, NSES 1996)
- ESEA Reauthorization required states to develop standards and

aligned assessments
Colorado standards first adopted 1995
First CSAP 1997 in grade 4 reading and writing
CSAP grade 8 science and math 2000
No Child Left Behind Act (ESEA) - signed into law January 2002
Established AYP annual increases (all students proficient or advanced by 2014)
(Supposed to be re-written & reauthorized in 2007)
CSAP 2002 grades 3-9 reading, writing and math; science grade 8
2006 Colorado Growth Model; CSAP science grades 5 and 10
2007 Revised Colorado science standards
Current ESEA/NCLB proposed reauthorization as A Blueprint for Reform (if bill not introduced this spring, will probably not happen until 2012 elections). NSTA and others advocating for science to be included in new ESEA accountability system and designate part of Title IIA for STEM professional development
New Colorado standards including science 2009
Colorado Education Accountability Act - 4 performance indicators (academic achievement, academic growth, academic growth gaps, post secondary and workforce readiness) CAP4K (CO achievement plan for kids)
Common Core Standards for ELA and Mathematics 2010 (review and enhance Colorado standards)
Common Core Standards for science will be developed
Colorado a member of federally funded The SMARTER Balanced Assessment Consortium (SBAC). There is another consortium of states called The Partnership for Assessment Readiness for College and Careers (PARCC).

Key science approaches
1920's - through mid 1950's
-John Dewey first emphasized science as inquiry (1920's) - didn't take off
-Learning cycle - referenced back to 1920's
-Science texts and curricula were focused on reading about science -facts
Late 50's after Sputnik and 60's
-NSF funded programs such as ESS, SAPA(Science, A Process Approach), SCIS (Science Curriculum Improvement Study), Chem Study (1959), BSCS Green, Yellow, Blue Versions (1st editions released 1963), PSSC

Physics (Physical Science Study Committee - 1st ed. 1960) BSCS formed in 1958.
-Learning cycle by Robert Karplus (SCIS) - Exploration, invention, discovery
-Inquiry especially fostered in elementary programs - messing around in science (David Hawkins)
-NSF Teacher In-Service Institutes for Sec. School Teachers (‘50’s -70s) No evaluation component

1970’s
-Continuation of ‘60s curricula and teacher insitutes
-Content versus process in curriculum materials
-Scientific method emphasis
-Constructivism

1980’s
-Scientific method in many materials
-NSF funded elementary science programs - FOSS (Full Option Science System), Insights, BSCS (now Tracs), STC (Science and Technology for Children) with focus on inquiry (late ‘80s)
-Federal funding Dwight D. Eisenhower teacher inservice programs for science and math (continued into early ‘90s) Formula-based funds

1990’s
-Secondary funded NSF programs - BSCS A Human Approach, Active Physics, ChemCom, SEPUP
-Professional development on specific science programs and inquiry
-NSF systemic state-wide grants (e.g. CONNECT in Colorado)
-NSF MSP grants started
-Research on NSF funded programs
-5e learning cycle model (introduced BSCS 1989)-included in many curricula developed through support from NSF
-Federal funds for state MSPs

2000 to current
-Science left out of AYP
-Science required testing under NCLB at one grade level for elementary, middle and high school

-Scientific Practices - 2010 is found in Conceptual Framework for new science education standards that are in development (inquiry and nature of science included under practices)
-Learning progressions - 2007 found in *Taking Science To School: Learning and teaching science in grades K-8*
-Claim, evidence, explanation -current best described my McNeill and Krajcik in their claim, evidence, and reasoning framework for talk and writing
-NSF and Department of Education funds for competitive science and math programs and professional development continues (Teacher Institutes for 21st Century)
-Push for STEM education (Need to clearly define STEM. There are too many definitions that vary across states. Oversight also varies among states)
-Role of informal science enhanced
-Educate to Innovate Programs (Introduced by President Obama in 2009 Examples: National Lab Day, Intel's National Science and Math Teachers Initiative, National STEM Video Game Challenge, Woodrow Wilson Teaching Fellowships

What are the most recent developments that will impact the future of science education?

