Research Supporting the Framework's Principles

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National Research Council

Principles

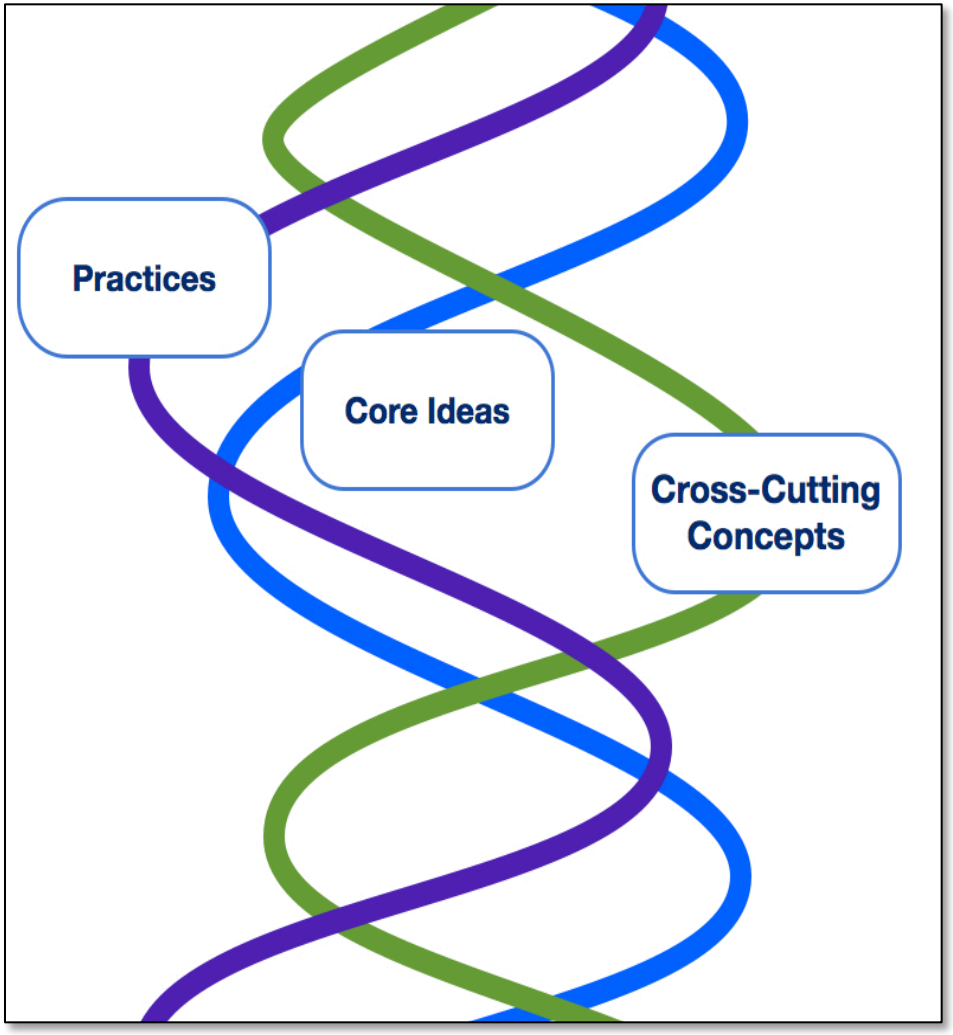
- Children are born investigators
- Focusing on core ideas and practices
- Understanding develops over time
- Science and engineering require both knowledge and practices
- Connecting to students interests and experiences
- Promoting equity

Science and engineering require both knowledge and practices

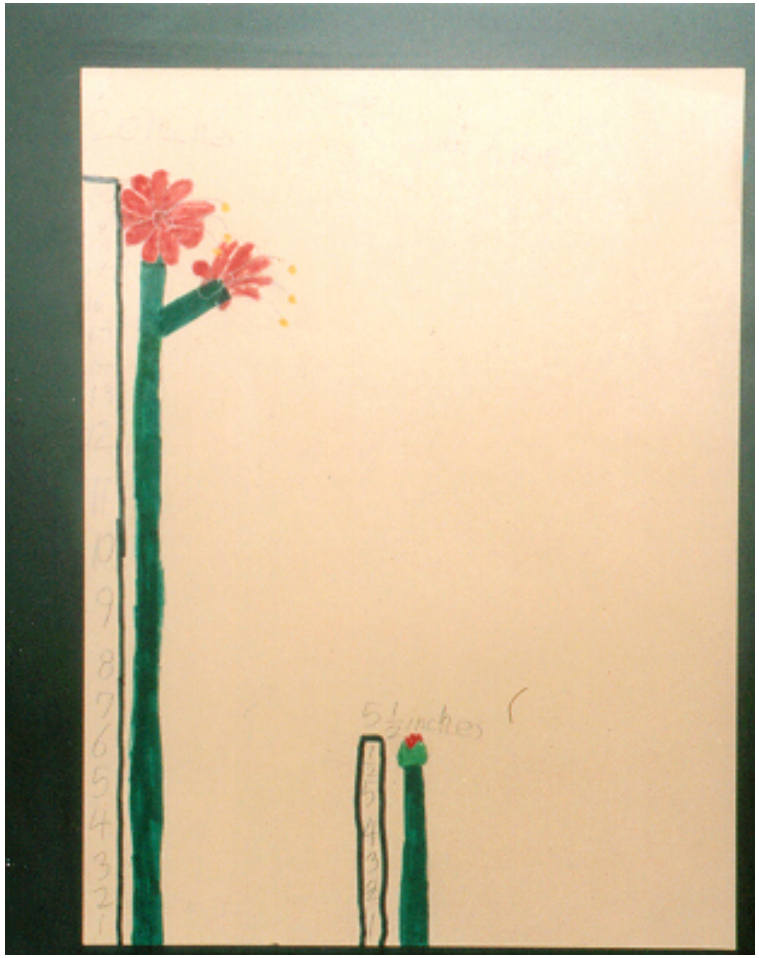
Elements of the principle

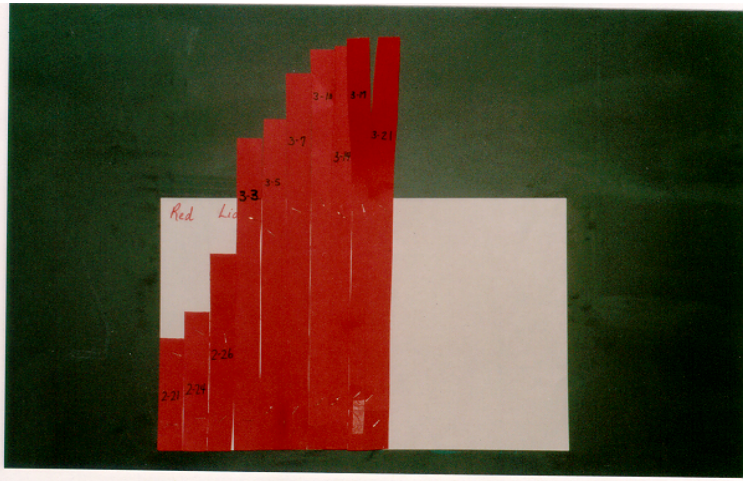
- Science is the body of knowledge that reflects current understanding of the world AND
- Science is the practices used to establish, extend and refine that knowledge
- This is the dimensions intertwined

