Problem solving and student thinking in science and math

Abstract reasoning and problem solving are at the heart of understanding scientific and mathematical processes. In fact, some argue that these very thought patterns are part of what makes us human. At the same time, thinking this way is a particularly difficult, learned skill. This session will analyze some of the research-based factors that play into the learning and utilizing of these skills, and open discussion about how to address these in the classroom.

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Disclaimer

I’m more confused about teaching and learning than anyone else I know.

What does it mean to “learn”?

- Gather facts
- Develop skills
- Change previous conceptions
- Be able to apply knowledge to new situations
- Develop a new self identity
- etc.

- Alternative message for today:
  Your learning goals must directly shape what you do in your class.

Dual Process Theory

- We all operate on two levels at the same time:
  - *Analytic processing*
    Logical processes requiring substantial evaluation
  - *Experiential processing*
    Gut processes referring to experience

Conceptual Change Theory

- We structure our knowledge at two different levels:
  - “Phenomenological primitives” -- pieces of experience that we reference quickly and subconsciously
  - “Conceptual frameworks” -- explicitly organized and interconnected pieces of information
  - [And, probably there’s a bunch of stuff in between.]

Isn't this all common sense?

Most of our pre-formed, societal ideas of learning imply:

- Schooling is for facts and skills.
- Knowledge is being poured/written into/onto empty-vessels/blank-slates.
- Learners are logical, hypo-deductive thinkers with nothing else in the way.

Comprehension test

Every Saturday night, four good friends get together. When Jerry, Mike, and Pat arrived, Karen was sitting in her living room writing some notes. She quickly gathered the cards and stood up to greet her friends at the door. They followed her into the living room, but as usual, they couldn't agree on exactly what to play. Jerry eventually took a stand and set things up. Finally, they began to play. Karen's recorder filled the room with soft and pleasant music. Early in the evening, Mike noticed Pat's hand and the many diamonds. As the night progressed the tempo of play increased. Finally, a lull in the activities occurred. Taking advantage of this, Jerry pondered the arrangement in front of him. Mike interrupted Jerry's reverie and said, "Let's hear the score." They listened carefully and commented on their performance. When the comments were all heard, exhausted but happy, Karen's friends went home.

Understanding part of the story . . .

Research Article

Cloudy skies: assessing public understanding of global warming

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Abstract

Surveys show that most Americans believe global warming is real. But many advocate delaying action until there is more evidence that warming is harmful. The stock and flow structure of the climate, however, means "wait and see" policies guarantee further warming. Atmospheric CO_2 concentration is now higher than any time in the last 420,000 years, and growing faster than any time in the past 20,000 years. The high concentration of CO_2 and other greenhouse gases (GHGs) generates significant radiative forcing that contributes to warming. To reduce radiative forcing and the human contribution to warming, GHG concentrations must fall. To reduce GHG concentrations, emissions must fall below the rate at which GHGs are removed from the atmosphere. Anthropogenic CO_2 emissions are now roughly double the removal rate, and the removal rate is projected to fall as natural carbon sinks saturate. Emissions must therefore fall by more than half even to stabilize CO_2 at present record levels. Such reductions greatly exceed the Kyoto targets, while the Bush administration's Clear Skies Initiative calls for continued emissions growth. Does the public understand these physical facts? We report experiments assessing people's intuitive understanding of climate change. We presented highly educated graduate students with descriptions of greenhouse warming drawn from the IPCC's nontechnical reports. Subjects were then asked to identify the likely response to various scenarios for CO_2 emissions or concentrations. The tasks require no mathematics, only an understanding of stocks and flows and basic facts about climate change. Overall performance was poor. Subjects often select trajectories that violate conservation of matter. Many believe temperature responds immediately to changes in CO_2 emissions or concentrations. Still more believe that stabilizing emissions near current rates would stabilize the climate, when in fact emissions would continue to exceed removal, increasing GHG concentrations and radiative forcing. Such beliefs support "wait and see" policies, but violate basic laws of physics. We discuss implications for education and public policy. Copyright © 2002 John Wiley & Sons, Ltd.

