Learner Centered Astronomy

College Teaching Excellence Workshop

Learner Centered Astronomy

A Teaching Excellence Workshop

Ed Prather and **Tim Slater**

University of Arizona

Conceptual Astronomy and Physics Education Research (CAPER) Team

Sponsored by the NASA Navigator Public Engagement Program

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Dedicated to the professional development of introductory astronomy instructors

"Teaching Excellence" Workshops

A series of two-and three-day interactive teaching excellence workshops that focus on the dilemmas astronomy teachers face, with practical solutions for big issues in curriculum, instruction, and assessment. More >>

Teaching Excellence

THIS MONTH'S STRATEGY:

Everyone Says Lecturing Doesn't Work ...Does That Mean I Should Never Do It? More >>

Ideas from Your Classrooms

Submit your own favorite teaching tips. More >>

Discussion Groups

Join a discussion with Astronomy faculty to explore what works and what doesn't in the classroom. More >>

Useful Resource Sites

Faculty Resources

Images

- Astronomy Picture of the Day (APOD)
- JPL Planetary Photojournal

Instructional Strategies

- Lecture Tutorials
- ASP Guide to Online Teaching Resources for

Professional Organizations

- American Association of Physics Teachers (AAPT)
- Astronomical Society of the Pacific (ASP)
- American Astronomical Society (AAS)
- American Association of Community Colleges
- Conceptual Astronomy and Physics

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Workshops Locations

Click a location to register for a specific workshop

Winter 2004/05

1. San Francisco, CA
   Dec. 11-12, 2004
2. San Diego, CA
   Jan. 8-9, 2005
3. Chicago, IL
   Jan. 28-29, 2005

Spring 2005

4. Shoreline, WA
   April 2005 TBD
5. New Rochelle, NY
   May 7-8, 2005
6. New Orleans, LA
   May 21-22, 2005
7. Minneapolis, MN
   May 28-29, 2005

Summer 2005

8. Kona, HI
   June 20-23, 2005
9. Bozeman, MT
   July 6-8, 2005
10. Salt Lake City, UT
    August 6-7, 2005

This free workshop is funded in part by the NASA/JPL Navigator Public Engagement Program and the National Science Foundation. Pre-registration is strongly encouraged.

Workshops Contact information:
Rhonda Jones: Rhonda.R.Jones@jpl.nasa.gov

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General Information WHO'S ON: **02:09 PM**

6 users are registered to the **Astronomy 101** forum. rss feed

There are currently **0** users logged in.

Category Listing	Topics	Last Post
Teaching Tips and Dilemmas	0	Forum is empty
Assessment, Testing and Grading Diagnostic Tests, Conceptual Assessments Classroom Assessments, Assessment Techniques	0	Forum is empty
Laboratory Exercises	0	Forum is empty
On-line Technology Distance Learning, on-line courses, on-line instructional resources	0	Forum is empty
Textbooks	0	Forum is empty
Observations	0	Forum is empty
Thoughts on Current Events	0	Forum is empty

Special Thanks To:

NASA JPL Navigator and Spitzer

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NSF DUE CCLI #9952232

National Optical Astronomy Observatory (NOAO)

Prentice Hall Publishing, Addison Wesley, Brooks Cole Publishing

Overview

- Assumptions and Expectations about the Participatory Workshop
- Setting Your Course Goals and Objectives
- Review Some Recent Research Results in Teaching and Learning
- Interactive Lectures and Collaborative Group Learning
- Student-Centered Classrooms
- Assessment Strategies
- Bloom's Taxonomy: What does it mean to understand?
- Multiple-Choice Tests, Grading Strategies, Performance Assessment, Concept Maps, Portfolios
- Action Planning

Expectations

- This is an important time to share and to learn:
  - Engage yourself in as many discussions as possible (among the participants and presenters, there is enormous expertise and experience around the room)
  - Critically examine your own beliefs about teaching and learning and respectfully question others' rationale
- If you didn't learn anything new in a particular session, you may need to engage more actively!

What we will **NOT** be able to cover

- Debate and defend the educational research that suggests the majority of introductory science courses are ineffective at developing rich conceptual understanding
- Explain why students today are not as motivated or as prepared as they were when we were in school
- Tell you how to improve your teaching evaluations from students
- Arm you with strategies on how to convince your department chair or college/university promotion and tenure committee that you are an excellent teacher

Critical Questions

- What are your beliefs about teaching and learning that guide your instruction?
- How do YOU want your students to be different as a result of the experiences you design?
- What do we know about how STUDENTS learn?
- What are some strategies and resources to actively engage students in learning?
- What evidence would you accept that students made significant gains in conceptual, attitudinal, and skill domains?

Goals

On a piece of paper, list what the three main goals are for <u>YOUR</u> course.

What do others think the goals for Astro-101 are?

Most Important Goals In Astronomy 101

1. Students Understand the Big Ideas: *Size and Scale, Nature of Light, Spectroscopy, Cosmology*
2. Students Understand How Science is Done: *Nature of Science, Scientific Method, Weaknesses of Pseudoscience, Careers*
3. Students Develop Positive Attitudes and Life-Long Learning Interests in Astronomy: *Read Newspaper Articles, Watch TV Shows, Visit their Local Planetarium, Desire to Look Through Telescopes*

Slater, Adams, Brissenden, and Duncan, What We Teach in ASTRO 101, *The Physics Teacher*, January 2001.

What Syllabi Analysis Shows Are Mostly Taught in ASTRO 101

1. Nature of Light and the Electromagnetic Spectrum
2. Techniques in Astronomy
3. Cosmology and the Big Bang
4. Tools and Telescopes
5. The Solar System
6. Our Sun
7. Motions in the Solar System
8. Moon Phases
9. Stellar Evolution
10. Characteristics of the Milky Way
11. Naked Eye Astronomy
12. Stellar Magnitudes
13. Stellar Spectral Classification

Slater, Adams, Brissenden, and Duncan, What We Teach in ASTRO 101, *The Physics Teacher*, January 2001.