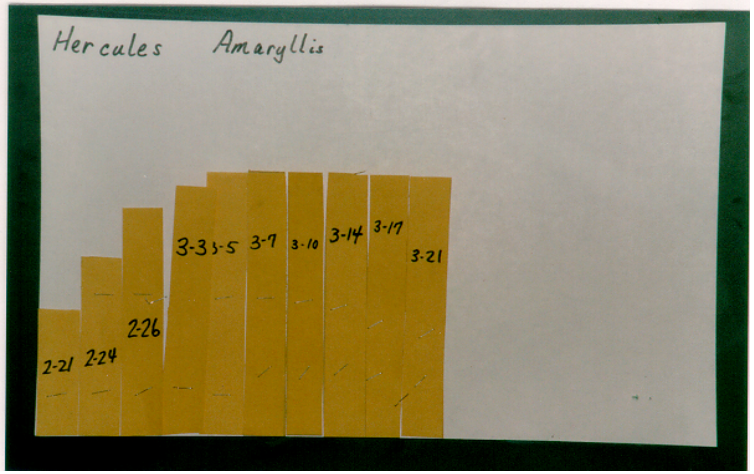
Intertwining of the Dimensions



Growth: First Grade*

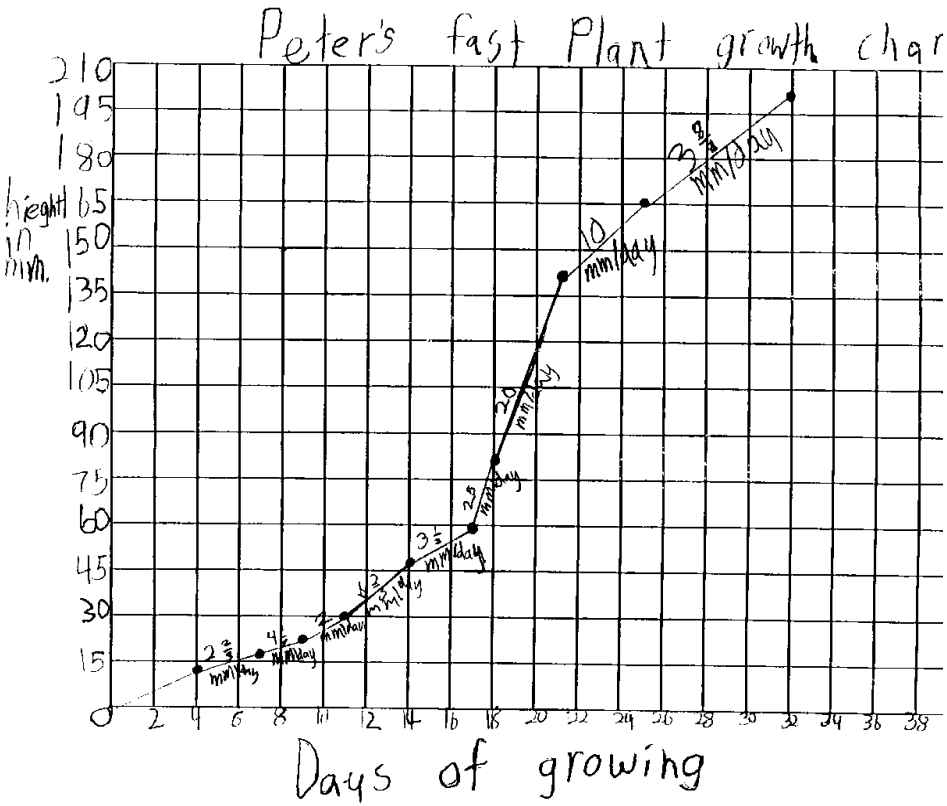


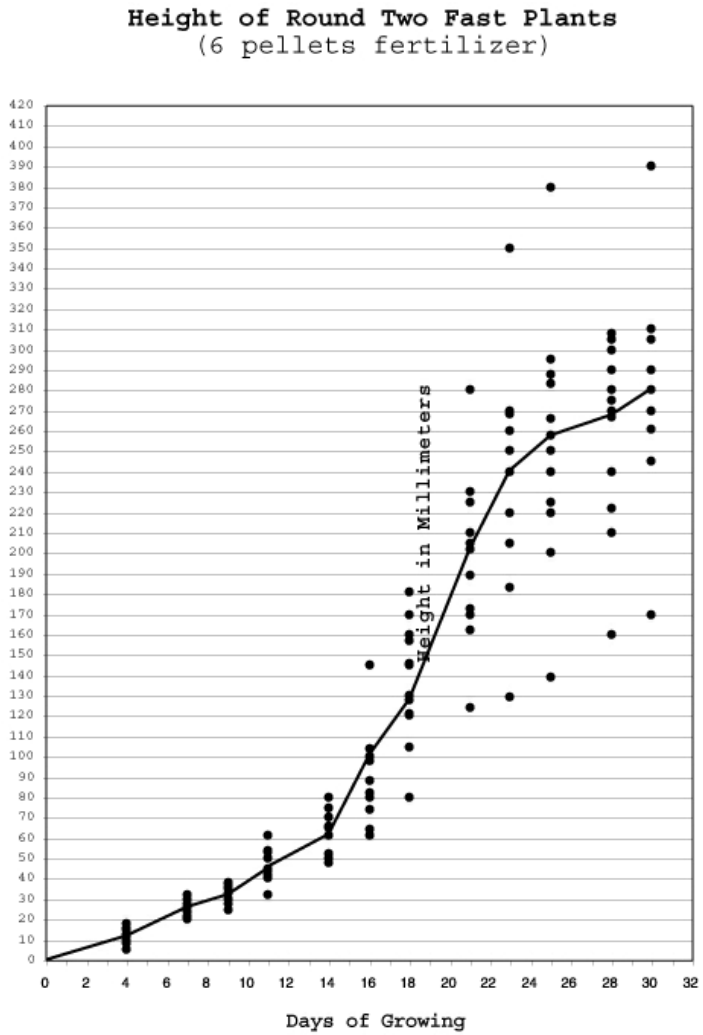




* From Richard Lehrer & Leona Schauble

Growth: Third Grade


Peter's fast Plant growth char
height in mm.
Days of growing

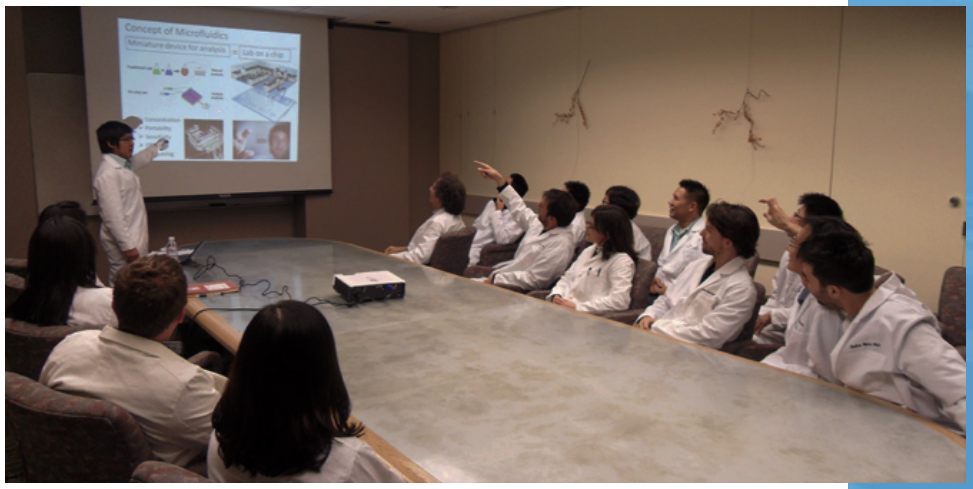

Height of Round Two Fast Plants
(6 pellets fertilizer)
Height in Millimeters
Days of Growing

Elements of the principle

- Science is a social enterprise
- The theories, models, instruments, and methods for collecting and displaying data, as well as the norms for building arguments from evidence, are developed collectively

Investigating science laboratories

- Molecular biology and immunology labs from the U.S., Canada and Italy.*
- Senior scientist, 3-4 post-docs, 5-6 graduate students and 1-2 technicians
- Videotape and audio tape lab meetings, then analyze sentence by sentence



Dunbar (1999). How Scientists Build Models: InVivo Science as a Window on the Scientific Mind

Distributed Reasoning

- Reasoning in science is done by groups – especially at critical moments of hypothesis formation, experimental design, data interpretation and discovery
- Over 50% of the reasoning in lab meetings is distributed
- Particularly important when an unexpected finding occurs

A simple example of distributed reasoning

A child loses her teddy bear and asks her father to find it. Their conversation:

Father: Where do you last remember having it?

Child: In the car.

Father: Let's look there. (No teddy bear in the car).

Father: Where did you go next?

Child: The kitchen.

Father: Ok, let's search the kitchen

(No teddy bear there).

They continue to several locations until the teddy bear is finally discovered in the playhouse in the backyard. Who found the teddy bear?

Science in the Classroom

- Study of 2 science classrooms, one grade 3 & 4 split, one grade 5*
- Students worked over 10 weeks to develop and refine explanations for sinking and floating
- Analysis of transcripts of whole class discussion and pre/post assessments