Conceptual Framework to guide development of the new national Science Education Standards (Achieve is leading this effort.)

- -identify and articulate core ideas in science in the disciplines of life, physical, earth and space, and engineering and technology
- -new addition is engineering and technology
- -cross cutting ideas
- -7 scientific practices (for example, explanations and argumentation) Inquiry is not explicit but can be found in the practices.
- -learning progressions (These are hypothetical not based on research and may not end up in the framework)
- -framework includes existing efforts that specify central ideas for science education (NSES, AAAS's Science for All Americans and Benchmarks for Science Literacy, 2009 NAEP Science Framework, redesign of AP science courses by The College Board)

The Conceptual Framework will provide guidance for development of curricula and assessment and help with alignment between K-12 and higher education.
http://www7.nationalacademies.org/bose/Standards_Framework_Homepage.html

Book from National Research Council. 2008. *Ready, Set, Science!: Putting Research to Work in K-8 Science Classrooms*
This book is based upon the work of the Committee on Science Learning, Kindergarten Through Eighth Grade that wrote *Taking Science to School: Learning and Teaching Science in Grades K-8.* In *Ready, Set, Science!* four strands are highlighted that offer a new perspective for the study of science. Research suggests that each strand supports the others and are interconnected. Previous assumptions about what constitutes the "content, process, and nature of science" are inadequate.
Strands:
Strand 1: Understanding Scientific Explanations
Strand 2: Generating Scientific Evidence
Strand 3: Reflecting on Scientific Knowledge
Strand 4: Participating Productively in Science
Note: Strand 4 is often overlooked by educators. Strand 4 emphasizes sharing ideas with peers, building interpretive accounts of data, and working together to decide which accounts are most persuasive.

New Book: *Supporting Grade 5-8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talk and Writing* by McNeill and Krajcik (2012)
This book provides a Scientific Explanation Framework that builds on National Science Education Standards, AAAS Benchmarks (1993, 2009), *Taking Science to School, and* the strands from *Ready, Set, Science!.* The Framework is adapted from work by Toulmin, S. 1958. *The Uses of argument.* Cambridge, Uk: Cambridge University Press.
Scientific Explanation Framework:

- Claim - A statement or conclusion that answers the original question/problem
- Evidence - Scientific data that supports the claim.
- Reasoning - A justification that connects the evidence to the claim using scientific principles.
- Rebuttal - Recognizes and describes alternative explanations, and provides counter evidence and reasoning for why the alternative explanation is not appropriate.

Note: Rebuttal is introduced to students later as they advance in their ability with claim, evidence and reasoning.
Use of this framework requires teachers to include more open-ended questioning, an emphasis on using evidence, and more facilitation of discussions in which students debate their position with reasoning and evidence. The authors have worked with classroom teachers for 10 years using the framework.

Informal Science Book (2010): National Academy of Sciences: *Surrounded by Science: Learning Science in Informal Environments*
There are six strands of informal science learning

Strand 1 -	Sparking Interest and Excitement* Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world.
Strand 2 -	Understanding Scientific Content and Knowledge Generating, understanding, remembering, and using concepts, explanations, arguments, models, and facts related to science.
Strand 3 -	Engaging in Scientific Reasoning Manipulating, testing, exploring, predicting, questioning, observing, and making sense of the natural and physical world.
Strand 4 -	Reflecting on Science Reflecting on science as a way of knowing, including the processes, concepts, and institutions of science. It also involves reflection on the learner’s own process of understanding natural phenomena and the scientific explanations for them.
Strand 5 -	Using the Tools and Language of Science Participation in scientific activities and learning practices with others, using scientific language and tools.
Strand 6 -	Identifying with the Scientific Enterprise* Coming to think of oneself as a science learner and developing an identity

as someone who knows about, uses, & sometimes contributes to science.
*Strands 1 and 6 are identified for informal science. Strands 2 - 4 are part of formal science education. Note: All 6 should be part of formal science education also.