Most Important Goals In Astronomy 101

- American Astronomical Society Chair's Goals
- Society of College Science Teachers Goals for intro-science courses

Most Important Goals In Astronomy 101

BOTTOM LINE:

CLEARLY STATING YOUR GOALS, FOR ***YOURSELF*** AND FOR YOUR ***STUDENTS***, IS CRITICAL TO BUILDING AN EFFECTIVE COURSE

Do you really want to know what your students think?

What Students Are Expecting from Astronomy 101?

Possible Survey Questions

What made you decide to take this course?

What do you expect to learn in this course

What made you decide to take this course?

in order of frequency

- interested in astronomy
- fun sounding course
- recommendation by peer, advisor or orientation leader
- required general education fulfillment
- required for major or minor
- was available in the schedule
- inflate grade point average

What do you expect to learn in this course?

stars
constellations
planets
galaxies
black holes
solar system
comets
asteroids

Moon
Sun
weather
atmosphere
UFOs and the unexplained

Perspectives on Teaching Astronomy

- Take a moment, read each statement and then rate them (1 – 5) according to how much they align with your beliefs about teaching and learning.

Case Study

- Read the “Number 1” case study from the *Case Studies Booklet for Introductory Science Teaching*.

- Before you talk to your neighbor, write down two possible responses that you might give to Sara as her ***educational therapist*** .

Basic Premise

Professor-centered lectures, no matter how entertaining, can only go so far in helping students learn. It is our premise that the most effective courses are learner-centered courses which provide clearly stated course goals and learning objectives, use interactive teaching approaches to continually engage students, and use a variety of assessment strategies.

So why doesn’t lecture work?

OR

Are you really teaching if no one is learning?

The Montillation of Traxoline

It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then brachter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

(attributed to the insight of Judy Lanier)

The Montillation of Traxoline

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Directions: Answer the following questions in complete sentences. Be sure to use your best handwriting.

1. What is traxoline?
2. Where is traxoline montilled?
3. How is traxoline quaselled?
4. Why is it important to know about traxoline?

What research into astronomy teaching and learning really looks like!

UA Faculty

Tim Slater
Ed Prather
Bruce Johnson
Chris Impey
Larry Lebofsky
Ingrid Novodvorsky

Ph.D. Students

Jessie Antonellis
Janelle Bailey
Audra Baleisis
Erik Brogt
Sanlyn Buxner
Erin Dokter
John Keller
James Little
Erika Offerdahl
Delphine Perrodin
Pebble Richwine
Andrew Shaner
Mathew Wenger

Post Docs and Staff Researchers

Gina Brissenden
Adrienne Gauthier
Jennifer Mangan
Jacob Noel-Storr

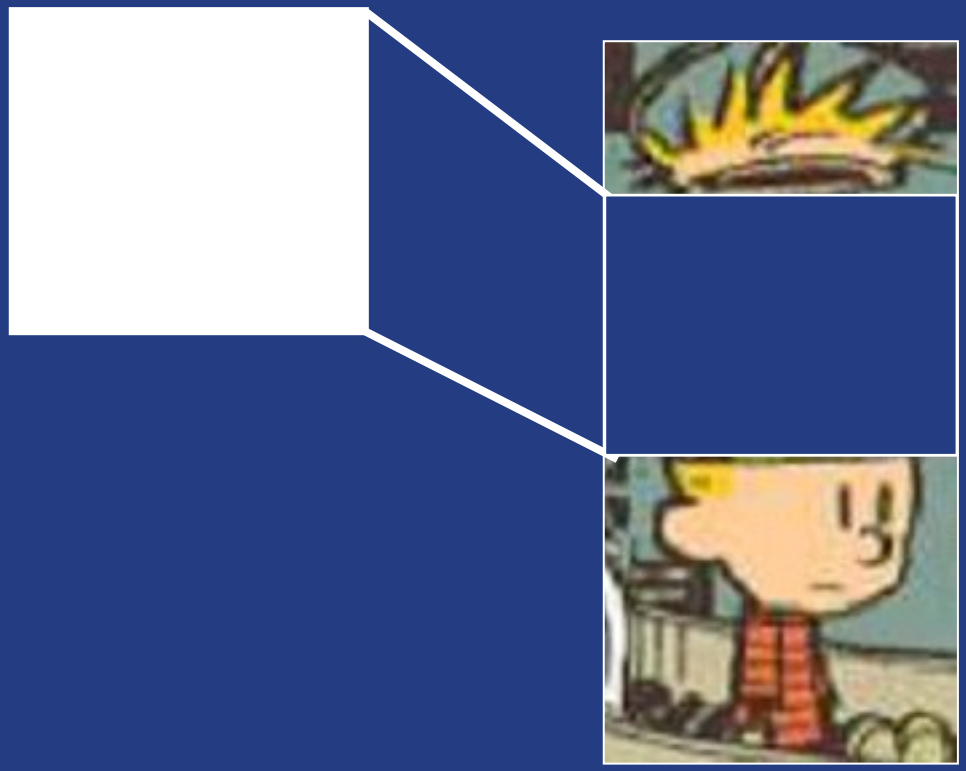
CAPER Team
Conceptual Astronomy & Physics Education Research
University of Arizona

