A Tool for Evaluating the Effectiveness of Educational Programs in Astronomy: The Astronomy and Space Science Concept Inventory

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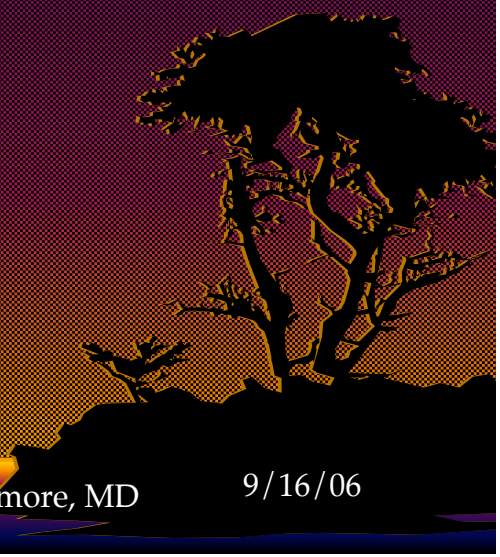
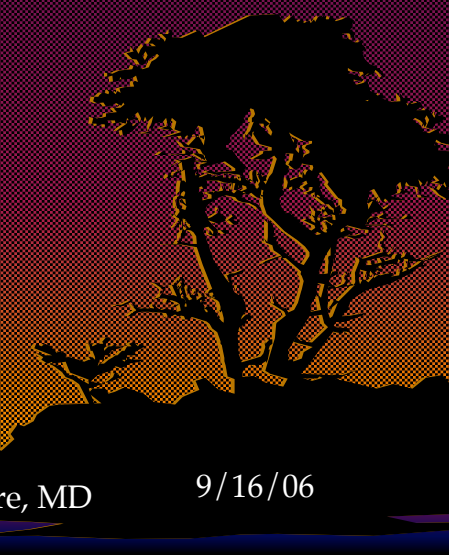
What we will I try to do?

- Characterize experiences in the field of astronomy education and public outreach

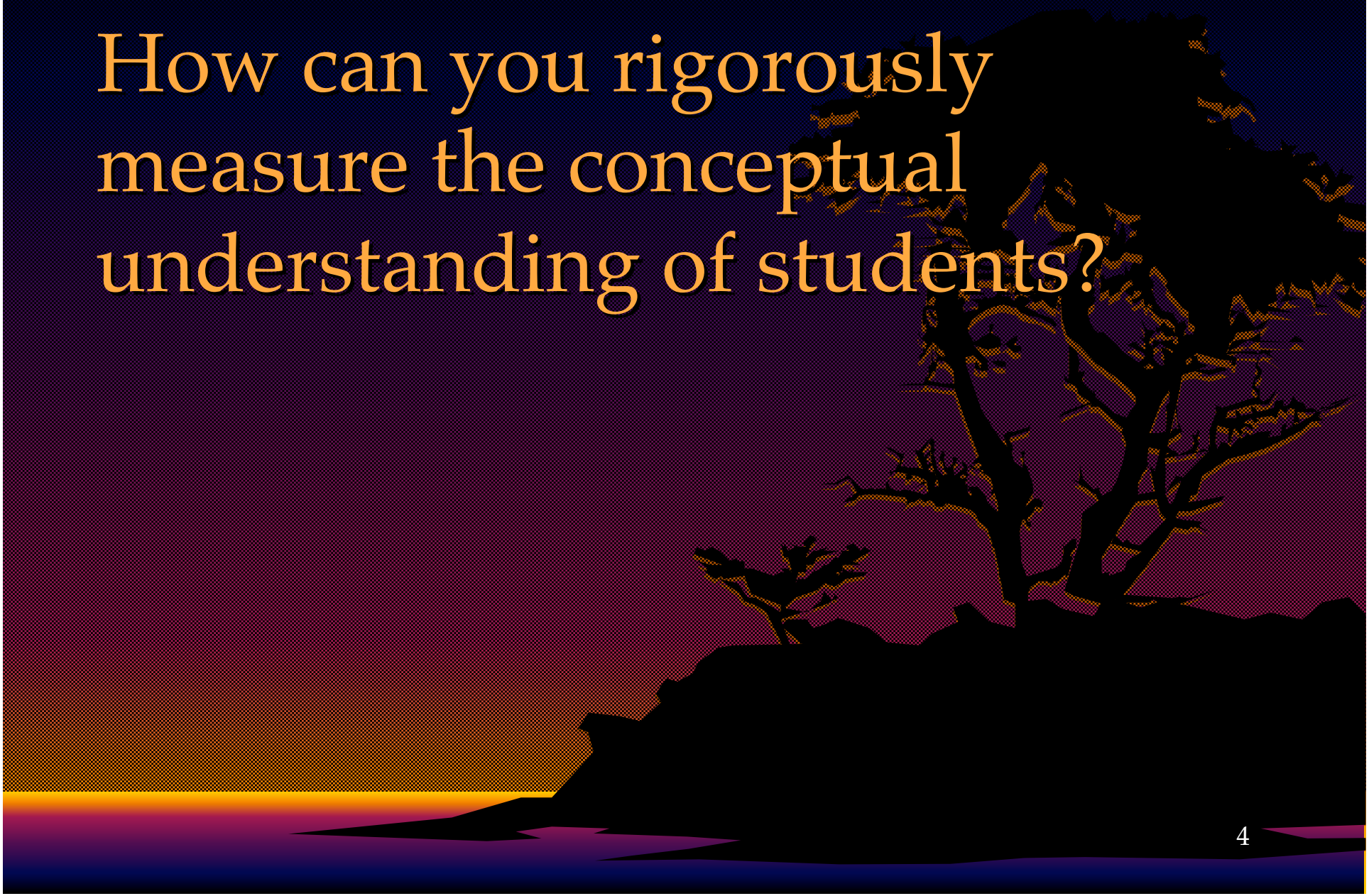


What we will I try to do?

- Characterize experiences in the field of astronomy education and public outreach
- Ground our observations in research results
  - Students, K-14, baseline and gains
  - Teachers, baseline and professional development

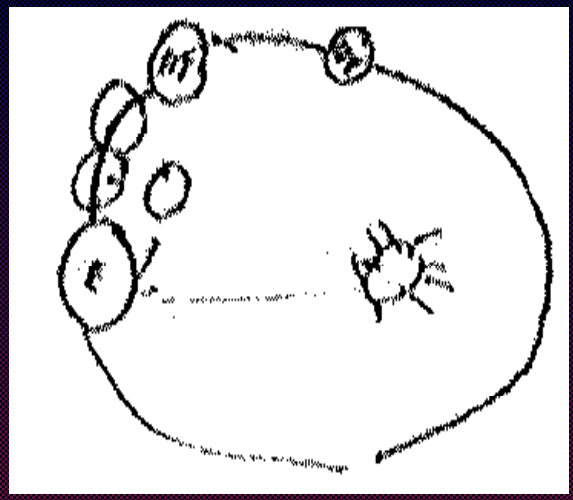


How can you rigorously measure the conceptual understanding of students?