* Herrenkohl, Palinscar, DeWater & Kawasaki (1999). Developing Scientific Communities in Classrooms: A Sociocultural Approach. Journal of the Learning Sciences

Science in the Classroom

- Baseline activity asked students to predict whether 16 everyday objects such as a plastic spoon, a piece of graphite or an apple would float or sink. Students were asked to test their predictions and record the results. Students then prepared a report for the class.

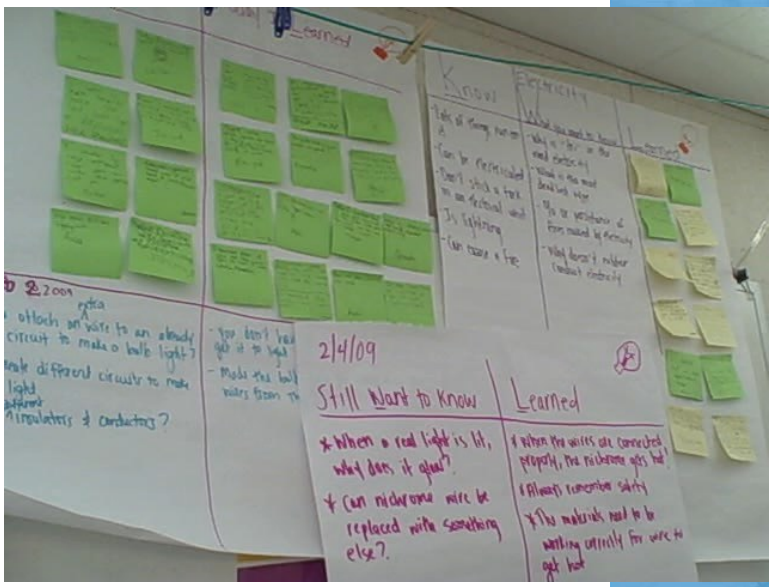
- Next, student rotated through 3 different investigations working in groups of 4-5 students. In this work students had various roles and developed public documentation.

Roles

- Roles during investigations – procedural (reporter, scribe)
- Audience roles -- questioner, commenter, critic. Plus guidance about what students might question or comment on.
- Students rotate through both sets of roles.

Public Documents

- Derived from whole class discussion and modified over the unit
- Question chart – helped students generate questions to ask reporters
- Theory chart -- students were responsible for articulating and adding theories
- In the middle of the unit, one class session was devoted to discussing the theory chart and deleting theories that were no longer plausible



Findings

- Students improved in their conceptual understanding of floating and sinking
- They also developed deeper understanding of scientific tools and theory
- The roles and public documents provided important supports – however the teacher played a key role in supporting students

Talk and Argument
(From Ready, Set, Science!)

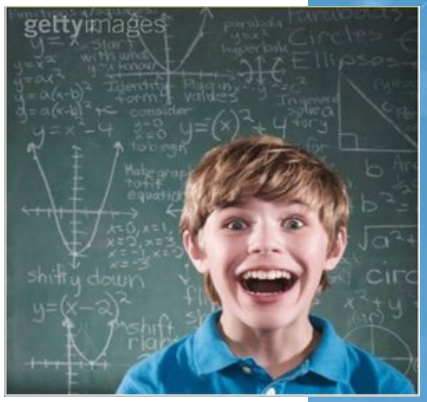
Teacher Move	***Example***
Re-voicing	"So let me see if I've got your thinking right. You're saying _____?" (with space for student to follow up)
Asking students to restate someone else's reasoning	"Can you repeat what he just said in your own words?"
Asking students to apply their own reasoning to someone else's reasoning	"Do you agree or disagree and why?"
Prompting students for further participation	"Would someone like to add on?"
Asking students to explain their reasoning?	"Why do you think that?" "What evidence helped you arrive at that answer?"
Using wait time	"Take your time…. We'll wait."