from ***How People Learn***

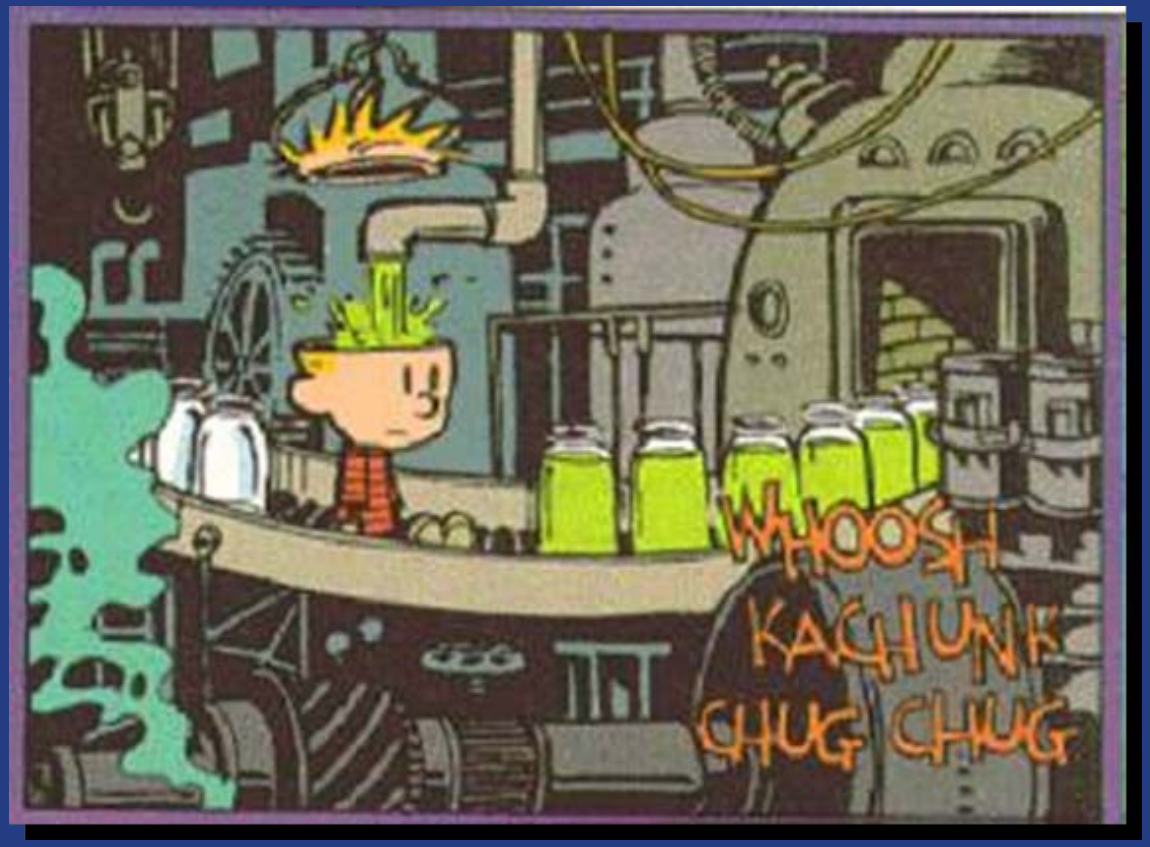
"Students enter your lecture hall with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom"

HOW PEOPLE LEARN, National Research Council, National Academy Press, 2000.

A Commonly Held Inaccurate Model of a Student's Conceptual Framework



A Commonly Held Inaccurate Model of Teaching and Learning



1. Seasons depend on the distance between the Earth & Sun
2. There are 12 zodiac constellations
3. The constellations are only the stars making the patterns
4. The North Star is the brightest star in the night sky
5. Stars last forever
6. All stars are same color
7. Stars really twinkle
8. All stars are isolated
9. Pulsars are pulsating stars
10. Asteroid belt is densely packed, as in “Star Wars”
11. Meteors, Meteorites, Meteoroids, Asteroids, and Comets are the same things
12. A shooting star is actually a star falling through the sky
13. Comet tails are always behind the comet
14. Comets are burning and giving off gas as their tails
15. All planetary orbits are circular
16. All planets have prograde rotation
17. All moons are spherical
18. We see all sides of the Moon
19. Ours is the only moon
20. Spring tide only occurs in the Spring
21. Only the Moon causes tides/the Moon has no effect on tides
22. High tide is only between the Earth and Moon
23. Once the ozone is gone, its gone forever
24. Mercury is hot everywhere on its surface
25. Giant planets have solid surfaces
26. Saturn is the only planet with rings
27. Saturn’s rings are solid
28. Pluto is always the farthest planet from the Sun
29. The Sun primarily emits yellow light
30. The Sun is solid & shines by burning gas or from molten lava
31. The Sun always rises directly in the East
32. Black holes are empty space
33. Black holes are huge vacuum cleaners in space, sucking everything in.

Taken from – Heavenly Errors, Comins N. , 2001

Not All of These Are Deeply Held Ideas

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3. The constellations are only the stars making the patterns
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Student (*mis*)-Understandings

the beliefs and reasoning difficulties students bring to the classroom

- Alternative Conceptions
  - Robust, locally consistent, naturally acquired, historically rooted, common default position
- Reasoning Difficulties
  - Misapplied details of underdeveloped conceptual models; confusion between model results and the model itself
- Stuff they can't name (*or simply name incorrectly*)

What do students struggle with?

