Using the Resources of Urban Students and the Results from Physics and Astronomy Research to Enhance the STEM Pipeline in Chicago

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Chicago State University

- Comprehensive, 4-year, minority-serving
- 85% African-American, 70% women
- Average age ~25
- Adding to the pipeline: one of the top producers of BAs
- Nationally, ~1-2 AA PhDs/year in astronomy, 11 in physics, 64 in chemistry
- Focus on addressing student needs BUT ALSO building on strengths

Space Grant at Chicago State

- Student scholarships, student research, tutors/learning assistants, faculty support, travel
- 10 faculty (50% women 60% minority)
- 45 students (55% women, 90% minority)

Kim Coble	Astronomy	Cosmology, education research
Sabrina Bailey	Earth science	Global warming course
Edmundo Garcia	Physics	Particle physics
Valerie Goss	Chemistry	DNA binding on meteorites
Austin Harton	Physics	Detector development
Kristy Mardis	Chemistry	Solar cells and fuel cells
Asare Nkansah	Chemistry	Fuel cells
Felix Rivas	Chemistry	Solar cells
Richard Solakiewicz	Math	Lightning
Laura Trouille	Astronomy	Astronomy education research

The Resources of Urban Students

- Receptiveness to the inquiry style of instruction
  - Easily engage in active learning and peer instruction
  - Appreciate process: elicit, confront, resolve
  - Builds confidence, appreciation, and self-efficacy

  "Since I took this class I feel like if I really study and have a genuine interest I could do better… before I never really had an interest"
- Willingness to be part of a scientific community
  - Knowledge is built through observations and peer discourse
  - Sophisticated group dynamics: highly value peer viewpoints, whether correct or not
- Robust (but hidden) content knowledge
  - Revealed through essay questions, interviews, and videotaping of labs
  - Strong content knowledge but issues that hamper student performance, e.g. student draws correct graph but resists it because it does not feel comfortable

Cosmology Education Research

- An example of developing innovative learning materials based on education research
- Why cosmology?

  "We can use numbers to answer deep questions"
- Why education research?
  - Students enter a course with different mental representations, and these representations can affect their learning.
  - Need to know where the students are in order to take them where we want them to be.
- Test in diverse environments

The Big Ideas In Cosmology Project

- Powerful new cosmological observations and advances in computation and visualization have led to a revolution in our understanding of the structure, composition, and evolution of the universe.
- Gains in cosmological research have been vast but their impact on education has been more limited.
- We are bringing these tools and advances to the teaching of cosmology through two major components:
  - Research on undergraduate learning in cosmology
  - Development of a series of interactive web-based cosmology learning modules

Collaborators

Chicago State University:

Kim Coble

Carmen Camarillo, Virginia Hayes, Melissa Nickerson, Donna Larrieu

K' Maja Bell, Porschoy Brice, Patrycia Hayes, Kathy Flagg, Harold Johnson, Tim Sanders, Henry Swain, Mike Tyler

Florida International University:

Geraldine Cochran

Sonoma State University:

Lynn Cominsky, Kevin McLin, Anne Metevier, Carolyn Peruta

Kevin John, Aurore Simonet, and the NASA EPO group

UNLV (now Temple):

Janelle Bailey, Roxanne Sanchez

Northwestern/Adler/CSU:

Laura Trouille

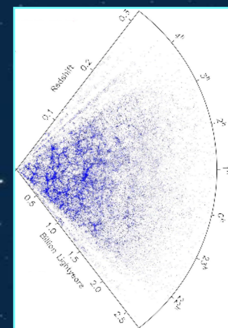
Kendall Hunt/Great River Tech.