Attending to the social in the classroom

- Social arrangement – grouping should allow students to be active and contribute in meaningful ways
- Social process – conversation, argument, note taking, other recording and review activities should be explicit
- Tools that support learning
- Purpose of the activity – make this explicit for students
- Role of the teacher

Connecting to students interests and experiences

Importance of Interest



- Emotions are linked to learning
- Interest helps determine what is retained and how long it is remembered
- Interest provides a filter for selecting and focusing on relevant information

Sparking Interest

Surprise

Challenge

Interactivity

Confidence/competence

Social interaction

Control

The color connection: Making colored lights

Cultivating and Sustaining Interest

- Situational interest
- Maintained situational interest
- Emerging individual interest
- Well-developed individual interest*

*See research by Ann Renninger

Supporting Interest in the Classroom

- Earlier phases of interest
  - Real-world connections and connections to prior experiences
  - Puzzles and group work might trigger interest for those with no interest
- Sustaining interest
  - Personalization and meaningfulness
  - More open learning environments (e.g. project or problem based)
- Later phases of interest
  - opportunity to continue to be challenged to think about the content itself

Identity

- Well-developed individual interest can lead to a change in identity
- The learner's sense that he or she can do science and be successful in science
- Usually develops over an extended time frame
- Can be influenced/shaped by culture and community

Developing an Identity in Science

Chantelle, a soft-spoken African-American girl in 6th grade rarely volunteered in science class and had average grades. She wanted to be a dancer and had little interest in science. By 8th grade, she had strong interest in science and wanted to be a green architect. What happened?

She participated in an after-school science and engineering club and got involved in a project to see how much the school could save by using energy efficient light bulbs. Then was able to link this experience to science in school. *

* Calabrese-Barton et al (2012). Crafting a Future in Science. American Educational Research Journal

Thinking about students' experiences

- Students bring experiences from outside of school into the classroom
- Such experiences can be very diverse and involve many different kinds of people and places in students' lives

Everyday Settings &
Family Activities

Designed Settings

Media

Programs

Productive Disciplinary Engagement*

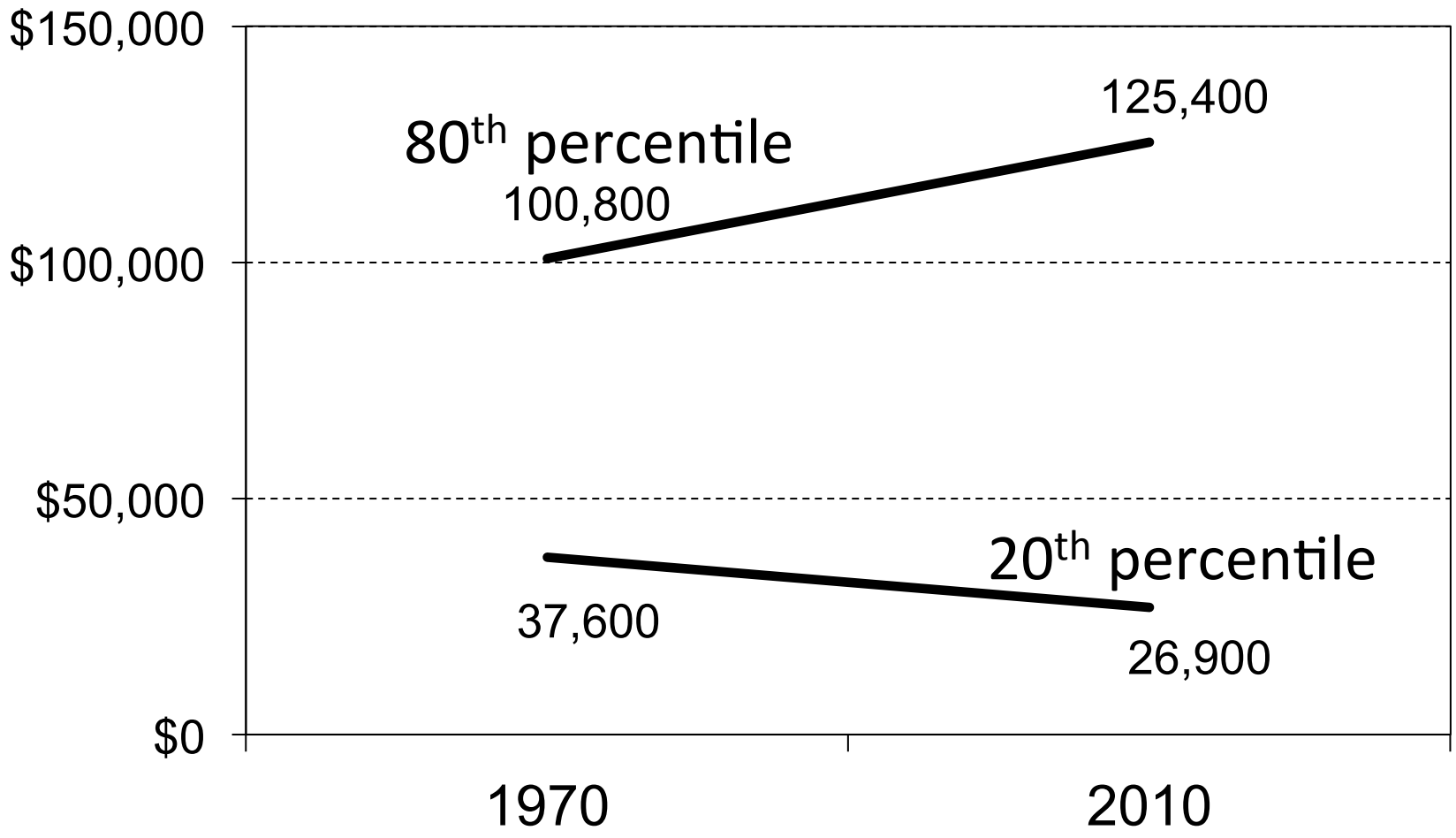
*Engle and Conant (2002). Guiding Principles for Fostering Productive Disciplinary Engagement. Cognition and Instruction