The Big Three

1. Seasons
2. Moon Phases
3. Gravity

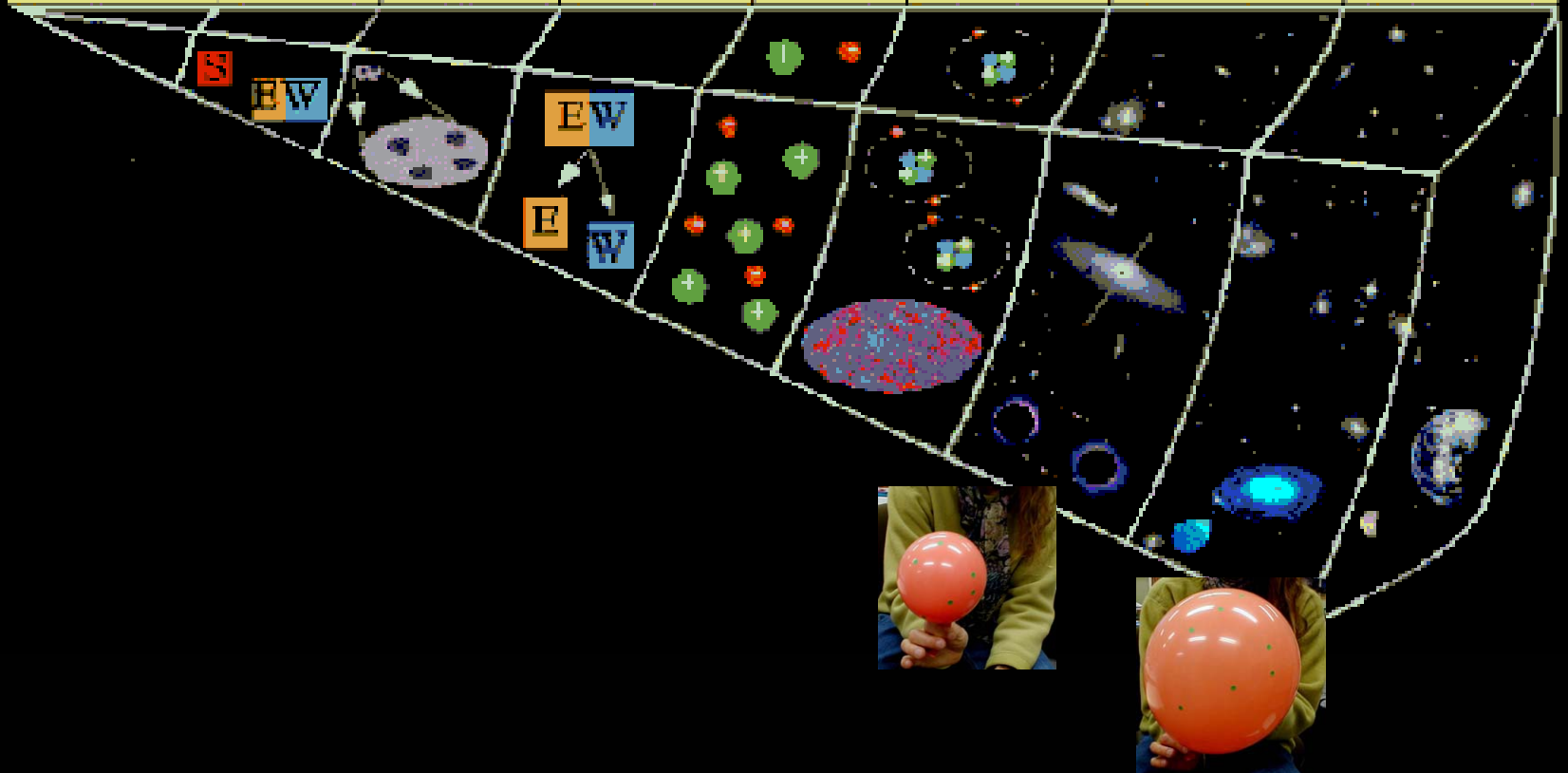
Modern Topics Too

- Stellar Formation
- Cosmology
- Astrobiology

A Review of Astronomy Education Research, Astronomy Education Review, **2**(2), 2003. J.M. Bailey and T.F. Slater

An Example on the topic of Cosmology – The Big Bang

10^{-44}sec	10^{-35}sec	10^{-32}sec	10^{-10}sec	300 sec	$3x10^{5}$yr	$1x10^{9}$yr	$15x10^{9}$yr
Radiation Era	GUT Era	Inflation Era	Electro-weak Era	Particle Era	Recombination Era	Galaxy and Star Formation	Present Era



An Example from the Topic of Cosmology – The Big Bang

Initial Question

- Have you ever heard of the Big Bang?
  - Describe what you think it is, and provide a sketch, if possible, to illustrate your answer.

Follow-up Questions

- Describe what you think existed or was occurring just before the Big Bang.
- Describe what you think existed or was occurring during the Big Bang.

Hints of a Fundamental Misconception in Cosmology
Astronomy Education Review, 1, (2), 2002
Edward E. Prather, Timothy F. Slater and Erika G. Offerdahl

	Question1			Question2				Question3			Question1			Question2				Question3	
Student1	2			1	4	6		1		Student53	9			1	2	4		7	
Student2	2			1	2	3		6		Student54	9			1	2	4		1	
Student3	3			1	2			1	2	Student55	2			1	2			2	
Student4	1			1	2	4		2	3	Student56	9			1				2	
Student5	9			7				7		Student57	2			1	2			1	
Student6	3	4		2	7			7		Student58	9			1	2	4		4	
Student7	9			2	4			4		Student59	2			1	2			7	
Student8	9			2	8	9		3		Student60	7			1	2	5		6	
Student9	9			1	2	7		7		Student61	7			1	2			4	
Student10	3	4		7				7		Student62	2			1	3	7		3	
Student11	2			1	4	6		1		Student63	2	5		2	1	4		2	3
Student12	2			1	4	6		1		Student64	5			1	2	4		7	
Student13	9			1	2	8		3		Student65	3	5		1	2	4	7	2	
Student14	3			1	2	9		7		Student66	9			1	2	4		7	
Student15	9			1	3	4	6	1		Student67	9			1	2	4		3	
Student16	7			10				6		Student68	2	5		1	2	4		2	
Student17	7			1	4			6		Student69	9			1	4	6		6	
Student18	7			1	4			3		Student70	3	5		1	2			7	
Student19	7			2	9			3	4	Student71	7			1	2			1	
Student20	9			1	2	7		5		Student72	2			1	2			6	
Student21	2			1	4	6		2		Student73	3	5		1	2	4		3	
Student22	5	7		1	2	7		1		Student74	9			1	2			6	
Student23	2	3		1	2	8		1		Student75	2			1	4	6		6	
Student24	9			10				7		Student76	5			1	2	7		6	
Student25	3			2				7		Student77	2	3	5	1	2			7	
Student26	7			1	2	8		7		Student78	2			2	9			7	
Student27	7			1				7		Student79	3	5		1	2			6	
Student28	7			1	4			7		Student80	2	5		1	7			7	
Student29	9			10				7		Student81	2	7		1	4	5		1	
Student30	9			10				7		Student82	9			2	4			7	
Student31	9			10				7		Student83	3	5		1	2	4		7	
Student32	9			10				7		Student84	9			10				7	
Student33	5			10				7		Student85	9			10				7	
Student34	7			4				1		Student86	1			2	8			3	4
Student35	2			2	8			1		Student87	9			10				7	
Student36	2				1	2		7		Student88	2	5		1	2	4		7	
Student37	9			9				2		Student89	7			1				7	
Student38	5			1	2	4		1	2	Student90	2			10				1	
Student39	9			1	2	4		1		Student91	7			1	2	4		2	
Student40	2	5		1	4			1		Student92	7			2	8	9	11	7	
Student41	9			1	2			2		Student93	7			1	2	9		7	
Student42	4			10				6		Student94	2			1	2	9		6	
Student43	3			2				7		Student95	3			1	4	5		6	
Student44	9			1				7		Student96	7			1	2	4		7	
Student45	2			1	3			6		Student97	7			1	2			6	
Student46	2			2				2		Student98	9			1	2	3	4	1	
Student47	9			1	2	9		1		Student99	9			1				7	
Student48	2			1	2			1		Student100	7			10				7	
Student49	2			1	2	6		1	3	Student101	7			1	2	6		7	
Student50	7			1	2			6	4	Student102	7			1	4			7	
Student51	2			1	2	4		3		Student103	9			1	2	3	4	7	
Student52	1			4				7		Student104	5			1	8			7	
										Student105	2			1	4			6	