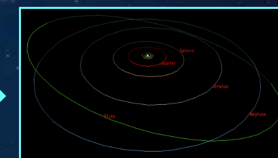
Support from NASA, ISGC, and NSF

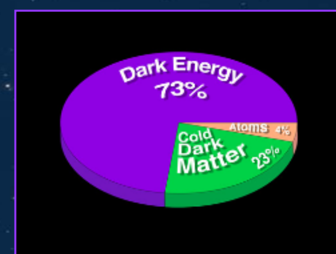
Illinois Space Grant Consortium

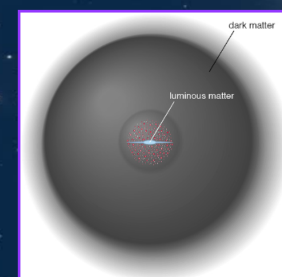
Our Web-Based Learning Modules

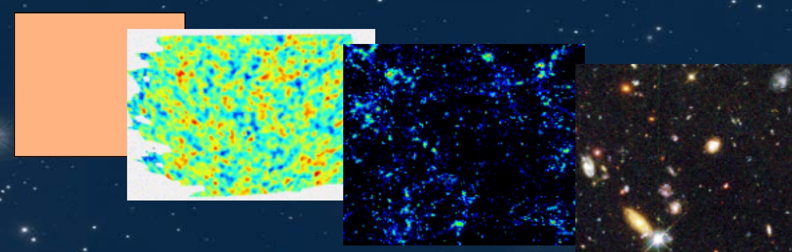
1. Size and Scope
2. Light
3. Telescopes
4. Motion
5. Time
6. Measuring Distances
7. Classical Physics: Gravity and Energy
8. Dark Matter
9. Special Relativity
10. General Relativity
11. Black Holes
12. Gravitational Lensing
13. The Expansion of the Universe
14. Large Scale Structure Formation
15. The Cosmic Microwave Background
16. The Early Universe
17. Dark Energy and the Fate of the Universe