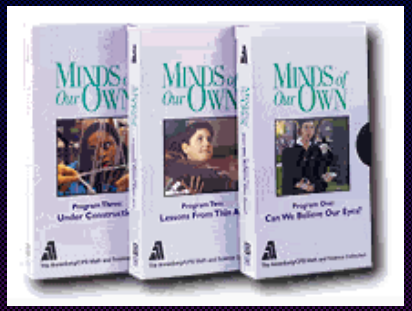
Relevant theory: Cognitive change from preconceptions

- Extensive literature
- Exist prior to instruction
- At odds with accepted scientific thought, "misconceptions"
- Commonly held, not idiosyncratic
- embedded in larger knowledge structures, not just an "error"
- resistant to change

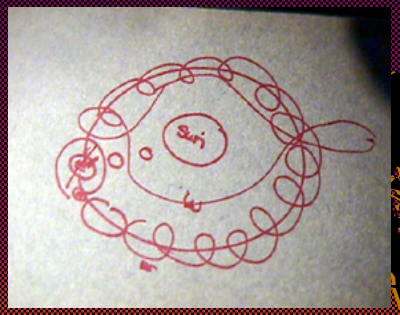


Clinical Interviews

On-on-one with students



Minds of Our Own consists of 3-one hour programs broadcast on PBS in 1997-98. It explores the ideas of students as they come to understand scientific concepts



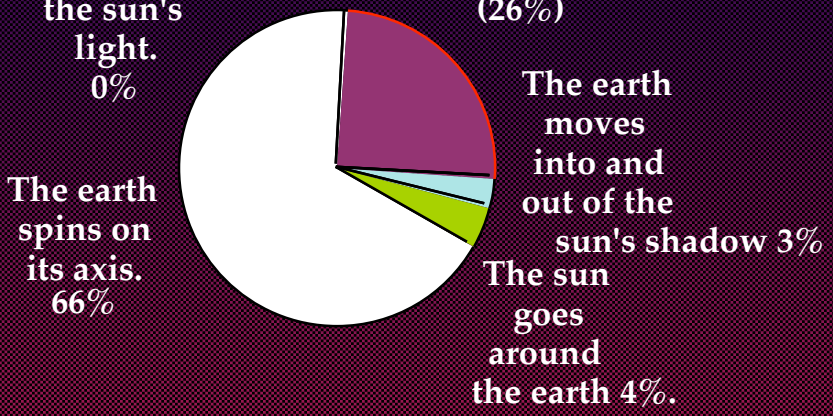
A Private Universe documents students' ideas through their own drawings and explanations

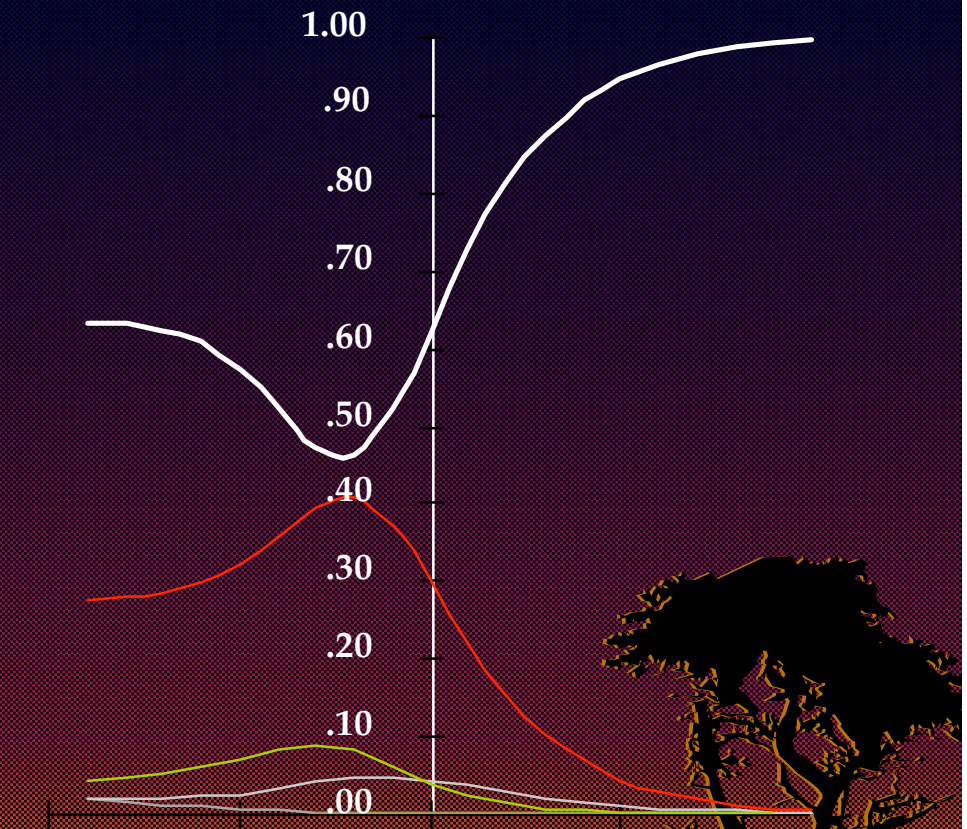
www.learner.org

Development of Multiple Choice Instruments

Study	Year	Domain	Interview	Written	Multiple Choice
Cohen	1982	astronomy	50		
Touger	1985	astronomy	113	99	
Treagust and Smith	1986	astronomy	24	113	
Viglietta	1986	astronomy		25	
Happs and Coulstock	1987	astronomy	25		
Sadler	1987	astronomy	25		213
Dai	1990	astronomy			185
Sadler	1992	astronomy			1414
Zeilk et al	1995	astronomy			228
Zeilik	1998	astronomy			1000
Hufnagel et al	2000	astronomy			1557
Lightman and Miller	1989	cosmology	250		1,111
Gunstone and White trial	1981	gravity		175	
Gunstone and White	1981	gravity		468	
Ogar	1986	gravity			189
Stead and Osborne	1980	light	36	144	
Anderson and Karrqvist	1983	light	21	207	
Anderson and Smith	1986	light	11	125	
Bouwens	1986	light			639

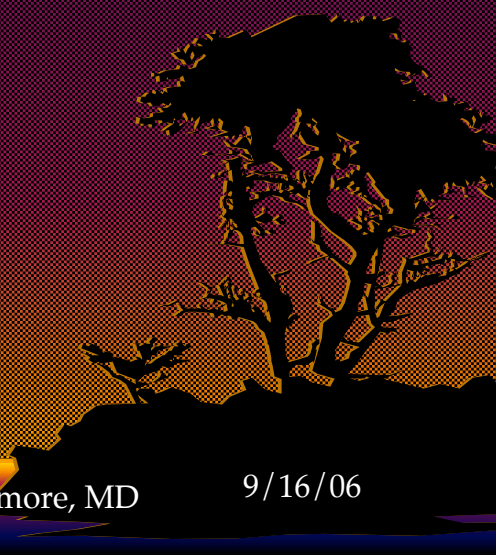
Psychometrics of Misconception Items: Reason for Day and Night





Steps in Generation of Instruments

- Breakdown of Standards or Goals
- Review and Catalog Relevant Literature on Student Conceptions.
  - Carry out additional work when needed
- Item Construction.
- Expert Review and Validation.
- Pilot Testing for Selection of Core Items.
- Test Construction (many forms)
- Calculation of Item Parameters
- Finalization of Instruments.