Promoting Equity

Elements of Equity

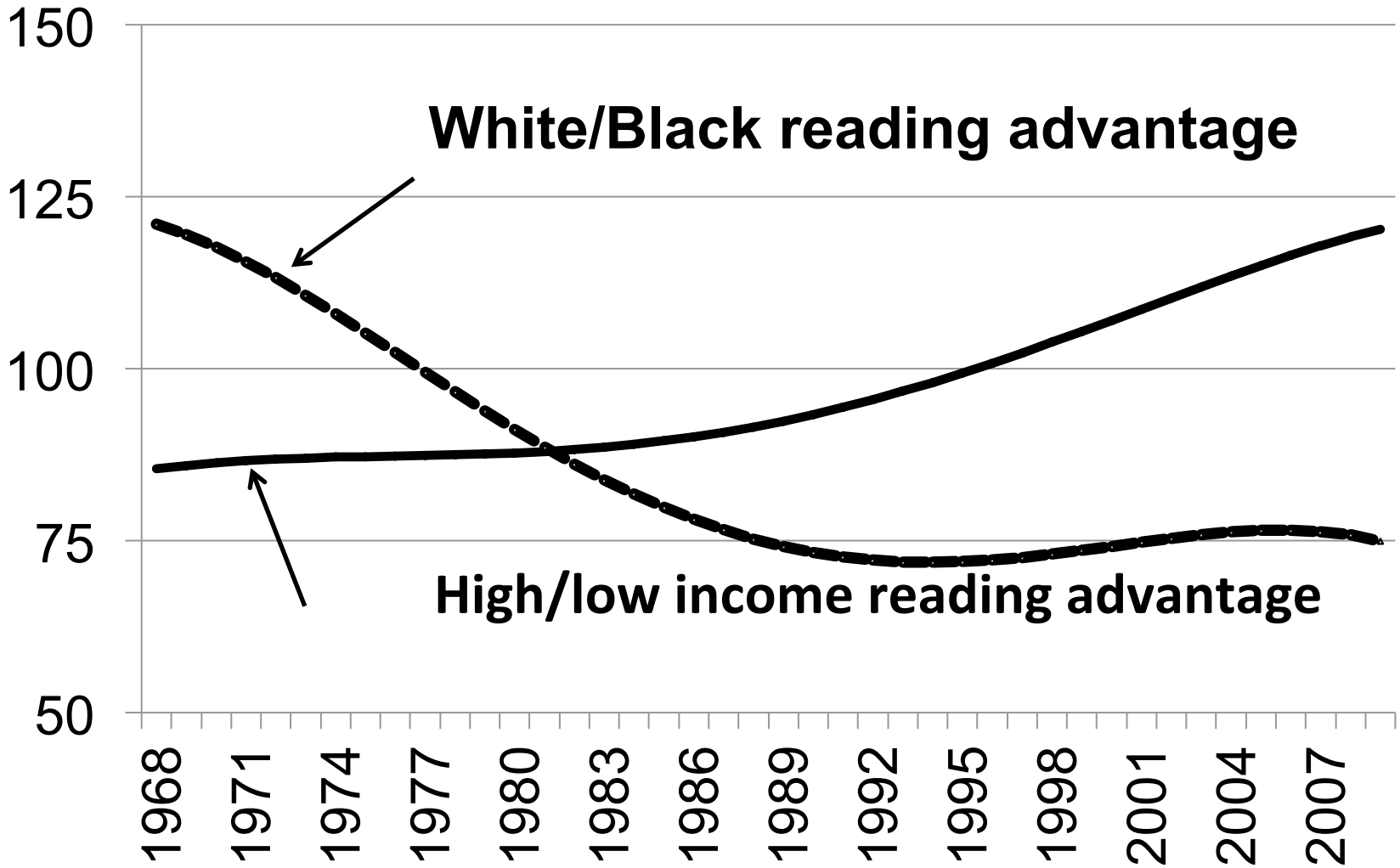
- Providing all students with equitable opportunities to learn
- Recognizing cultural assets on which to build
- Attending to cultural, linguistic and other differences
- Providing equitable access to ALL students

Children's family income



Note: Chart shows 20th and 80th percentiles of the distribution of family incomes for all children age 5-17. They based on data from the U.S. Bureau of the Census and are adjusted for inflation. Amounts are in 2012$.

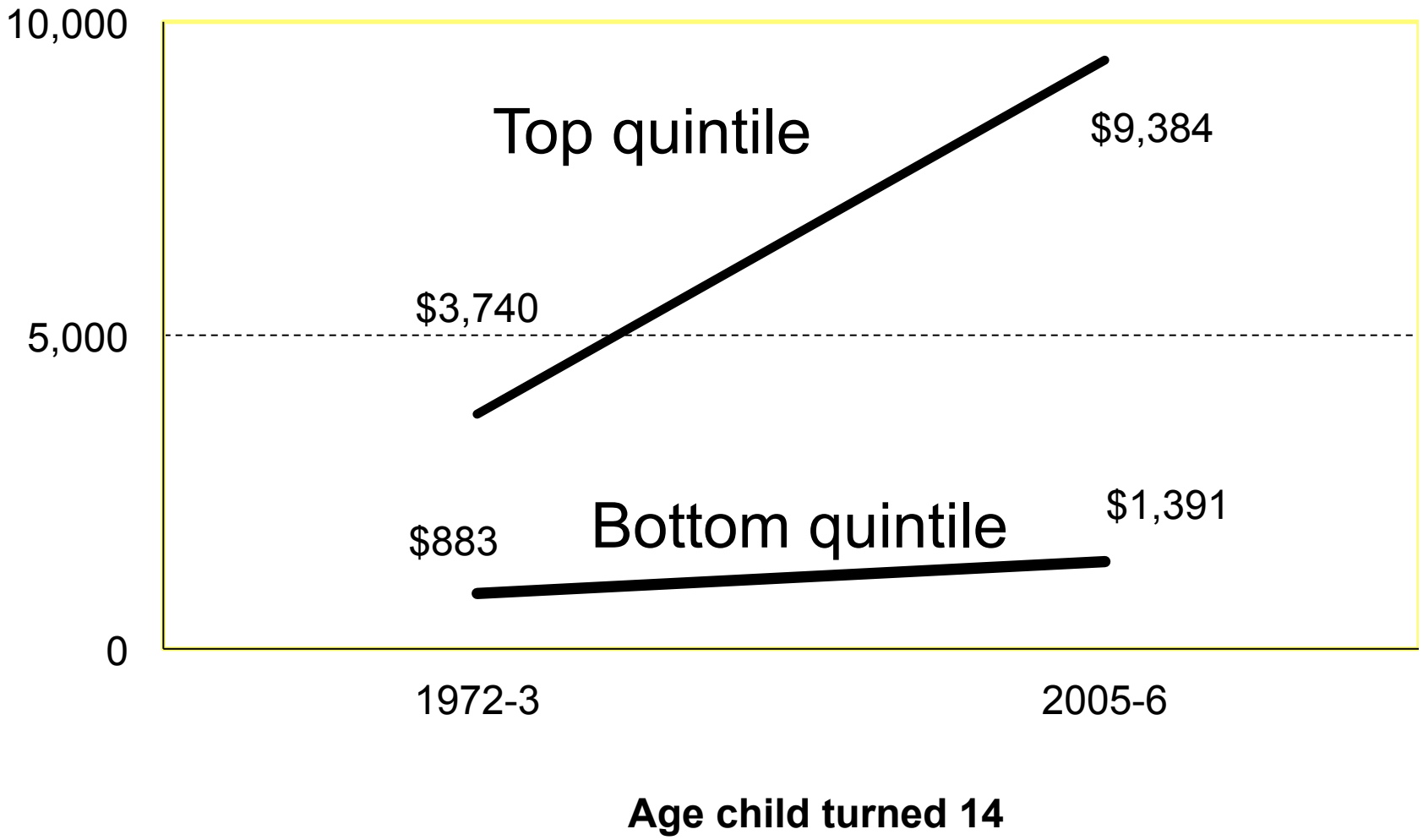
Race and income-based gaps in reading achievement in SAT-type units