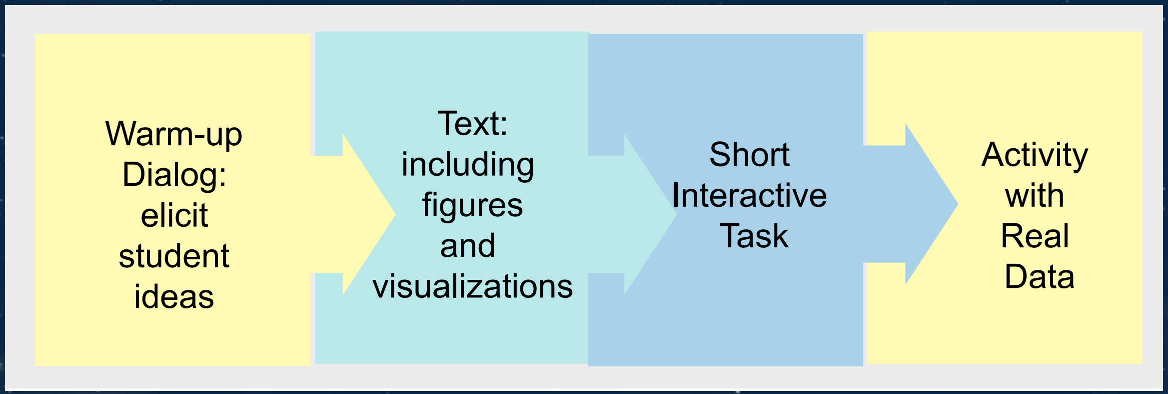


Curriculum Is Informed by Our Data

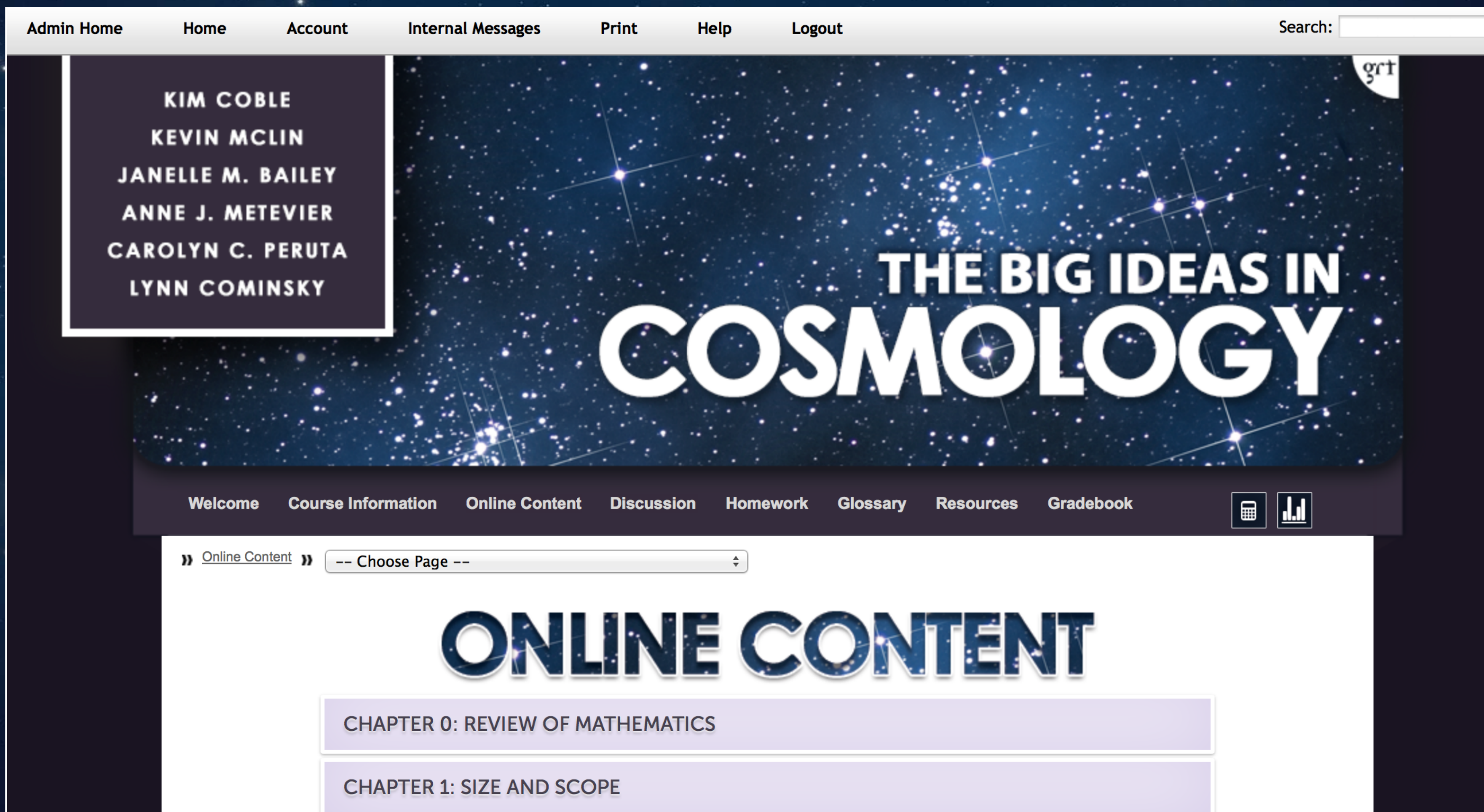
- Multi-institution open-ended written surveys (N = 1270)
  - Pre-instructional
  - Analyzed through iterative coding procedure
- Oral Interviews conducted at CSU (N = 15)
  - Taken throughout the instructional process
- CSU course-specific (N ~ 60)
  - Homework essays, open-ended lab pretests, short and long exam questions, lab comments, lab videotaping
- Targeted areas so far: structure, distances, composition, expansion/age/big bang, interactive engagement
- Future: geometry, fate of universe

Pedagogical Approach

- Move beyond typical curricula, which are mostly text-based with occasional animations or simulations.
- Higher level of learner-centered interactions. Engaging connection to the material, go beyond what has traditionally been possible with textbooks and other passive media such as film.