Astronomy and Space Science Assessment: NRC & AAAS Standards

Sample	Standards	Teachers	Students	Items
Primary	4	49	1879	42 +6 core
Middle School	9	68	3763	100 +6 core
High School	7	64	1958	60 +6 core
Total	20	181	7600	208

Sample Items, Forum Assessment

Primary School K-4

7. If there are no clouds in the sky, how often can you see the Moon at midnight?

a. It can always be seen at midnight. 39%
b. It can usually be seen at midnight. 40%
c. It can be seen at midnight about half the time. 17%
d. It can occasionally be seen at midnight. 4%
e. It can never be seen at midnight. 2%

Teachers' prediction of correct students: 46%

Middle School 5-8

57. Scientists explain that we have night and day because:

a. the Sun goes out. 4%
b. the Earth moves around the Sun. 37%
c. clouds block out the Sun's light. 3%
d. the Earth turns on its axis. 45%
E. the Sun goes around the Earth. 10%

Teachers' prediction of correct students: 76%

High School 9-12

200. In order for scientists to detect distant objects in space, electromagnetic radiation must:

a. reach a detector. 21%
b. be converted into matter. 9%
c. be converted into light. 21%
d. be converted into radio waves. 38%
e. be converted into energy. 10%

Teachers' prediction of correct students: 48%

Middle school Standard 5-8, All Students Answered

137. Which answer shows the most accurate pattern of the three objects in order from closest object to the Earth to farthest from the Earth?

a. Space Shuttle in orbit → Stars → Pluto xxx
b. Pluto → Space Shuttle in orbit → Stars
c. Stars → Space Shuttle in orbit → Pluto
d. Stars → Pluto → Space Shuttle in orbit
e. Space Shuttle in orbit → Pluto → Stars

Teachers' prediction of correct students: 41, 53,96

K-4 Standards

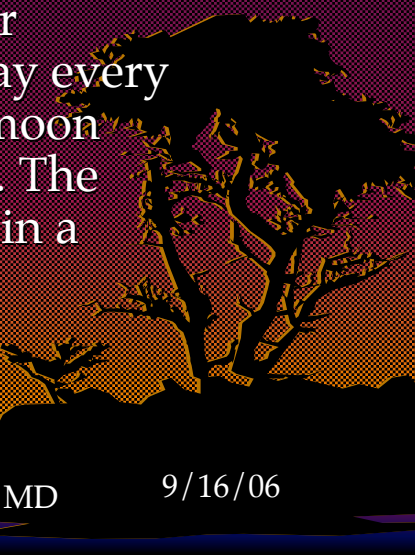
OBJECTS IN THE SKY

The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.

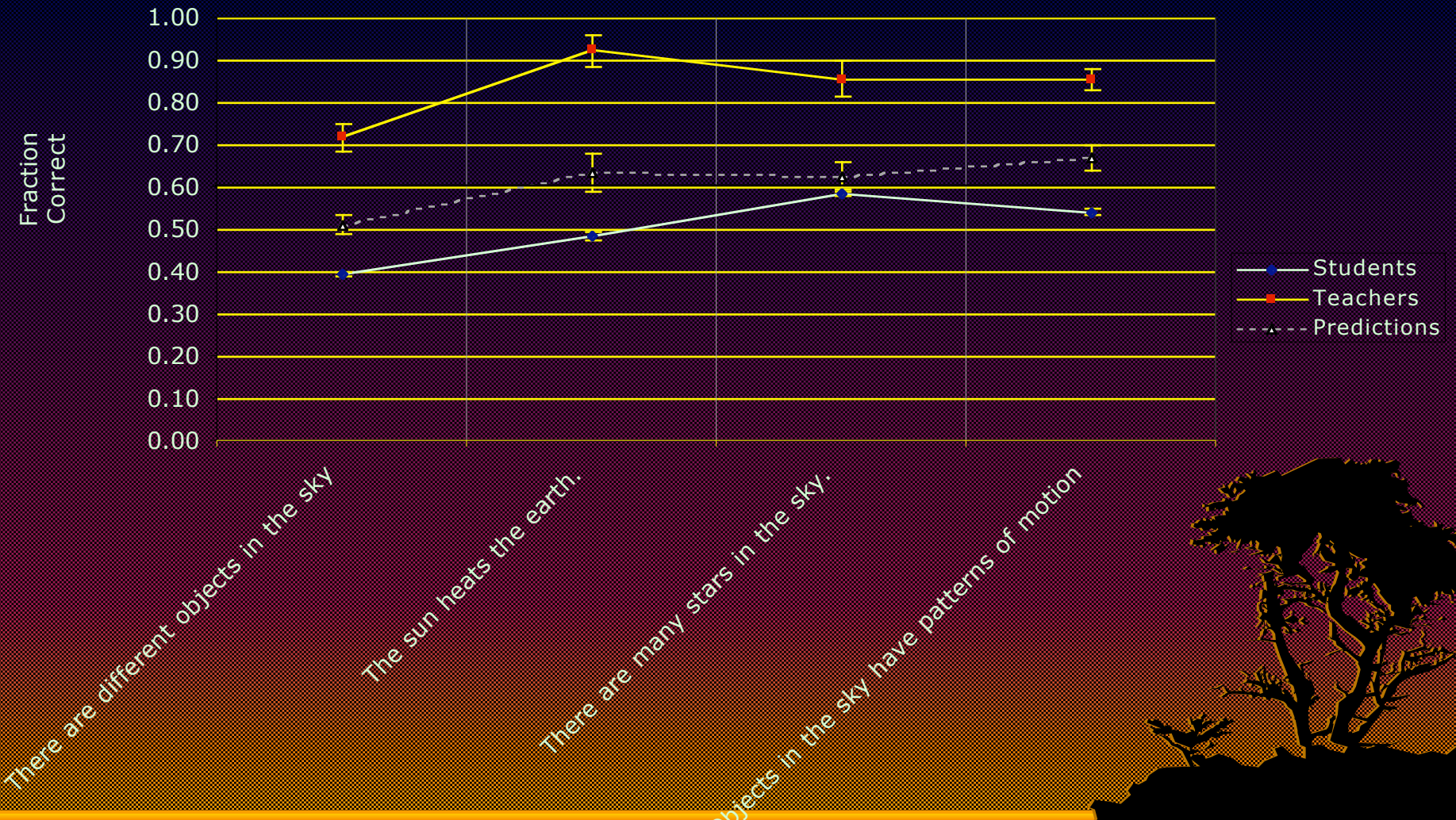
The sun provides the light and heat necessary to maintain the temperature of the earth.

CHANGES IN THE EARTH AND SKY

Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.



Grade 5,6 Teacher and Student End-of-Year Results



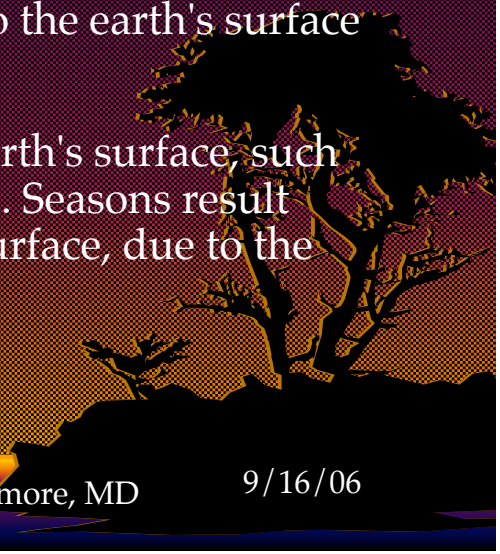
K-4 Common Student Misconceptions

- The moon can be closer than the clouds
- Period of the moon's phases
- The moon is never gibbous*
- Seasonal changes in daylight
- the North Star cannot be seen all night*
- All stars are white
- The apparent movements of stars and moon*
- Role of the sun in heating the earth.