Reardon (2011)

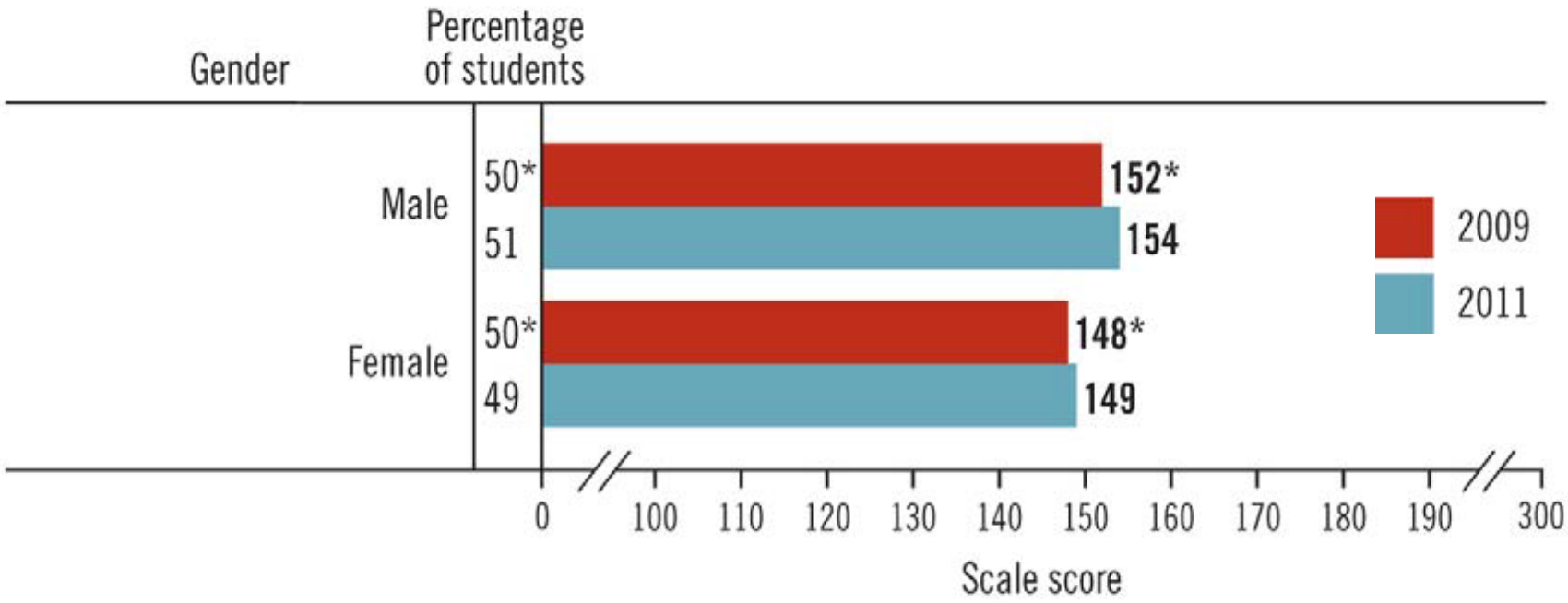
Age turned 14

Family enrichment expenditures

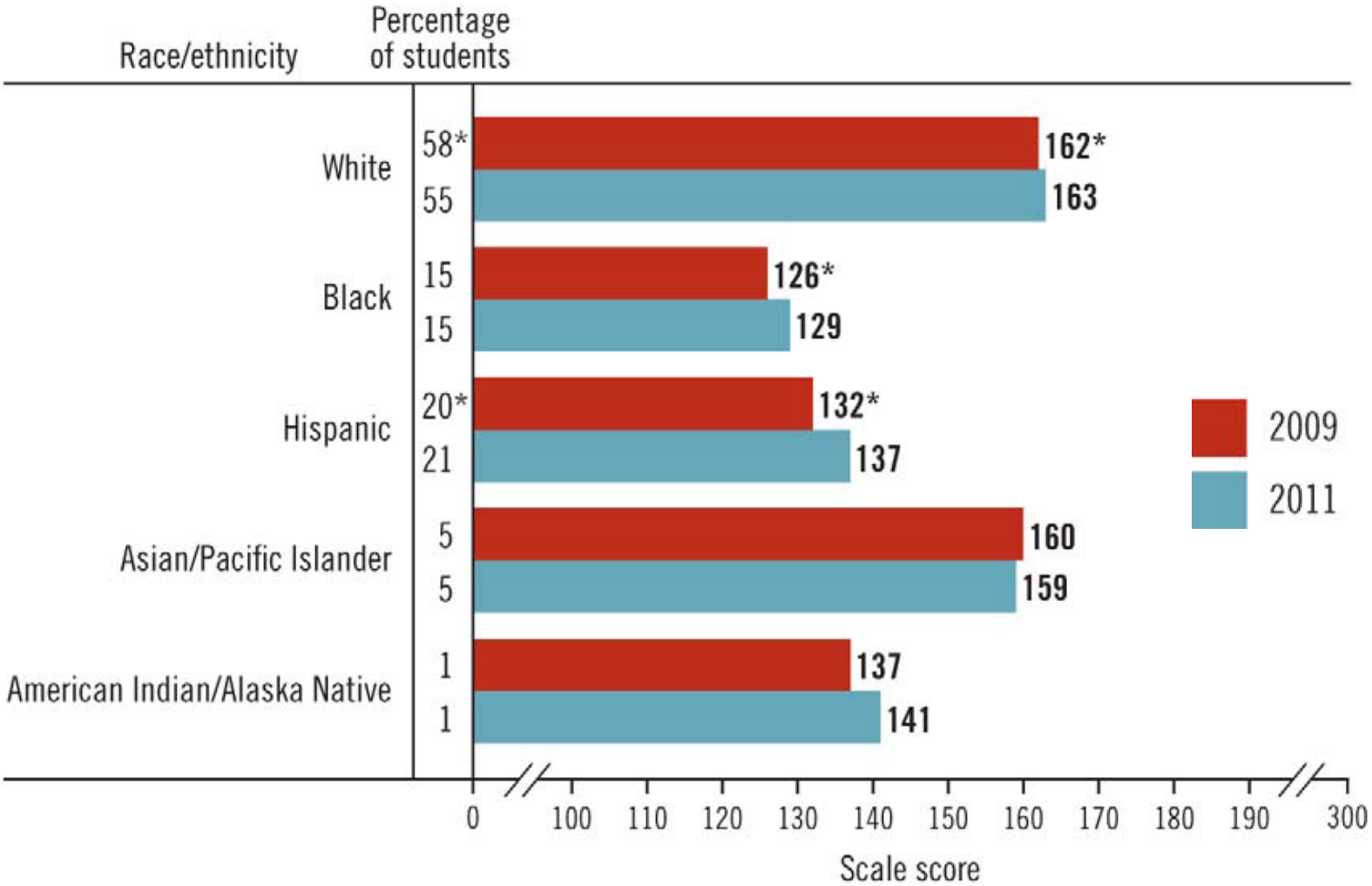


NAEP 8th Grade Science Scores

Percentage of students and average scores by gender

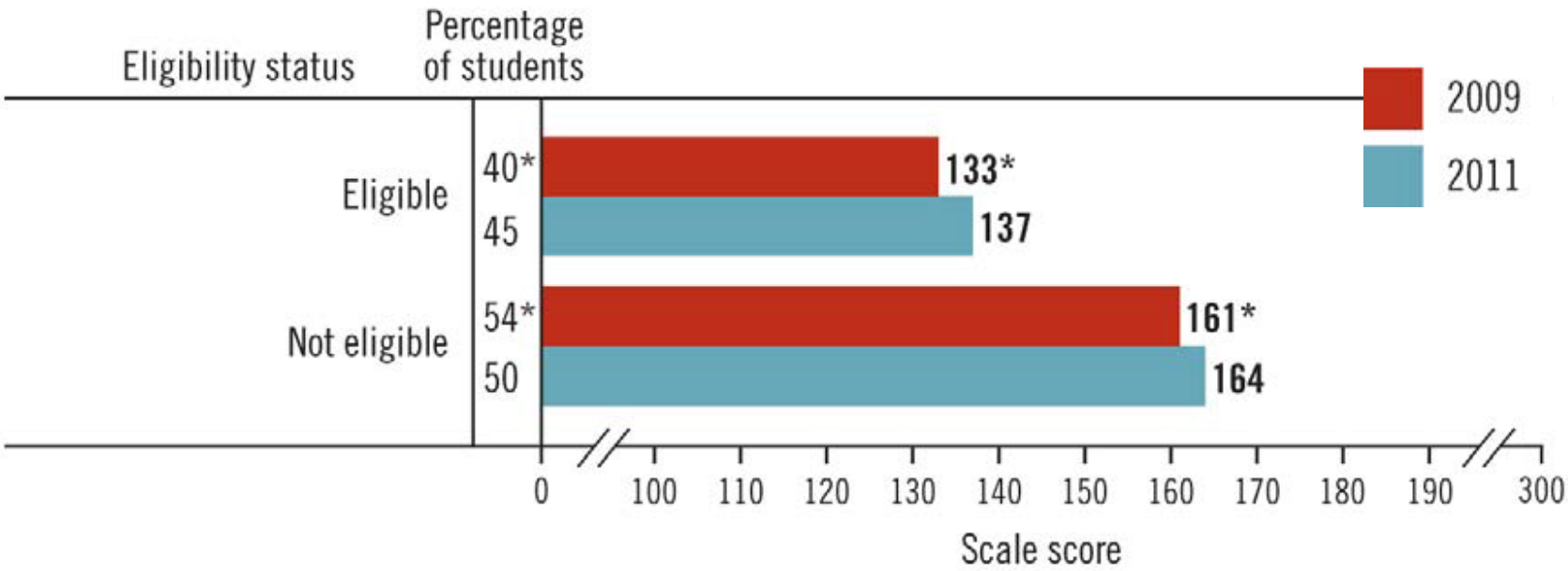


Percentage of students and average scores by race/ethnicity: 2009 and 2011



* Significantly different ($p < .05$) from 2011. NOTE: Black includes African American, Hispanic includes Latino, and Pacific Islander includes Native Hawaiian. Race categories exclude Hispanic origin. Detail may not sum to totals because results are not shown for students whose race/ethnicity was unclassified or two or more races.

Percentage of students and average scores by eligibility for National School Lunch Program: 2009 and 2011