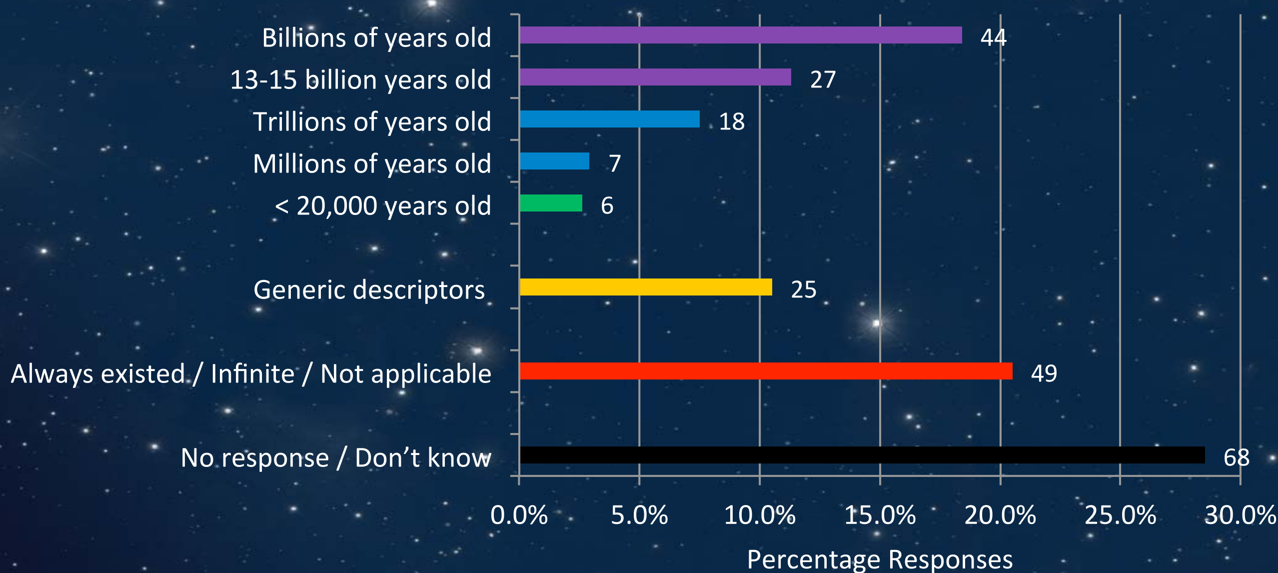


Blueprint of Website



Age of the Universe: Survey Results

- Does the Universe have an age?
  - Yes – 59%
  - No, always existed – 26%
  - NR/contradiction – 15%
- What is the age, if it has one?