What Research Tells Us About How Students Learn Science

Important principles of learning

- Assess for prior student understanding of the science concepts.
- Actively involve students in the learning process.
- Help students be more metacognitive so that they can acknowledge the science concepts they understand, the goals for their learning, and the criteria for determining achievement of the learning goals.
- Ensure that learning is interactive and include effective classroom discussions.

Source: Donovan, S., and J. Bransford. 2005. *How Students Learn.*

Characteristics of Effective Science Lessons - See handout 1.1

Tweed, A. 2009. *Designing Effective Science Instruction, What works in Science Classrooms* (adapted from Weiss et.al. 2003. *Looking inside the classroom: A study of K-12 mathematics and science education in the United States.*)

National Research Council. 2007. *Taking Science To School, Learning and Teaching Science in Grades K-8.* R. A. Duschl, H. A. Schweingruber, and A. W. Shouse, Editors. Washington, DC: The National Academy Press.

New Framework for Proficiency in Science
The four strands represent learning goals for students and serve as a broad framework for curriculum design. They incorporate the scientific practices that students need to demonstrate their proficiency.
Students who are proficient in science:

1. know, use, and interpret scientific explanations of the natural world,
2. generate and evaluate scientific evidence and explanations,
3. understand the nature and development of scientific knowledge, and
4. participate productively in scientific practices and discourse.

Conclusions on What Children Know and How They Learn

- Children entering school already have substantial knowledge of the natural world, much of which is implicit.
- What children are capable of at a particular age is the result of a complex interplay among maturation, experience and instruction. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on their prior opportunities to learn.
- Students' knowledge and experience play a critical role in their science learning, influencing all four strands of science understanding.
- Race and ethnicity, language, culture, gender, and socioeconomic status are among the factors that influence the knowledge and experience children bring to the classroom
- Students learn science by actively engaging in the practices of science.

- A range of instructional approaches is necessary as part of a full development of science proficiency.

Taking Science To School, Learning and Teaching Science in Grades K-8. Continued

Recommendations: What, When and How To Teach
Recommendation 1: Developers of standards, curriculum, and assessment should revise their frameworks to reflect new models of children's thinking and take better advantage of children's capabilities.
Recommendation 2: The next generation of standards and curricula at both the national and state levels should be structured to identify a few core ideas in a discipline and elaborate how those ideas can be cumulatively developed over grades K-8.
Recommendation 3: Developers of curricula and standards should present science as a process of building theories and models using evidence, checking them for internal consistency and coherence, and testing them empirically. Discussions of scientific methodology should be introduced in the context of pursuing specific questions and issues rather than as templates or invariant recipes.
Recommendation 4: Science instruction should provide opportunities for students to engage in all four strands of science proficiency.
Recommendation 5: State and local leaders in science education should provide teachers with models of classroom instruction that provide opportunities for interaction in the classroom, where students carry out investigations and talk and write about their observations of phenomena, their emerging understanding of scientific ideas, and ways to test them.
Recommendations for Professional Development
Recommendation 6: State and local school systems should ensure that all K-8 teachers experience sustained science-specific professional development in preparation and while in service. Professional development should be rooted in the science that teachers teach and should include opportunities to learn about science, about current research on how children learn science, and about how to teach science.
Recommendation 7: University-based science courses for teacher candidates and teachers' ongoing opportunities to learn science in service should mirror the opportunities they will need to provide for their students, that is, incorporating practices in the four strands, that constitute science proficiency and giving sustained attention to the core ideas in the discipline. The topics of study should be aligned with central topics in the K-8 curriculum.
Recommendation 8: Federal agencies that support professional development should require that the programs they fund incorporate models of instruction that combine the four strands of science proficiency, focus on core ideas in science, and enhance teachers' science content knowledge, knowledge of how students learn science, and knowledge of how to teach science.