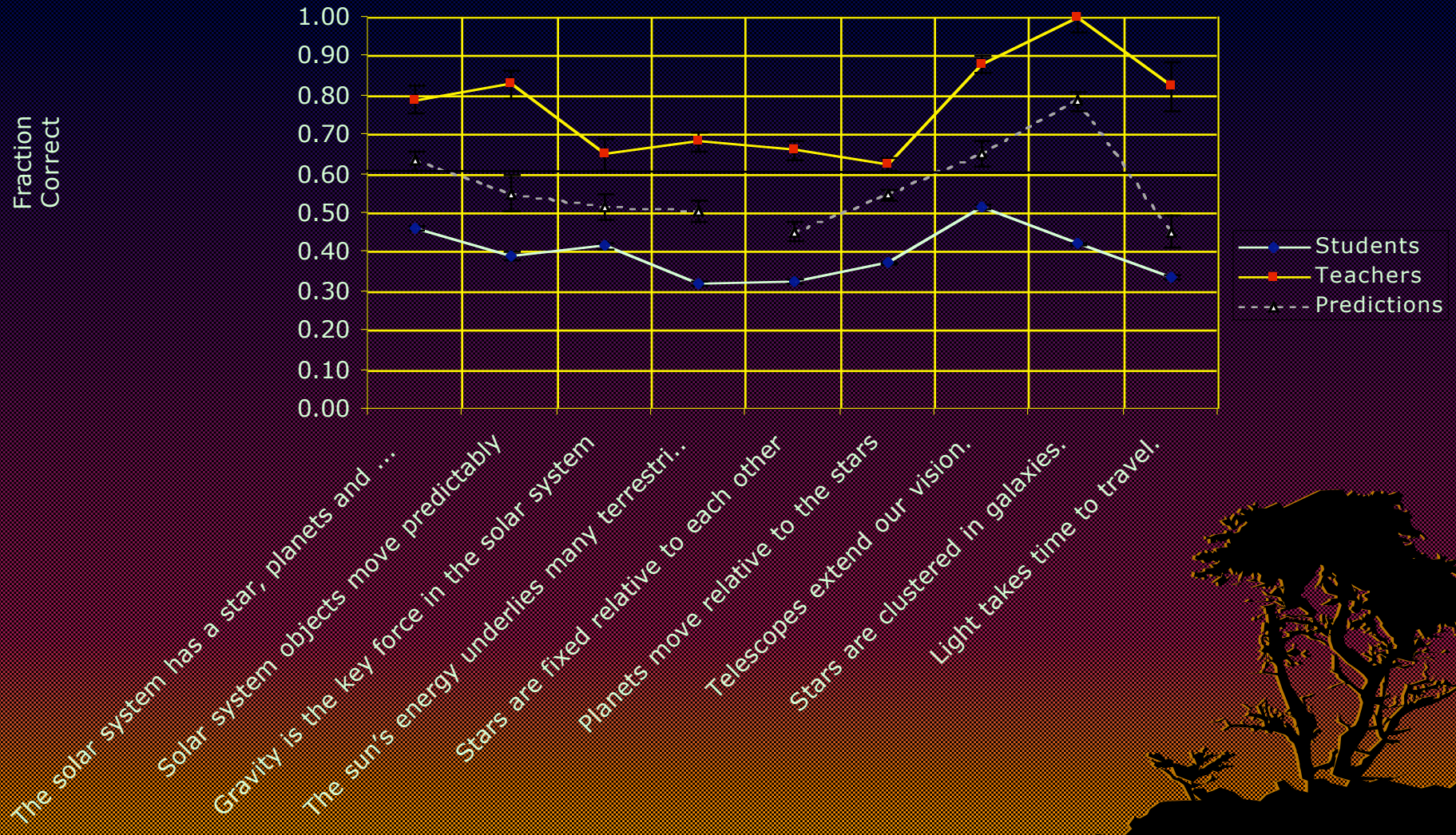
*common teacher misconceptions

5-8 Standards

- ***EARTH IN THE SOLAR SYSTEM***
  - The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.[See Unifying Concepts and Processes]
  - Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.
  - Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system. Gravity alone holds us to the earth's surface and explains the phenomena of the tides.
  - The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.



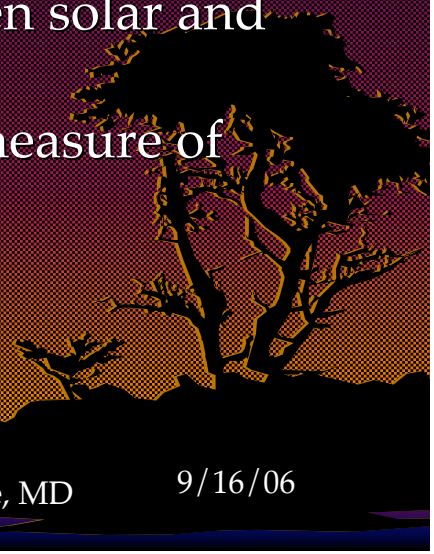
Grade 7,8 Earth Science Course Teacher and Student Results



5-8 Common Student Misconceptions

- Asteroids are not part of the solar system
- The sun is not a star and not a member of the solar system
- There are many stars in the solar system
- Stars are closer than Pluto
- The earth's orbit is highly elliptical.*
- Day/Night results from the earth's orbit
- The earth turns on its axis once a year
- There is no gravity in space*
- Plants role in oxygen on earth
- Star patterns are not constant
- Planets do not move in the sky in a year*
- Telescope only allow you to see farther (not dimmer)
- Galaxies are in the solar system
- Difference between solar and lunar eclipses*
- A light year is a measure of time