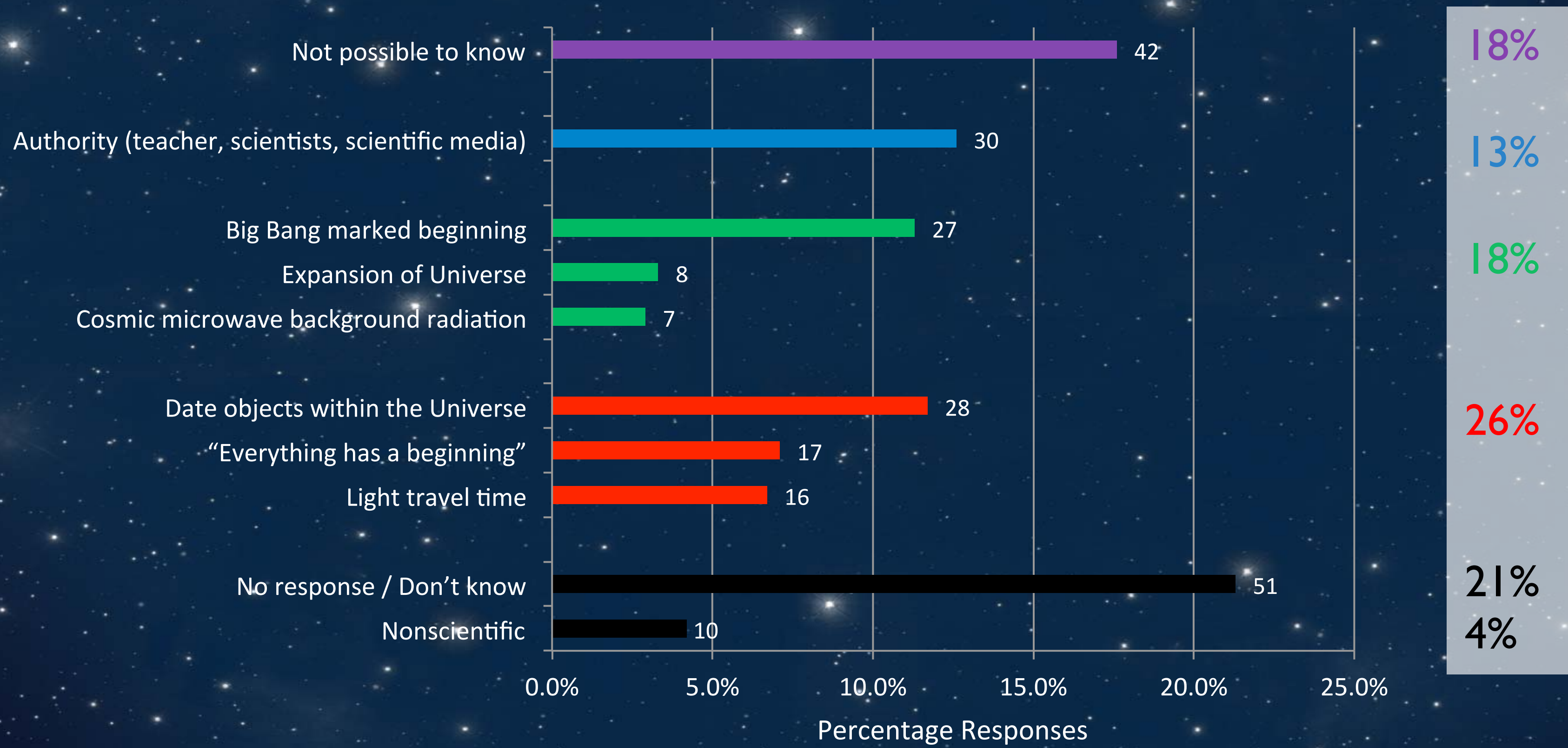
18% billions
11% 13-15 billion

3% < 20,000
11% "hella old"

29% NR

Age of the Universe: Survey Results

- How do we know the age of the Universe?



Age of the Universe: Example

3. Does the universe have an age? If so, what is its age? How do we know?

The universes age is infinity. It has been around longer than we have and dinosaurs. There isn't a way to tell except for scientific hypothesis. But those are not completely based on facts and real evidence.

10/2

Big Bang: Multi-Institution Survey Results

- What is the Big Bang?
  - Explosion – 50%
  - Small point/mass/ball – 18%
  - Collision between objects or particles– 9%
  - Distribution of matter– 10%
  - Beginning of expansion– 9%
  - Creation/formation of:
    - Universe - 33%
    - Solar System– 26%
    - Earth – 11%
    - Life – 8%
  - No response/don't know – 13%

Big Bang: Multi-Institution Survey Results

- What is the evidence for the Big Bang?
  - Expansion – 14%
  - Solar system or planets – 12%
  - Life – 6%
  - Fossils, dinosaur extinction – 5%

  - Authority – 8%
  - There is no evidence for it – 5%
  - "We're here" – 4%

  - No response/don't know – 38%

The Importance of Understanding Data

- Surveys show that students are initially skeptical that e.g. the age of the universe is measurable or that the Big Bang model is supported by evidence
- In interviews, students describe the value of real data and interactive engagement in understanding the material and in changing their beliefs

"Actually, when you told me, I was less inclined to believe it, to tell you the truth… I really didn't understand… At first I thought a lot of scientists kind of sometimes make up facts… I never understood it, so I thought a lot of stuff was made up. … Now I do, now that I saw the calculations. And done it myself."

"We did it during the lab, which was awesome… we took pictures of galaxies and we actually measured them and we recorded them on the graph and we actually came up with real authentic data from real galaxies… it was really real authentic information, so I got a lot from that…"

Big Bang: Interviews

- Students need good visuals to replace incorrect old ideas:

"I've always heard about the big bang theory and how it was this big explosion and that's how the planets and everything else came about… I don't really remember what the actual Big Bang Theory is now, but I do know that I was told otherwise in my new class… I need some kind of visual to explain to me how things work in science."