Current Trends and Influences That Impact Science Education

Trend/Influences	Impact on Science Educ.	Solution
Continued push on student and school accountability through use of high stakes (Testing and accountability became main levers of school reform - hijacked standards D. Ravitch) NCLB focus - measure and punish focus rather than support	ELA and math factored into AYP Goal 100% proficiency by 2014. Outcome less time on science especially at elementary level. Colorado - science tested only at grades 5, 8 and 10. CSAP continues until new assessment 2011-2012 (use CSAP items that align with new standards) 2013-2014 - all new assessment items	Should science be included in AYP?
Teacher evaluation and accountability	Colorado legislation, Senate Bill 10-191, reform on teacher and principal evaluation process passed. 50% of teacher evaluations based on student academic growth (more than CSAP)	
Common Core Standards - Colo. accepted ELA and mathematics (Part of Race to the Top)	Colorado has revised state standards (inquiry embedded)-adopt by 12/2011 National level - Conceptual Framework in final development for new science education standards Targeted release 2nd quarter 2011 (inquiry not specified	Students need to engage with community/world problems -River Watch -Phenology -CoCoRahs -Ground Water study

	but incorporated under scientific practices)	-Energy projects -Ecology projects
	Need avenues to interest more students in science careers & engage all students on importance of science in their lives	Educ. & Outreach Center at CSU teacher grants- real research, Annenberg PD, Tutoring program, Sci Trek Camp, CO Science & Engineering Fair, STEM loan kits, From the Ground Up Workshop, Clean Energy Super Cluster Seed Grant, World Window
Push for STEM education	Various coalitions national and state level	
Competitive grants (not formula-based) MSP will change under “A Blueprint for Reform” to competitive grants	Some states get left out (e.g. Race to the Top - no Western states were funded except Hawaii) Colorado as a state may not have funds like MSP	Build more state partnerships with business and government labs
Teacher Preparation Colo. 800 hours of clinical experience Senate Bill 154 - candidates must show competence in 8 performance-based standards.	Shortage of qualified science teachers especially in physical and earth/space sciences	Increase number of students in teacher prep. (e.g. U Teach Model)

Influence of Nonprofit Foundations (e.g. Gates, Broad, Walton)	Influence on federal, state and district policies increasing Experiment with their latest idea (e.g. smaller high schools, latest Gates Foundation effort that most effective teachers teach more students, more funding to charter schools especially in low income urban areas)
Continued emphasis on ELA and math	Elementary science very limited or non-existent especially in low income urban schools Middle school science reduced time in low-performing schools
More school choice including increased number of charters. (destroys concept of neighborhood schools)	Competition for highly qualified science teachers. Often results in teachers with less experience in low-performing schools
Federal and state budget cuts Colo. ranks 44th in funding for K-12 & higher ed. per $1000 of personal income. CO spends $1,682 less per pupil than national average	Less resources for science May see more simulations rather than hands-on lab investigations Teacher lay offs Increased class size

Technology tools - more variety	Incorporate a variety of technology - e.g. cell phones, facebook, internet, student produced videos	
Bridging research into practice	More resources available that provide research and classroom application (e.g. NSTA, National Academies of Science, Corwin Press publications, online resources such as NSDL, Annenberg)	
U.S. student performance on international tests (e.g. PISA) falls below many other countries	Media headlines state science education falling behind other countries.	Media needs to report the performance of our top 10 - 20% of students (Data shows our best students at the top)
Role of after school & informal programs	Enhanced learning of science concepts and practices	MESA programs throughout CO, Sci. Olympiad
Use of formative assessment to determine student learning and preconceptions	Use of assessment probes to determine science preconceptions and understanding Use authentic formative assessment Use of science notebooks to enhance writing	

Several Examples of Inquiry Definitions:
Question: How are the definitions similar and different?

Example 1: Science as Inquiry from the *National Science Education Standards*
"The standard should not be interpreted as advocating a "scientific method." The conceptual and procedural abilities suggest a logical progression, but they do not imply a rigid approach to scientific inquiry. On the contrary, they imply co-development of the skills of students acquiring science knowledge, in using high-level reasoning, in applying their existing understanding of scientific ideas, and in communicating scientific information. This standard cannot be met by having the students memorize the abilities and understandings. It can be met only when students frequently engage in active inquiries." (NSES, 1996, 144-145)
Science as Inquiry Standards (developed into tables in BSCS *Why Does Inquiry Matter? Because That's What Science Is All About!* **Refer to Tables 1 and 2, pages 6-10)**
Abilities of scientific inquiry at fourth, eighth, and 12th grades
Understandings of scientific inquiry at fourth, eighth, and 12th grades

Example 2: The Essential Features of Inquiry (identified in *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning)*
1. Learner engages in scientifically oriented questions.
2. Learner gives priority to evidence in responding to questions
3. Learner formulates explanations from evidence.
4. Learner connects explanations to scientific knowledge.
5. Learner communicates and justifies explanations.