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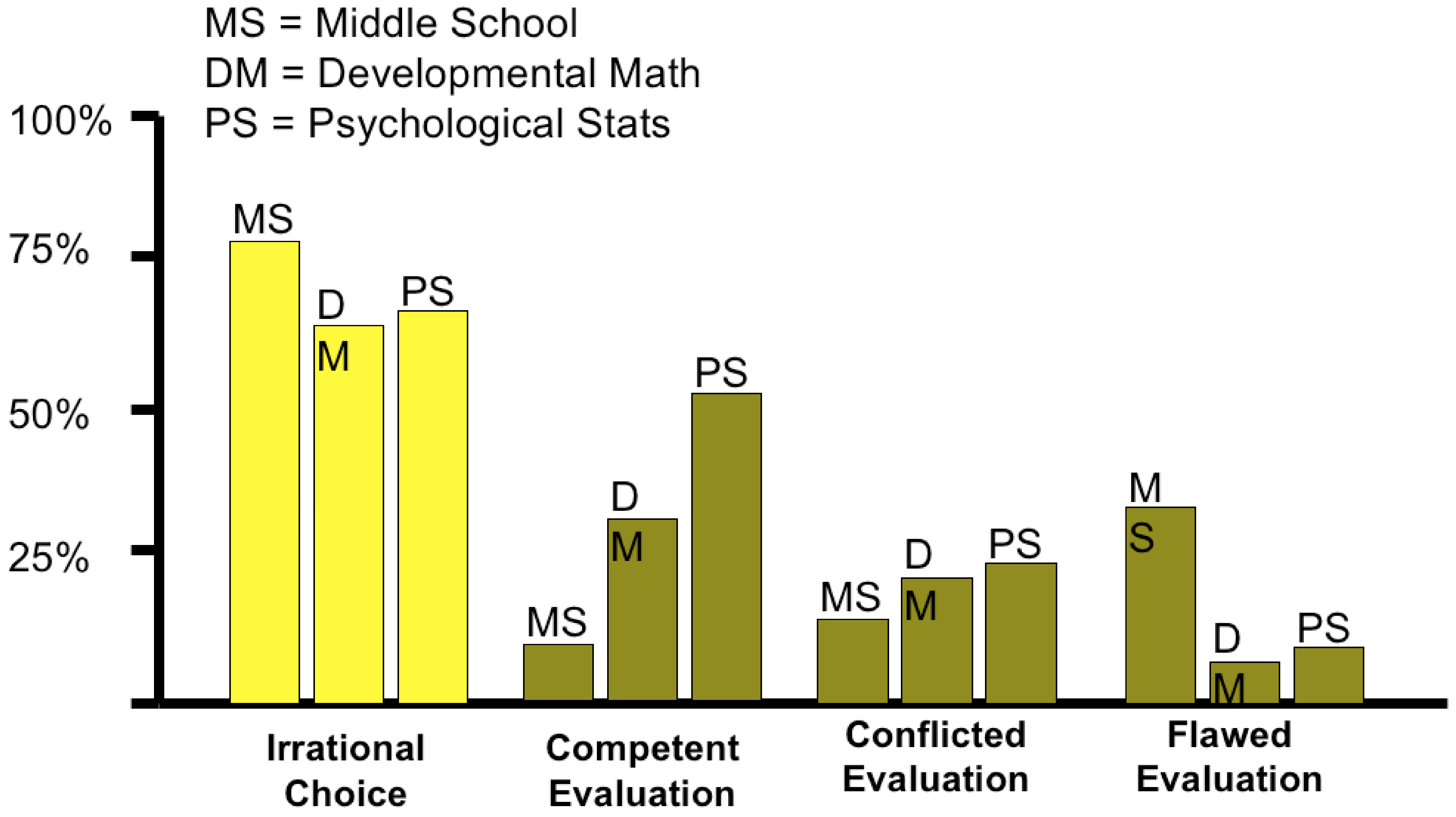
Conceptions of ratio