- Of the students who discuss the Big Bang in the post-instruction interviews, 71% explicitly state that while before taking the class they thought the Big Bang referred to an explosion, they now know that no explosion is involved.
- Two main visualizations that have helped them replace this misconception with a more scientifically accurate view:

"What […] helped me learn it and get a better understanding of it was that whole movie going backwards in time

"I learned from the class the big bang was not that concept [an explosion] – it was more like uh-things beginning to stretch out and the universe is vast and continue to-to expand. That the Big Bang is really not a big bang, it's really a big stretch [referring to the stretchy band used in class to demonstrate the expanding universe]"

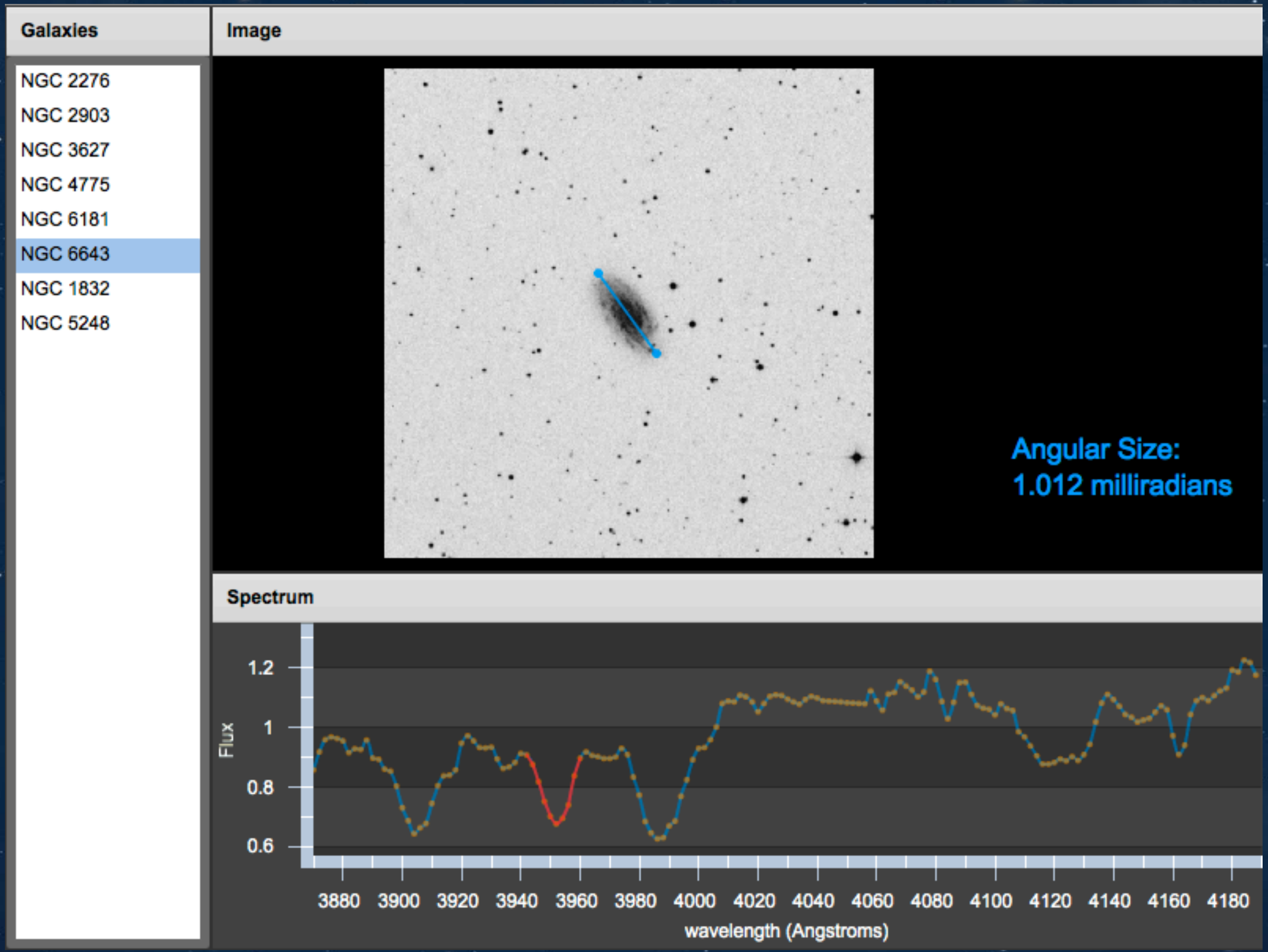
Sample Dialog

Some students are looking up at the stars, discussing the age of the Universe and how we know it.

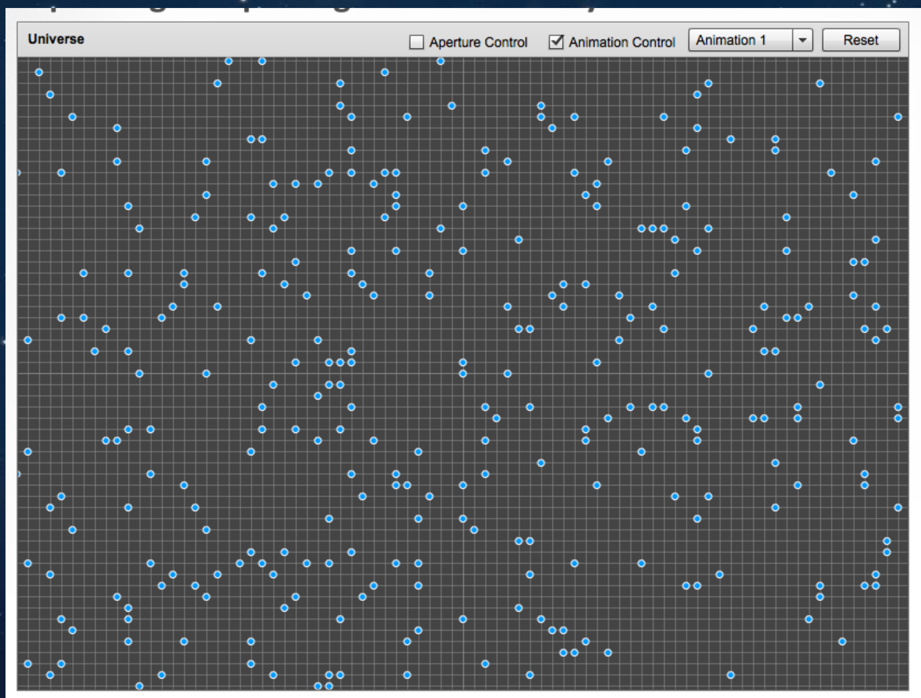
- Monty: "I think the Universe has existed forever. Because it's here and it's always been here."
- Nadine: "I disagree. I think the Universe has an age—it is billions of years old. I just don't know how you would measure it."
- Oscar: "That's because you can't measure it. There is no concrete evidence to establish an age. Nothing other than guessing its age has been done."
- Patti: "I agree with Oscar. We don't have the technology to go far enough out in space. It's not like testing the age of trees. You can't just be like 'oh look at those rings, it's forty years'."
- Quincy: "No, I think you could use carbon dating of fossils."
- Ruby: "Personally, I think the Universe is only a few thousand years old."

Which student(s) do you agree with, if any? Explain your reasoning.

Hubble Law and Age



Expansion vs. Explosion



The Big Bang Theory

Watch the two animations, which each show a region of space and the matter in it. In both animations, the grid lines represent space, and the dots represent matter. You can toggle back and forth between the animations with a pull-down menu. The animation begins when you click on any dot. Reset the animation using the "reset" button. Answer the following questions.

Play Activity | View My Answers

1. In animation #1, how did physical distances between objects that you observed change, if at all?
   - a. The physical distance became bigger.
   - b. The physical distance became smaller.
   - c. The physical distance stayed the same size.