Summary of Students' Pre-instruction Ideas on the Big Bang

- 86% of students (N=167) report that they have heard of the Big Bang. *Only 54% of these students describe the Big Bang as a theory about the creation of the universe.*
- 69% of students (N=133) describe some configuration of matter existing in the universe prior to the Big Bang.
- 49% of students (N=133) describe the Big Bang as an explosion that distributes matter throughout the universe.
- 17% of students (N=133) describe the Big Bang as event that combined matter together to form objects in the universe.

So what's the point?

Student responses indicate a belief that the Big Bang was an event that organized pre-existing space and/or matter.

Two Models Of Students' Understanding

Misconception Model

Primitives Model

Fundamental reasoning elements

- When children touch something on the stove, they learn that temperature increases with decreasing distance
- When children hear a car's horn, they learn that sound intensity increases with decreasing distance
- When children see a bright flashlight, they learn that brightness increases with decreasing distance

FACETS Of Knowledge

(similar to Minstrell, 1989)

⇨ **CLOSE MEANS MORE**

Phenomenological Primitives or p-prims

(similar to di Sessa, 1993)

How Do “p-prims” Influence the Teaching and Learning of Astronomy?

CLOSE MEANS MORE	It’s hotter in the summer because we are closer to the Sun
INTERFERENCE	I can’t see all of the Moon because the Earth is in the way
OHM’S P-PRIM	All bright stars must be very hot

What is the underlying idea that drives these student responses about the Big Bang?

- ✓ Matter cannot be created or destroyed – Conservation of Matter
- ✓ Energy cannot be created or destroyed – Conservation of Energy

What is the underlying idea that drives these student responses about the Big Bang?

You can't make something from nothing!!

How Do “p-prims” Ideas Impact Teaching and Learning Astronomy?

CAN’T MAKE SOMETHING FROM NOTHING	The Big Bang organized pre-existing matter

Current State of Affairs

- Students and teachers have strongly held ‘misconceptions’ (Comins, 2001; Hufnagle, et. al, 1999; Sadler, 1998, 1992, 1989; Bailey & Slater, 2004)

- Students find introductory science courses to be boring, irrelevant, and incongruous with the stated goals of scientists (Reddish, 1996; Tobias, 1986)

- ‘Active Engagement’ approaches produce significant and long-lasting learning gains compared to even the most entertaining of lectures (Hake, 1996; Francis, Adams, and Noonan, 1998)

Key results from research into education and cognition

- Learning is productive / constructive - learning requires mental effort.
- Knowledge is associative / linked to prior mental models and cognitive structures.
- The cognitive response is context dependent – what and how you learn depends on the educational setting.
- Most people require some social interactions in order to learn deeply and effectively.

Critical Questions

- What are your beliefs about teaching and learning that guide your instruction?
- How do YOU want your students to be different as a result of the experiences you design?
- What do we know about how STUDENTS learn?
- What are some strategies and resources to actively engage students in learning?
- What evidence would you accept that students made significant gains in conceptual, attitudinal, and skill domains?

Our Assumptions

- The introductory course for non-science majors could be significantly improved
- Although the lecture approach is largely insufficient, there are instructional strategies available to accompany lecture that intellectually engage students
- Large enrollment courses can use **learner-centered** instructional strategies
- Awareness of and exposure to **active learning** techniques will motivate faculty to try them

Active Learning

- Active learning is when students take active responsibility for participating in and monitoring of their own learning by engaging in critical reasoning about the ideas presented in the class.

What Can I do Besides Lecture to Engage Students in their Learning?

- Ask students questions (not all questions are equal) Use demonstrations (interactive lecture demos)
- Surprise quizzes (graded/ungraded)
- In-class writing (with/without discussion)
  - muddiest point
  - summary of today's main points
  - 5-minute free writing
- Think-Pair-Share (Peer Instruction-*ConcepTests*)
- Small Group Interactions (closed/open; in/out of class)
- Student Debates (individual/group)
- Whole Class Discussions
- Jigsawing

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Ways to Screw Up Your Lecture

1. Insufficient "Wait-Time"
2. The Rapid-Reward
3. The Programmed Answer
4. Non-Specific Feedback Questions
5. Teacher's Ego-Stroking & Classroom Climate
6. Fixation at a Low-Level of Questioning

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Some Examples of Writing Prompts

Directions:

Over the next five minutes, I'd like you to write a response, in the form of a paragraph, to the following question. After five minutes, I'll ask for volunteers to read their passages WITH FEELING and I'll ask others to describe what are the most important parts and what the passages make them think of.