Additional Key Findings

- Students doing hands-on projects or investigations in class more frequently score higher (30% of students do this once or twice a month or less)
- About two-thirds of students work on science projects together at least weekly
- Students who report doing science-related activities that are <u>not</u> for schoolwork score higher

Inequities in Quality of Instruction

- Students in high schools with lower percentages of non-Asian minority students spent more time with hands-on, manipulative or lab work (NRC, 2006).

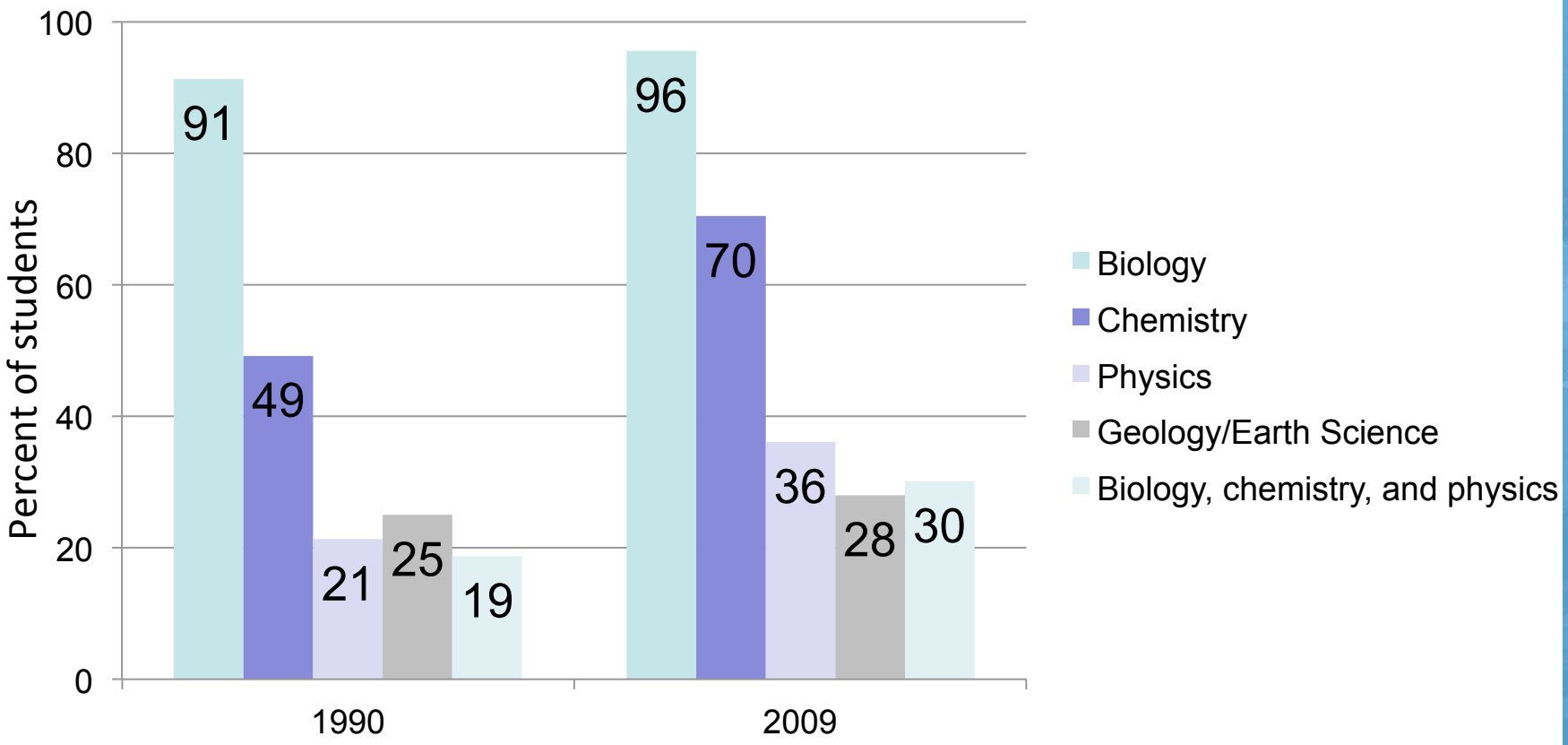
- Teachers in high schools with higher percentages of non-Asian minority students were more likely to engage students in individually reading texts or completing worksheets (NRC, 2006).