Save & Check | View Answer

6. Which animation shows an explosion?
   - a. Animation #1
   - b. Animation #2
   - c. Both
   - d. Neither

Save & Check | View Answer

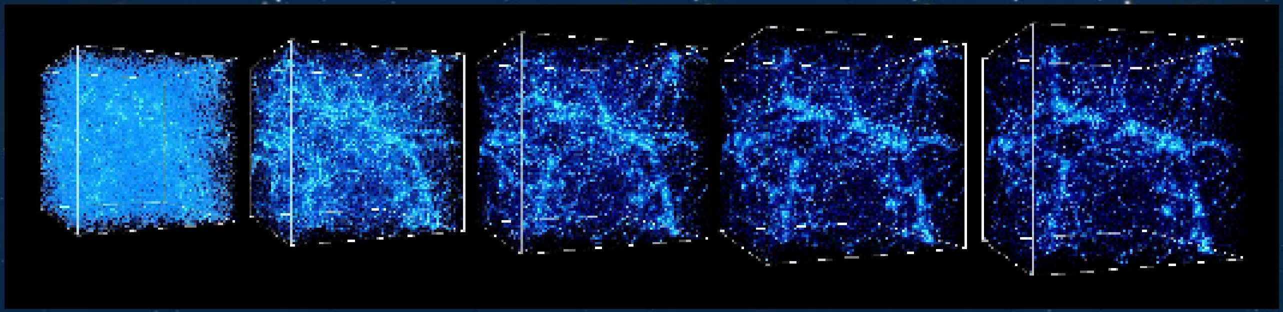
7. Which animation shows an expansion?
   - a. Animation #1
   - b. Animation #2
   - c. Both
   - d. Neither

Save & Check | View Answer

8. Which animation most accurately models how our Universe behaves?
   - a. Animation #1
   - b. Animation #2

Save & Check | View Answer

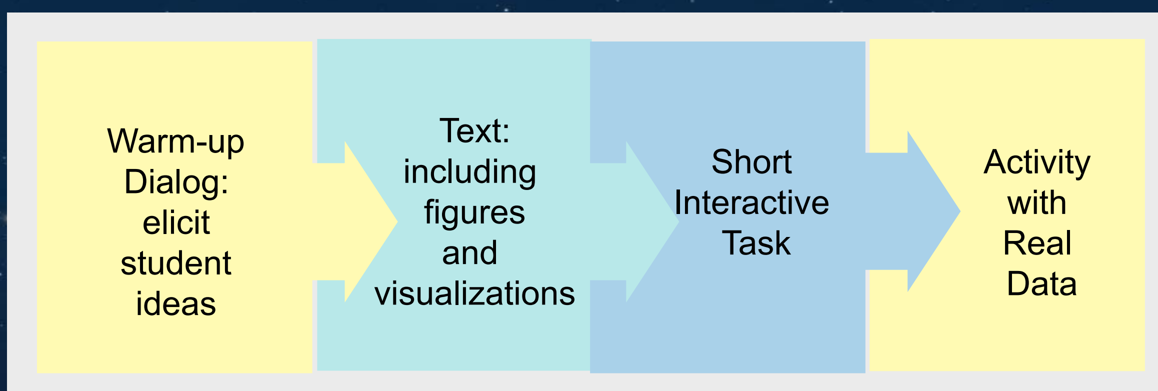
Visualizations: Evolving Universe



- Computer models:
  - Large Scale Structure Formation
  - Galaxy Cluster formation
  - MW Formation
- Compare with data:
  - Hubble Deep Field Fly Through
  - Sloan Digital Sky Survey

Curriculum Is Informed by Research

- Cognitive science: students enter a course with various mental representations, which affect their learning.
- Target conceptual difficulties, build upon strengths.
- Math skills often weak but can be built up with practice: approach conceptually then numerically, make connections.
- Activities involving the analysis of real astronomical data (which often involve using mathematical skills) are important for the believability of results.



Thank You!