An Example of a Writing Prompt

What are the elements of your classroom that you most want to change and why?

Some Examples of Writing Prompts

- Illustrate the meaning of "standard candle" using one example taken from everyday life and one example from astronomy.
- What about the enterprise of science makes it different than business?
- If we establish communication with an intelligent, extraterrestrial civilization, who should speak for Earth and what should he/she/they say?
- What do you need to do to get high grades in this course and what will you do differently before the next exam?

What Can I do Besides Lecture to Engage Students in their Learning?

- Ask students questions (not all questions are equal) Use demonstrations (interactive lecture demos)
- Surprise quizzes (graded/ungraded)
- In-class writing (with/without discussion)
  - muddiest point
  - summary of today's main points
  - 5-minute free writing
- Think-Pair-Share (Peer Instruction-*ConcepTests*)
- Small Group Interactions (closed/open; in/out of class)
- Student Debates (individual/group)
- Whole Class Discussions
- Jigsawing

Are these suitable questions to promote student engagement?

1. What is the largest planet in the solar system?
2. How long will the Sun live?
3. Which would appear brighter a star with an apparent magnitude of 0.03 or a star with an apparent magnitude of 0.3?
4. Which is brighter a B spectral class main sequence star or a M spectral class main sequence star?

Are these suitable questions to promote student engagement?

1. Does a planet's radius depend on how far it is from the Sun? Give an example to support your answer.
2. How long do stars live?
3. Which factors influence a star's apparent brightness?
4. Which is brighter a B spectral class main sequence star or a M spectral class main sequence star?

Think-Pair-Share (ConcepTests)

Answer first by yourself, then with a partner:

Which of the following makes the determination of Hubble's constant most difficult?

a. *inexact recessional velocities*
b. *inexact galactic distances*
c. *existence of dark matter*
d. *lack of federal funding*

Think-Pair-Share (ConcepTests)

Answer first by yourself, then with a partner:

Considering its distance and size, Pluto is most likely a/an

a. Gas giant

b. Kuiper Belt Object (KBO)

c. Comet

d. Asteroid

Personal Responder Devices

- What are responders?
  - IR or Radio wireless voting device
  - Sometimes referred to as Classroom Communication Systems (CCS), “clickers”, etc.

Class Response System – Low Tech

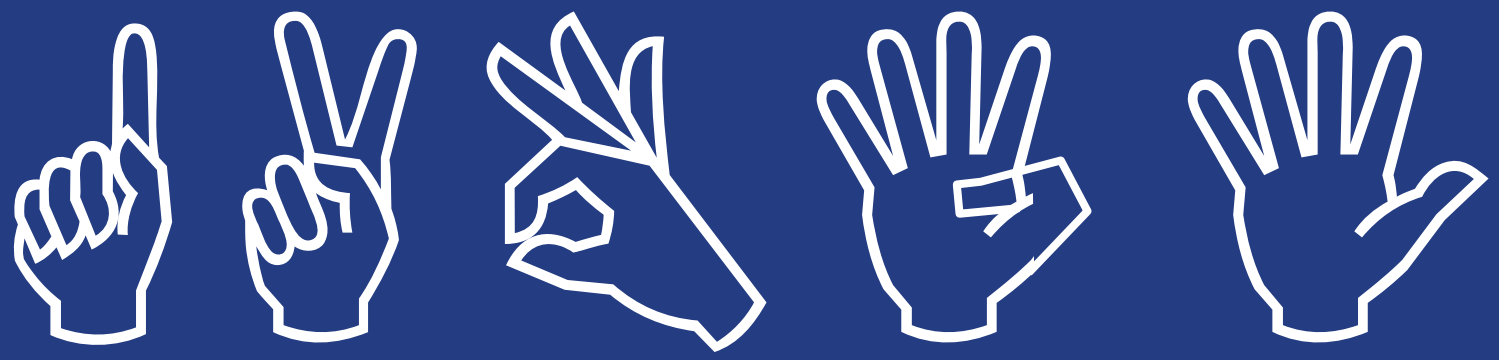
A

B

C

D

Class Response System – Low Tech



Create a suitable questions to use for think-pair-share?

- Work with a small group
- Make sure your question is multiple choice
- Select a member of your group who will model "think – pair – share" using your question

On the topic of:

Stellar Evolution

Given that a seed grows into a massive tree, where does most of the mass of the tree come from?

1. From water
2. From dirt and soil
3. From the air
4. Its already in the seed.

What Can I do Besides Lecture to Engage Students in their Learning?

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As Yet Unanswered Burning Questions

Learner Centered Astronomy

A Teaching Excellence Workshop

Ed Prather, **Tim Slater**, **Gina Brissenden**,
University of Arizona

Conceptual Astronomy and Physics Education Research (CAPER) Team

Sponsored by the NASA Navigator Public Engagement Program

http://astronomy101.jpl.nasa.gov

Critical Questions

- What are your beliefs about teaching and learning that guide your instruction?
- How do YOU want your students to be different as a result of the experiences you design?
- What do we know about how STUDENTS learn?
- What are some strategies and resources to actively engage students in learning?
- What evidence would you accept that students made significant gains in conceptual, attitudinal, and skill domains?

As Yet Unanswered Burning Questions

Our Assumptions

- The introductory course for non- science majors could be significantly improved
- The lecture approach is insufficient and there are strategies available to accompany lecture
- Large enrollment courses can use **learner-centered** instructional strategies
- Awareness of and exposure to **active learning** techniques will motivate faculty to try them

Active Learning

- Active learning is when students take active responsibility for participating in and monitoring of their own learning by engaging in critical reasoning about the ideas presented in the class.