Inequities in Teachers' Backgrounds

- Students in high schools with higher concentrations of minority or poor students are more likely to be taught science by a teacher without a major or minor in the subject (US Dept of Ed, 2004).

- Science classes in high poverty schools are more likely than those in low poverty schools to be taught by teachers with 5 or fewer years of experience.

High School Science Course-taking



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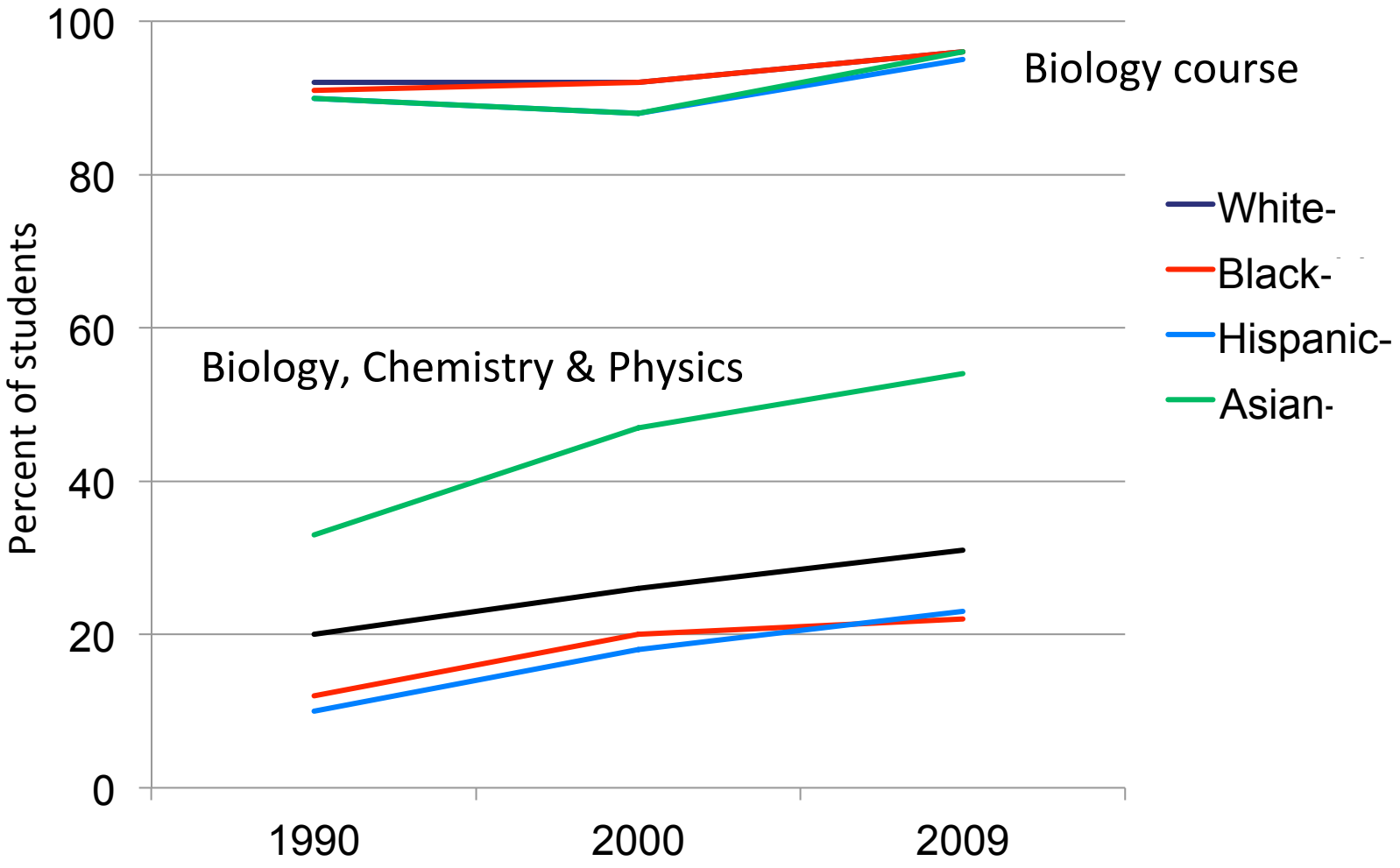
Science course-taking by race/ ethnicity



Inequities in Course Offerings

- Fewer AP courses are offered in schools with higher percentages of low-income students, rural schools and small schools (Horizon Research, 2012).
- Only 66% of schools serving the highest percentages of black and Latino students offer chemistry and only 74% offer Algebra 2 (US Dept of Ed, Office of Civil Rights).

Indicators of Opportunity to Learn*

- Monitoring of professional development
- Documentation of classroom assignments and student work
- Time allocated to science instruction
- Adoption of instructional materials that reflect the NGSS and *Framework*

*NRC (2014). Developing Assessments for the NGSS

As we move forward with implementation – don't forget the last 3 principles!