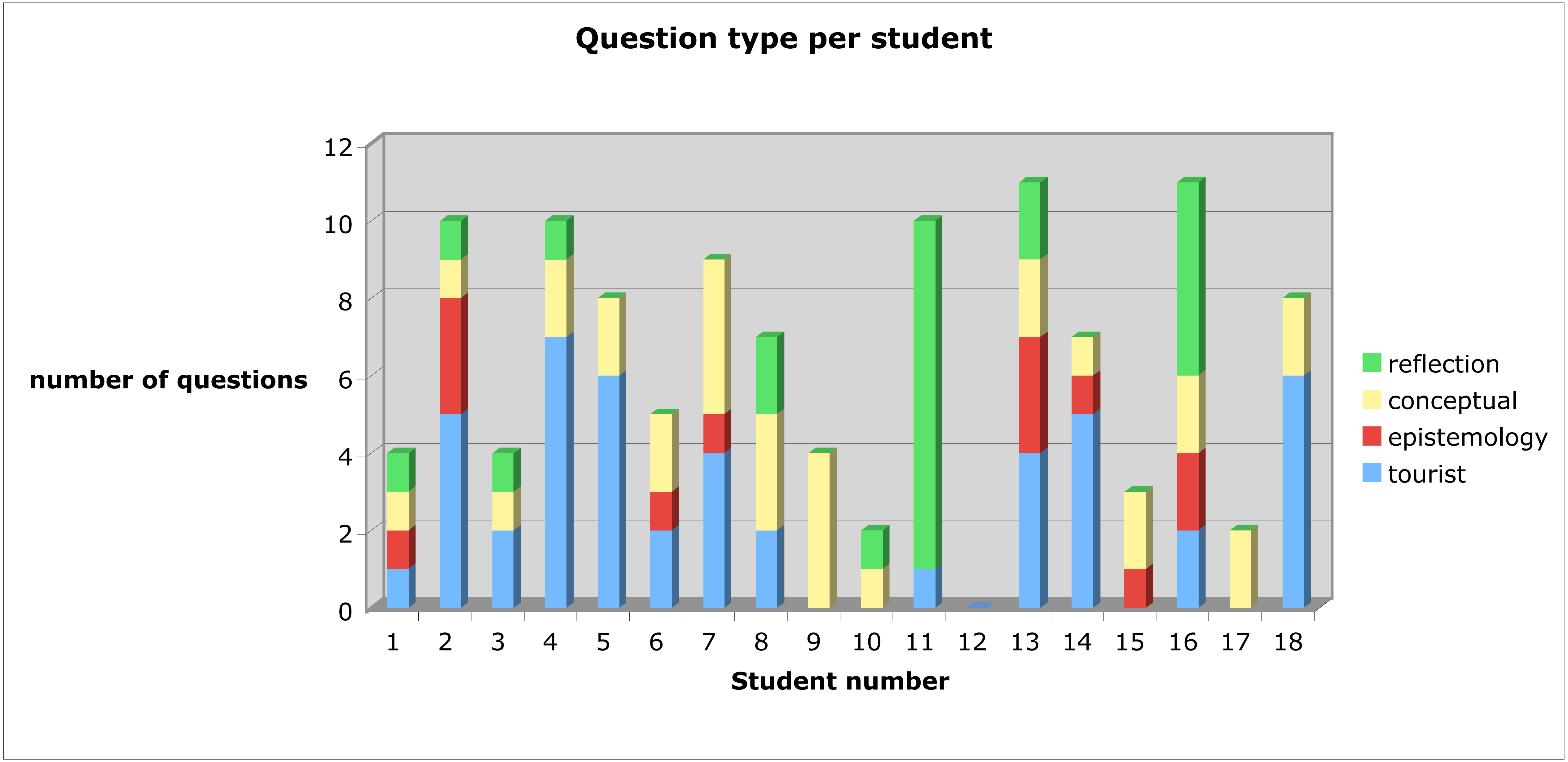
- Students were asked about a preference in gambling: 1/10, 10/100, or no preference [These students were explicitly told that 1/10 is equivalent to 10/100.]
- Students were additionally asked how "rational" their choice was.

Example of dual processing



From Amsel, Close, Sadler & Klaczynski (2005)

Student questions in astronomy



Student questioning

- Students ask questions with the following frequencies in an astronomy course:
    - Course logistics and miscellany (14%)
    - Tourist (35%)
    - Procedural (5%)
    - Conceptual (22%)
    - Epistemological (9%)
    - **Reflective** (15%)

The moral of the story

Physical concepts are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world.

Albert Einstein

- Questions left to consider:
  - How do we help students to shape these “free creations?”
  - How do we accurately represent the process of doing math/science and the process by which we ourselves think about math/science?