What Can I do Besides Lecture to Engage Students in their Learning?

- Ask students questions (not all questions are equal) Use demonstrations (interactive lecture demos)
- Surprise quizzes (graded/ungraded)
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- Think-Pair-Share (Peer Instruction-*ConcepTests*)
- **Small Group Interactions**
- Student Debates (individual/group)
- Whole Class Discussions
- Jigsawing

Let's Try an In-Class Small Group Activity

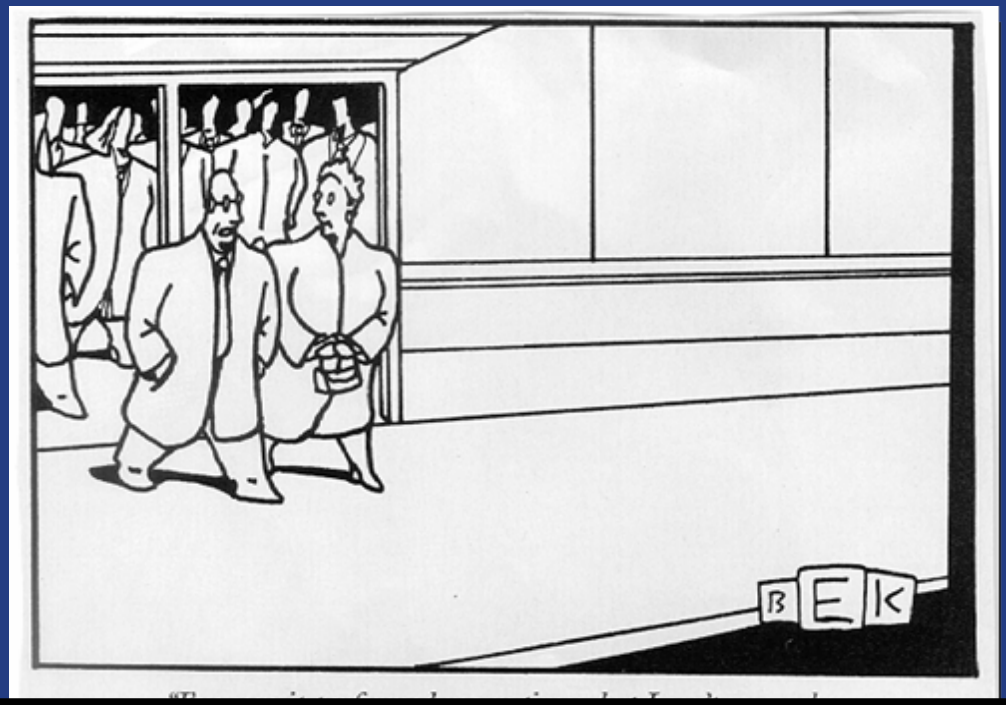
From:

Lecture-Tutorials for Introductory Astronomy

Adams, Prather, and Slater, 2004, Prentice Hall

How Research on Student Beliefs and Reasoning Difficulties are used to Promote a Learner-Centered Introductory Astronomy Classroom

Another talk about the teaching and learning…..



"I've seen it performed may times, but I can't remember ever sleeping through it so peacefully"

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How often do you hear the following from your students?

- I just can't do science!
- I just can't do math!
- I understand your lectures and the readings, but I can't do the homework.
- I did all of the homework three times, but I can't do well on your tests.
- ~~I just can't do history!~~

From a teaching and learning perspective, just what is it that makes astronomy different?

BUT I AM A GREAT TEACHER!!!!

Astronomy Diagnostics Test (ADT)

If you could see stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?

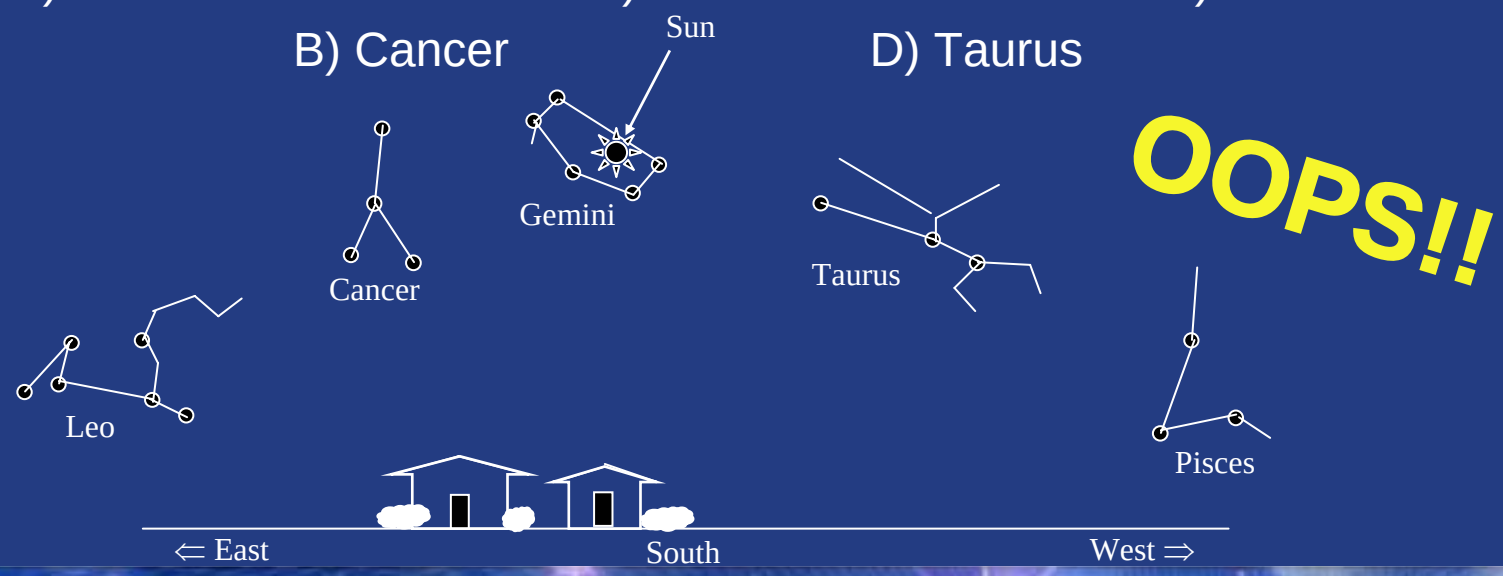
A) Leo

B) Cancer

C) Gemini **11%**

D) Taurus

E) Pisces **73%**



OOPS!!