*common teacher misconceptions



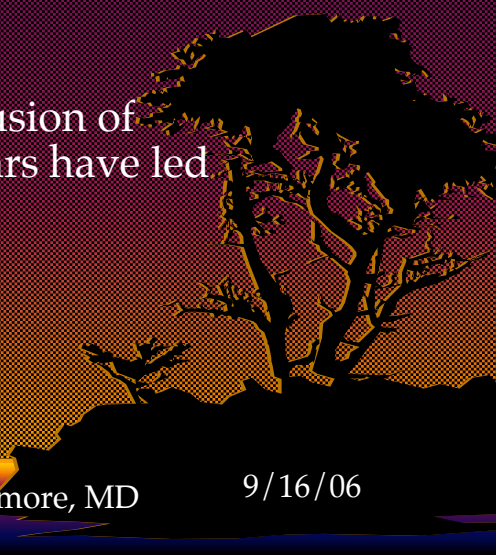
9-12 Standards

THE ORIGIN AND EVOLUTION OF THE UNIVERSE

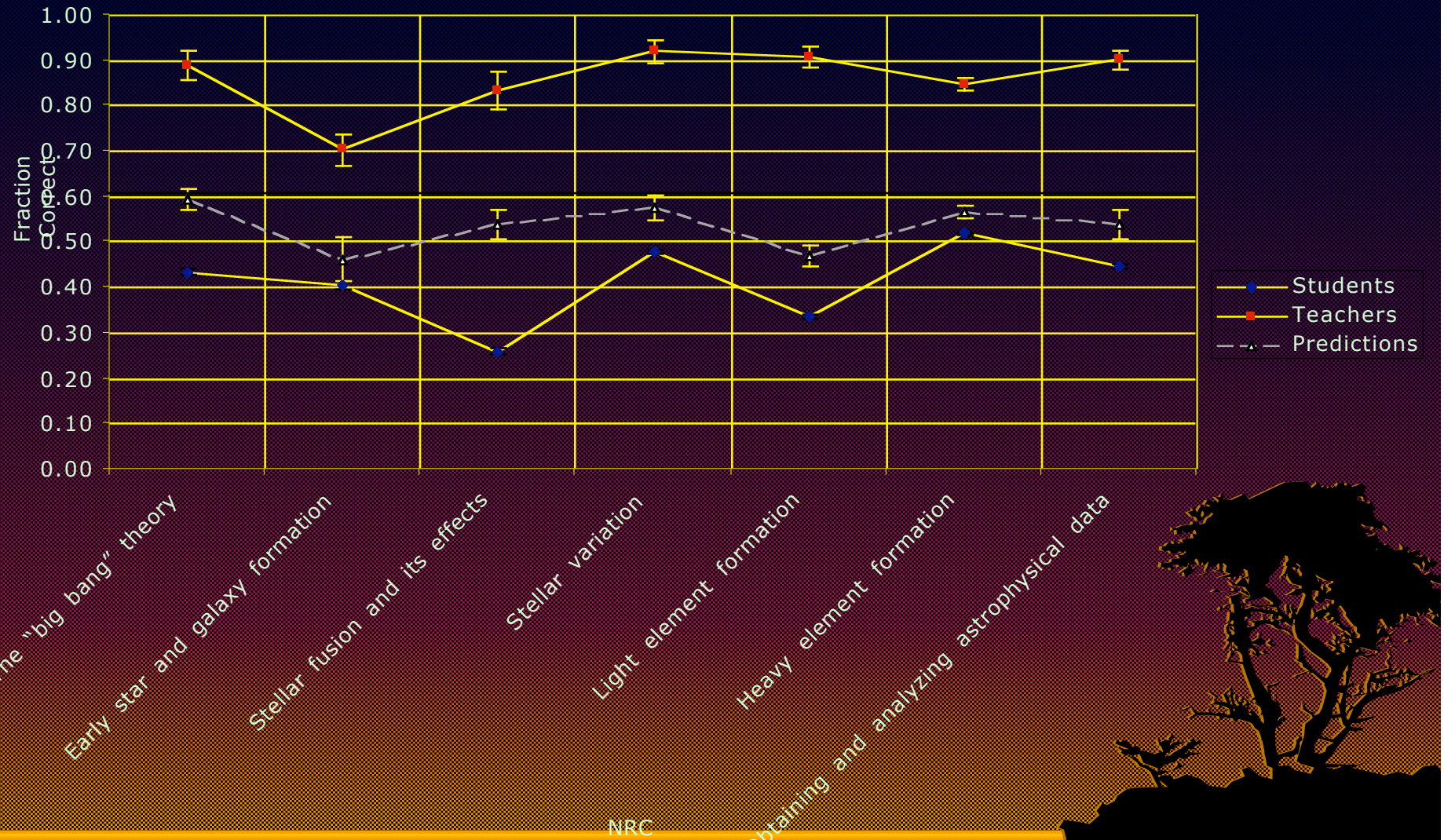
The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since. [See Content Standard A (grades 9-12)]

Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.

Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.



Grade 9-12 Astronomy Course Science Teacher and Student Results

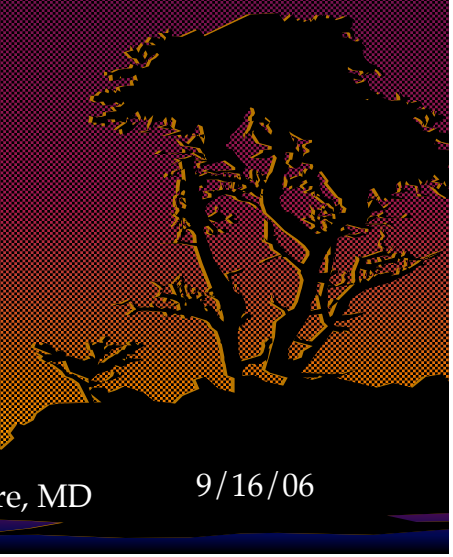


9-12 Common Student Misconceptions

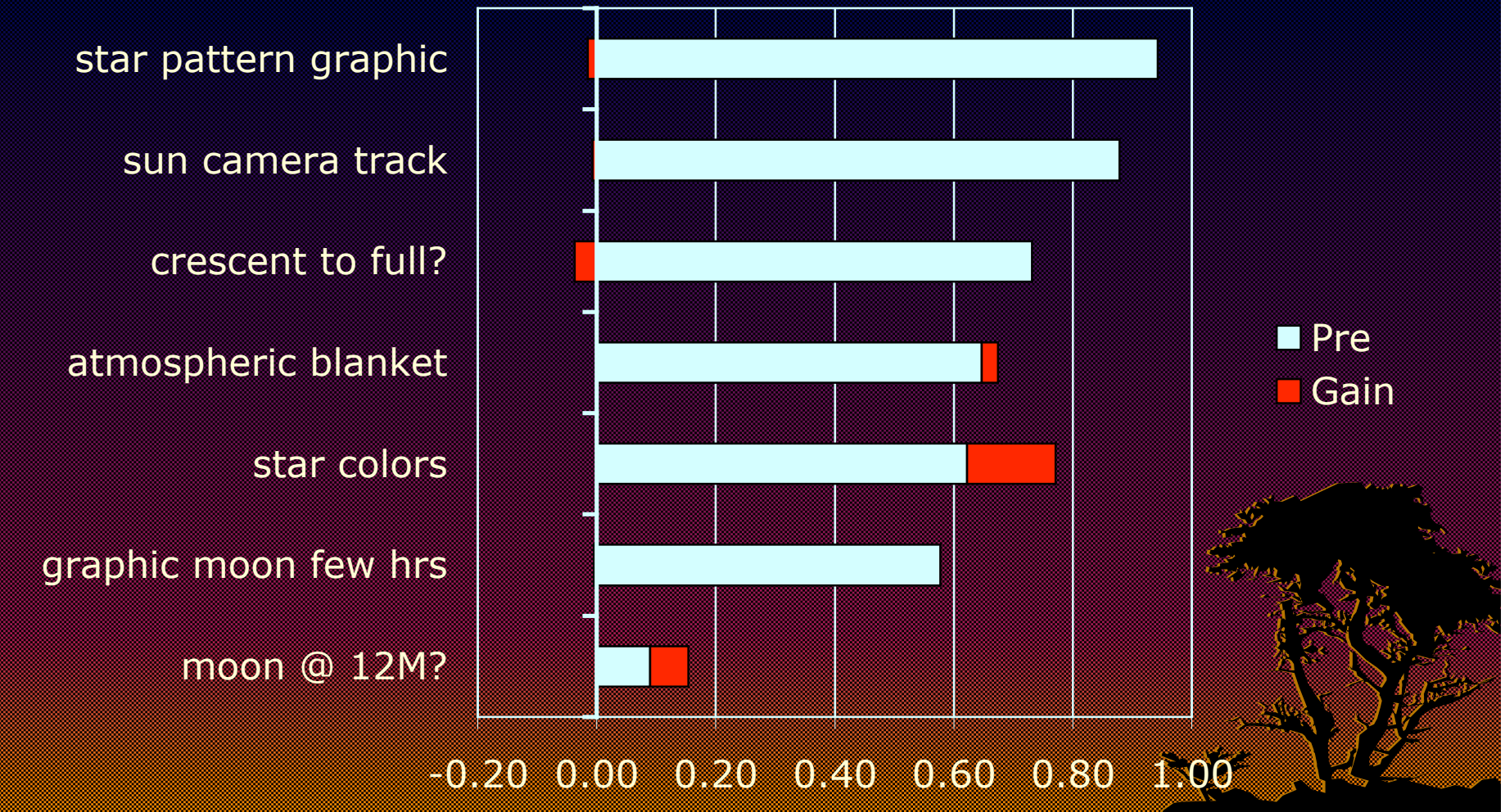
- The big bang created our solar system and all elements
- Galaxies are held together by electromagnetism (not gravity)
- The universe is getting hotter
- Probes have brought back samples from many planets
- Astronauts have gone beyond the moon
- Red light is the most energetic
- Telescopes are put in space to get closer to astronomical objects