See Handout of Features from AfterSchool Training Toolkit: Investigating Science Through Inquiry

Example 3: Investigating Science Through Inquiry (SEDL National Center for Quality AfterSchool)
Inquiry is both an approach to teaching and a way of learning. It involves a process of exploring through asking questions and looking for answers. It includes making observations, planning and conducting investigations, using tools to gather, analyze and interpret data, and learning more about the world by proposing explanations that lead to new understandings.

Example 4: Table 2-7. Common Components Shared by Instructional Models
(*Inquiry and the National Science Education Standards)*
Phase 1: Students engage with a scientific question, event, or phenomenon. This connects with what they already know, creates dissonance with their own ideas, and/or motivates them to learn more.
Phase 2: Students explore ideas through hands-on experiences, formulate and test hypotheses, solve problems, and create explanations for what they observe. Phase 3:

Students analyze and interpret data, synthesize their ideas, build models, and clarify concepts and explanations with teachers and other sources of scientific knowledge.
Phase 4: Students extend their new understanding and abilities and apply what they have learned to new situations.
Phase 5: Students, with their teachers, review and assess what they have learned and how they have learned it.

Example 5. Inquiry-Based Science Instruction-What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002.
See handout with abstract and Table 1 Inquiry Science Instruction Conceptual Framework
Journal of Research in Science Teaching, 47 (4), 474-496 (2010)
Authors: Daphne D. Minner, Abigail Jurist Levy, Jeanne Century

Example 6. The Inquiry Continuum

1. Structured inquiry. In this very controlled approach, you would give the students a problem to solve, the materials needed to solve the problem, and the specifi instructions that should be followed. You would provide detailed steps on how to proceed with the investigation.
2. Guided inquiry. In this modified structure, you would again give the student a problem to solve, and you would also provide the materials for solving it. However, you would not provide detailed steps on how to proceed with the investigation. Instead, your students would have to develop their own methods to solve the problem.
3. Open inquiry. In this non-structured approach, you would not give the students a problem to solve. You would still, however, provide the materials and resources students might need to solve whatever problems they formulate. Students would then formulate their own problems to investigate, design appropriate methods of investigation, and determine solutions to their problems.

Hinrichsen, J., and G. Jarrett. 1999. *Science Inquiry for the Classroom: A Literature Review.* Portland, OR: Northwest Regional Educational Laboratory.

Example 7. The Inquiry Wheel Handout
Refer to handout.
Source: Reiff, R. et. al (cited in A. Tweed book *Designing Effective Science Instruction, What Works in Science Classrooms*, page 84)

Some Myths About Inquiry-Based Learning and Teaching
Myth 1. All science subject matter should be taught through inquiry.
Myth 2. True inquiry occurs only when students generate and pursue their own questions.
Myth 3. Inquiry teaching occurs easily through use of hands-on or kit-based instructional materials.
Myth 4. Student engagement in hands-on activities guarantees that inquiry teaching and learning are occurring.
Myth 5. Inquiry can be taught without attention to subject matter.

Source: *Inquiry and the National Science Education Standards,* NRC 2000, p 35 - 37

What is inquiry?
SEDL Videoclip: Investigating Science Through Inquiry: Exploring Trebuchets
Questions: Are students learning science concepts and processes? Where? What is your evidence? What type of inquiry do you see?
Jot down your individual thoughts. Discuss as a table.
Issues with defining inquiry - many definitions and ways of thinking about this (both content and instruction)
Give handout on inquiry from national documents.
Have some definitions on chart paper.
Myths and perceived problems with inquiry