Patterns

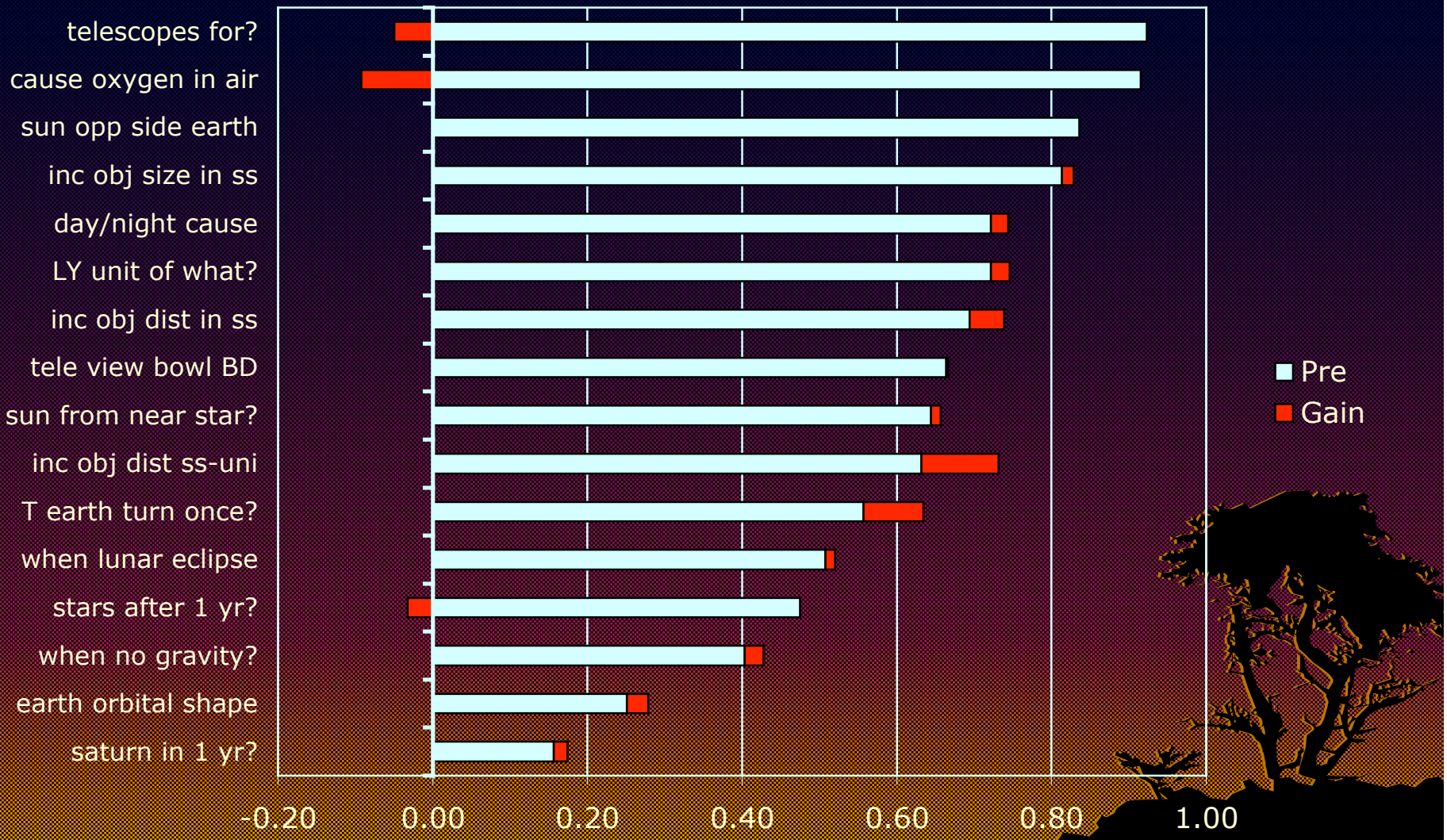
- For each standard at each level
  - Students have not achieved mastery
  - Teachers overestimate student knowledge, but do not expect mastery by the end of their courses
  - Teachers know much more than their students



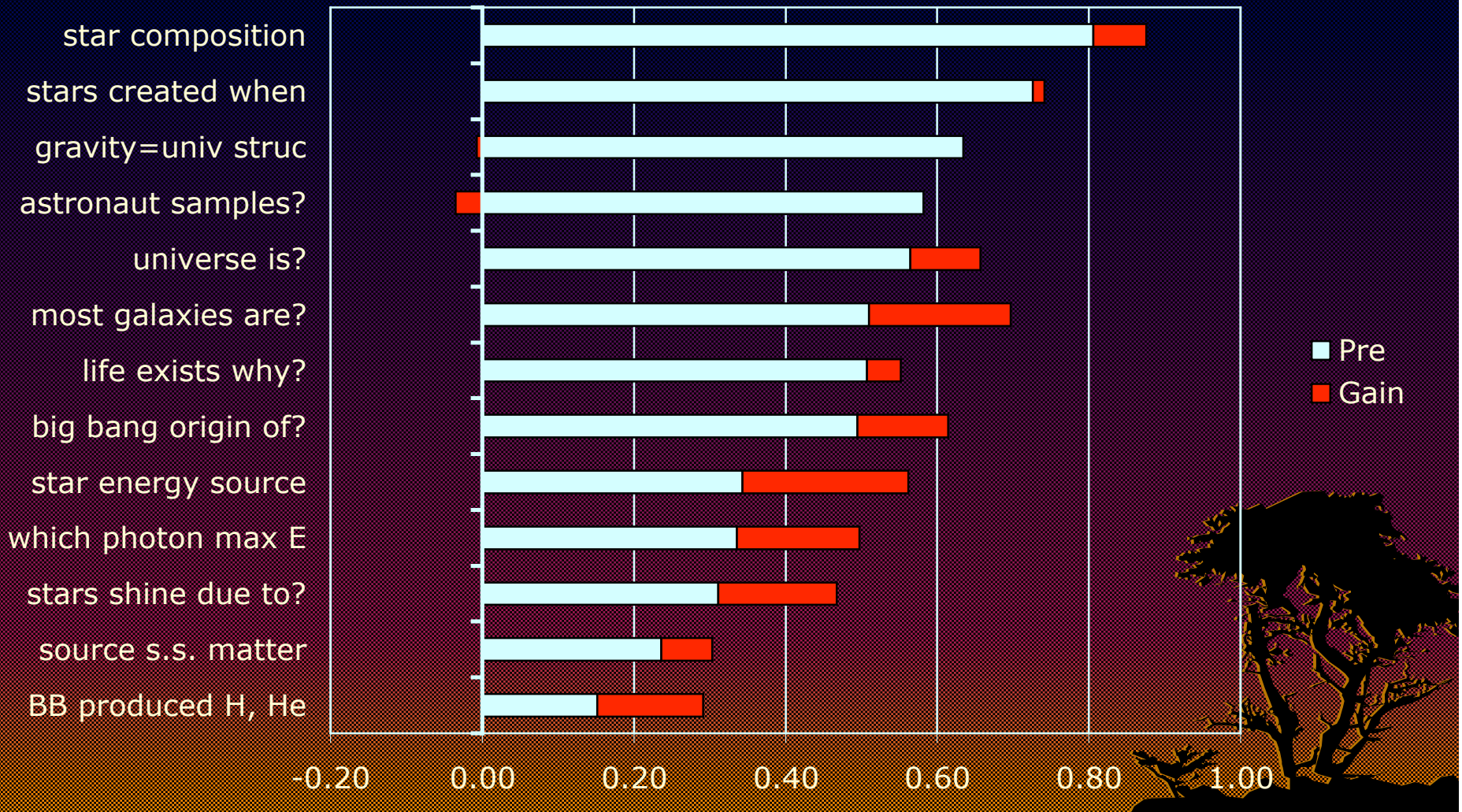
High School and College Astronomy Students' Gain: Elementary School Standards



High School and College Astronomy Students' Gain: Middle School Standards

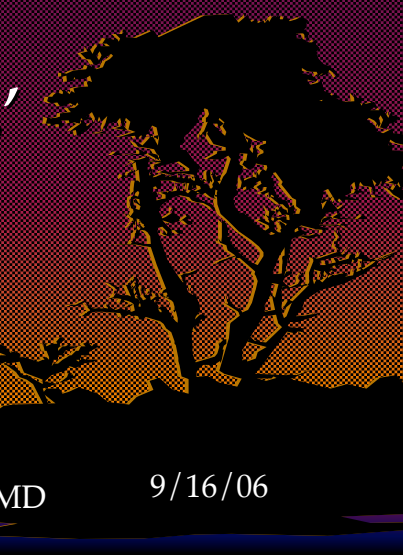


High School and College Astronomy Students' Gain: High School Standards

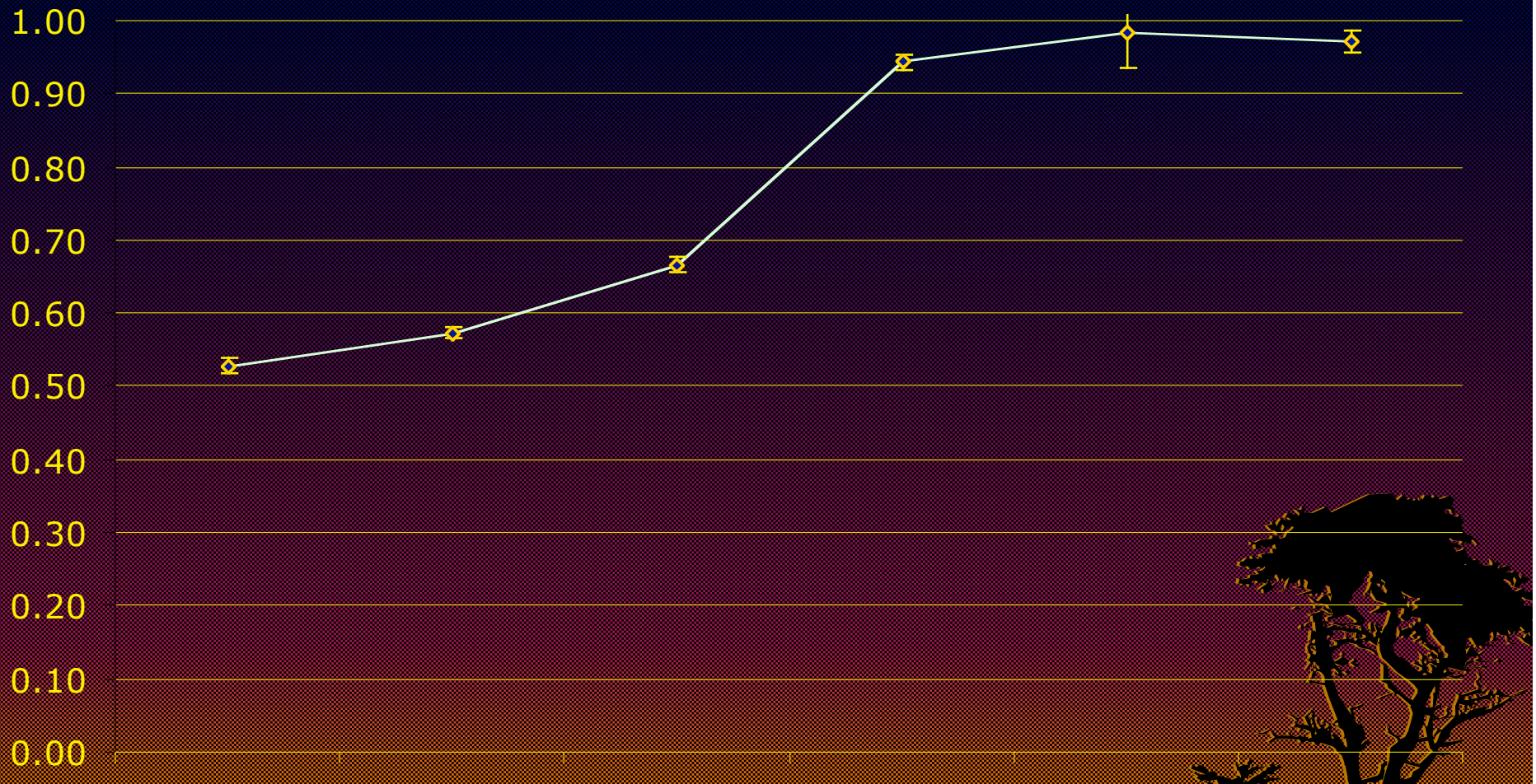


Analysis Between Grade Bands

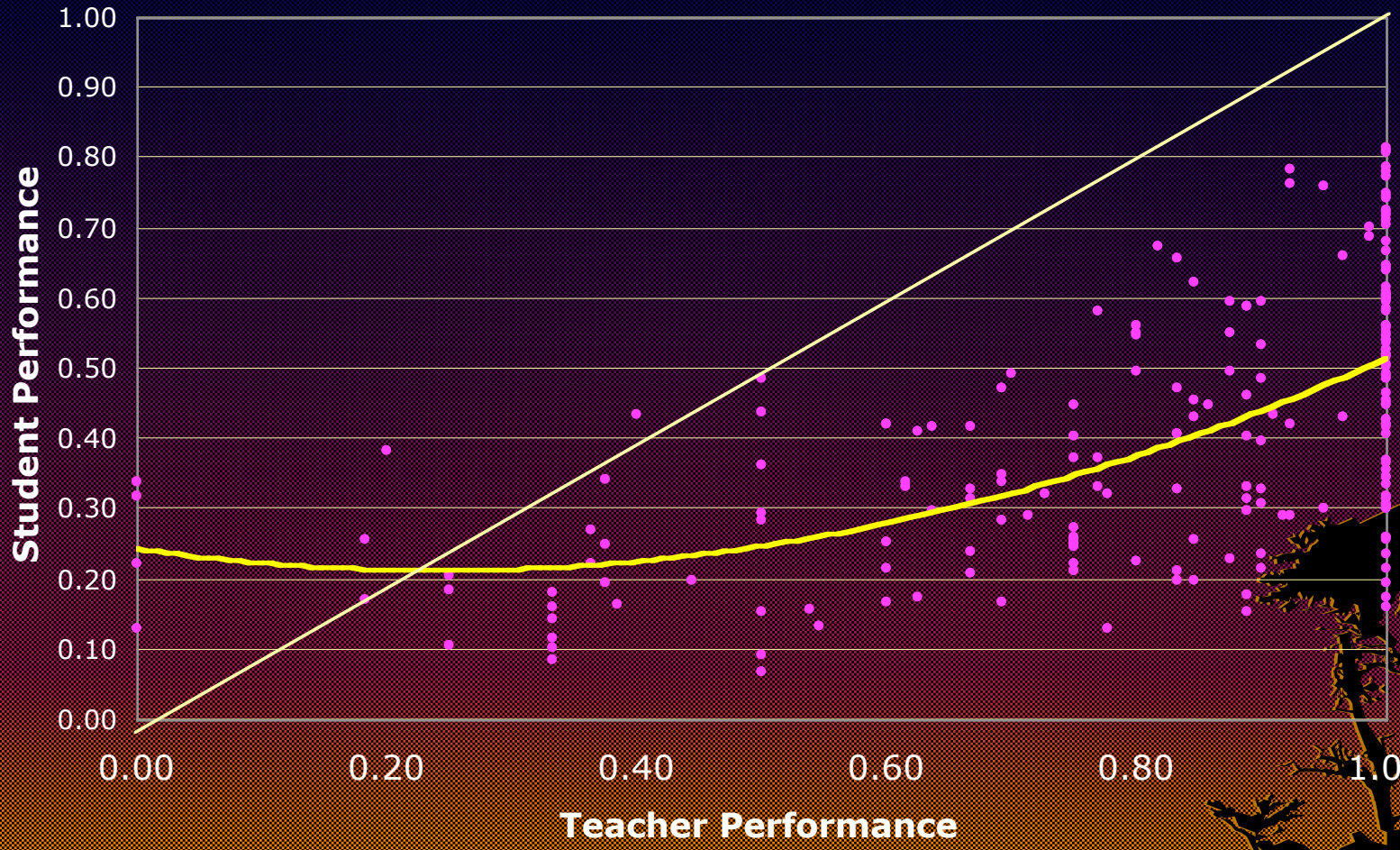
1. How much more do students learn about astronomy as they progress through school?
2. How do teachers perform compared to students?
3. What is the relationship between teacher knowledge of a concept and student knowledge of it?
4. How familiar are teachers with students' ideas?



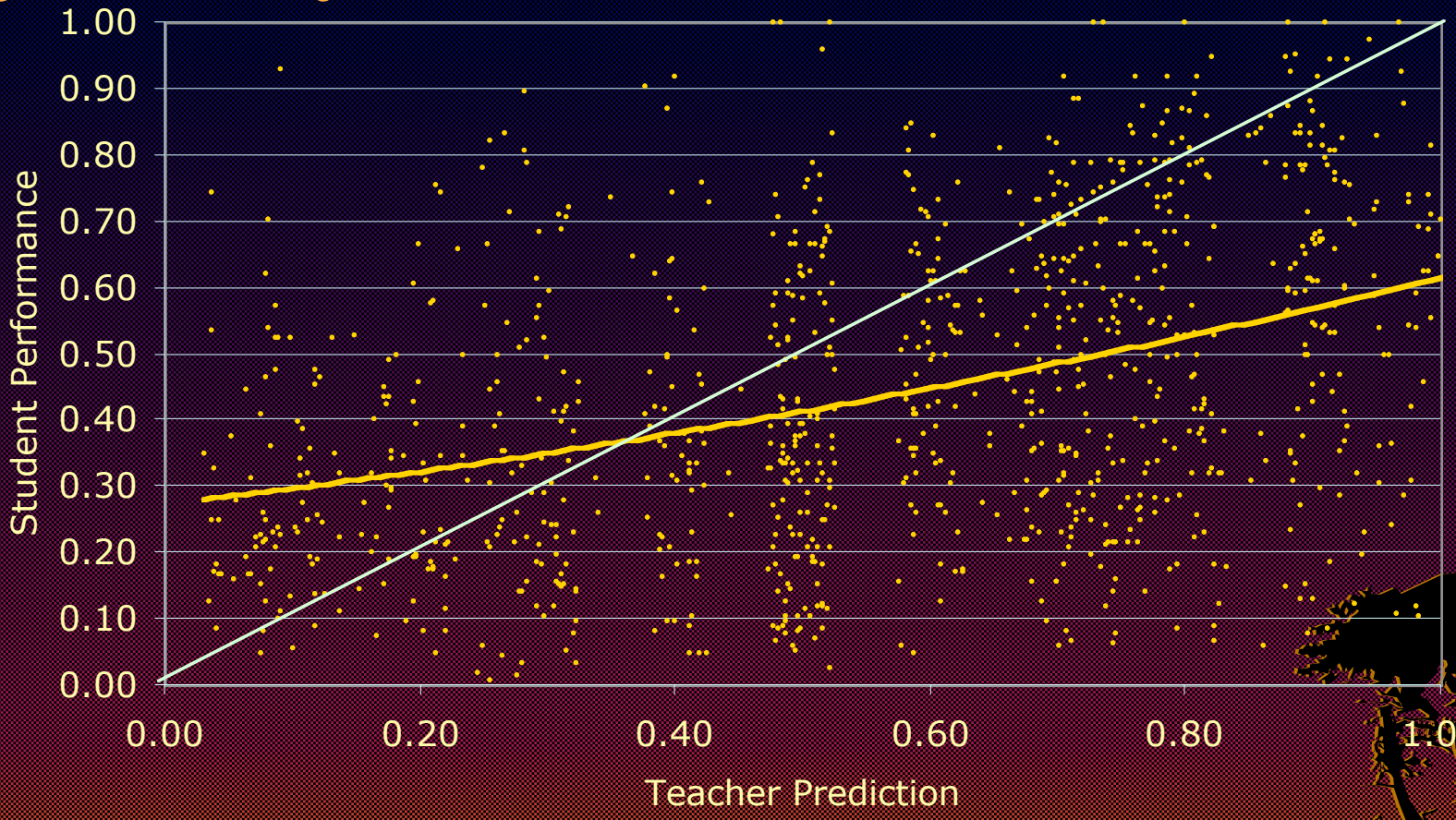
Performance on 6 Core Items



Relationship between Teachers' and their Students' Performance on Test Items



Accuracy of Teacher Prediction by Item by Teacher



Conclusions

- K-12 students are not achieving mastery of the NRC standards in astronomy.
  - Many areas of weakness.
- Their teachers are knowledgeable at the level that they teach.
- Teachers overpredict student knowledge.
  - Overprediction and the resultant lack of student mastery is more problematic than teacher knowledge.
- Student gains are small unless misconceptions are specifically addressed.

Opportunities

- Measurement of effectiveness across states
- Collaboration with professional development and curriculum projects.
- Custom test generation and data analysis.
- Inclusion in proposals to NASA and NSF
- Public versions of K-4, middle school, and high school level instruments available are available from:
  http://www.cfa.harvard.edu/smgphp/mosart

Acknowledgments

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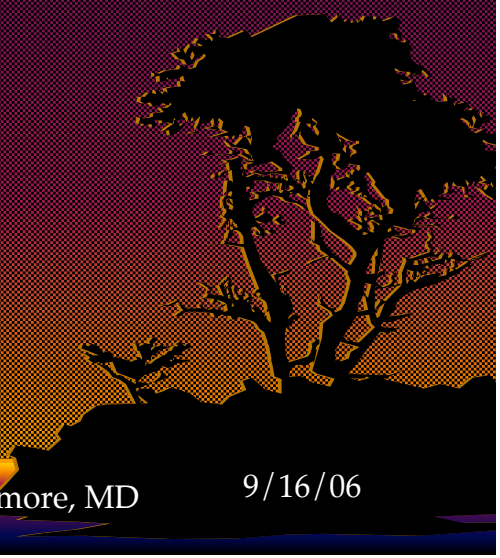

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