From ***How People Learn***

"Humans are viewed as goal-directed agents who actively seek information. They come to formal education with a range of prior knowledge, skills, beliefs, and concepts that significantly influence what they notice about the environment and how they organize and interpret it. This, in turn, affects their abilities to remember, reason, solve problems, and acquire new knowledge. … If students' initial ideas and beliefs are ignored, the understandings that they develop can be very different from what the teacher intends."

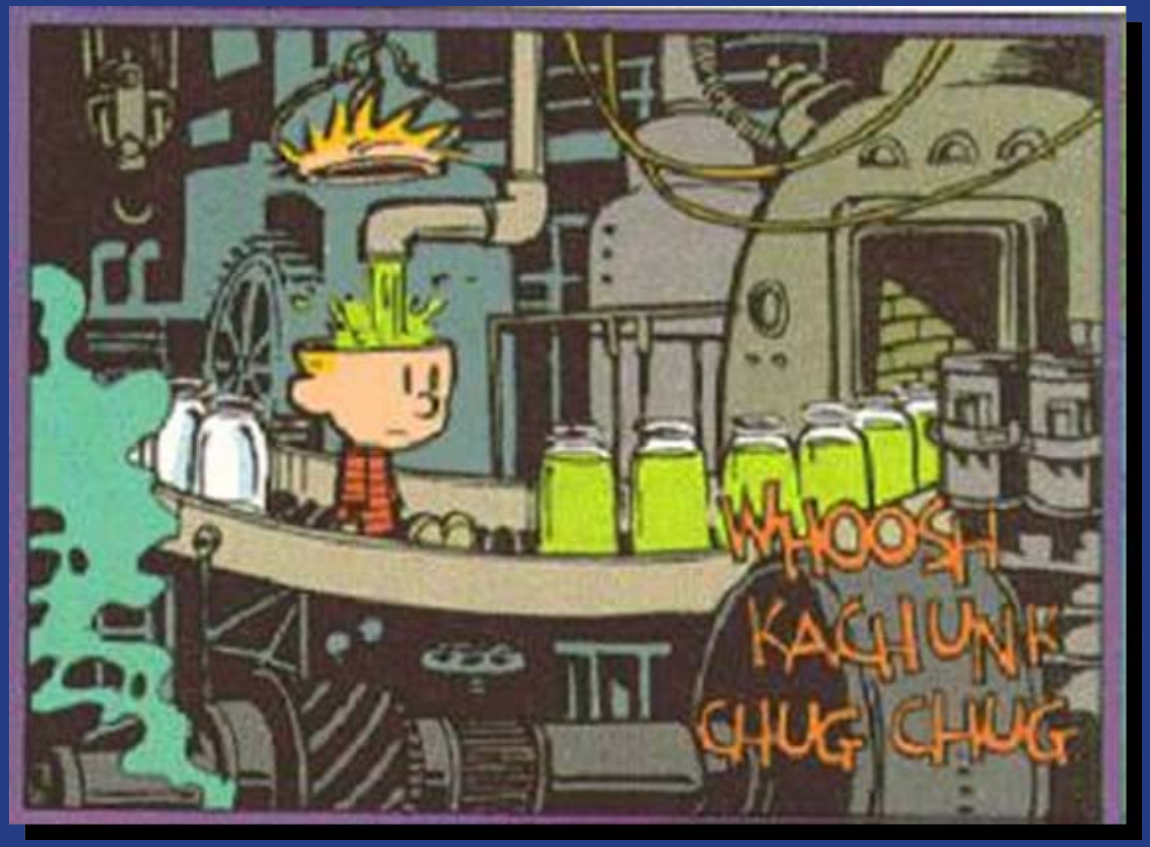
HOW PEOPLE LEARN, National Research Council, National Academy Press, 2000.

How People Learn

- Students enter the classroom with preconceptions about how the world works. *If their initial understanding is not fully engaged, they may fail to grasp new concepts in meaningful ways that last beyond the purposes of an exam.*
- To fully develop competence, students must:
  (1) have a deep foundation of factual knowledge, (2) understand interrelationships among facts and concepts and (3) organize knowledge in ways that facilitate retrieval and application
- A "metacognitive" approach to instruction can help students learn to take control of their own learning and monitor progress.

How People Learn: Brain, Mind, Experience, and School (Expanded Edition), National Research Council, National Academy Press, 2000.

A Commonly Held Inaccurate Model of Teaching and Learning



So What Can You Do About It?

- Lecture more loudly?

Assumption #1 - Lecture is ineffective at promoting deep conceptual change.

- This was NOT a traditional case study that had a control group and used two treatments with a randomized population of participants
- Population – students enrolled in the introductory astronomy course for non-science majors

Assumption #1 - Lecture is ineffective at promoting deep conceptual change.

- Instrument used: A 68 items research based multiple choice questionnaire
- Pre-Course: two forms, A&B, which each contained a subset of questions
- Post-Lecture: questions administered in subsets that directly reflected topic of lecture

Celestial Motion of Objects

You observe a star rising directly to the east. When this star reaches its highest position above the horizon, where will it be?

a) high in the northern sky
b) high in the eastern sky
c) high in the southern sky
d) high in the western sky
e) directly overhead

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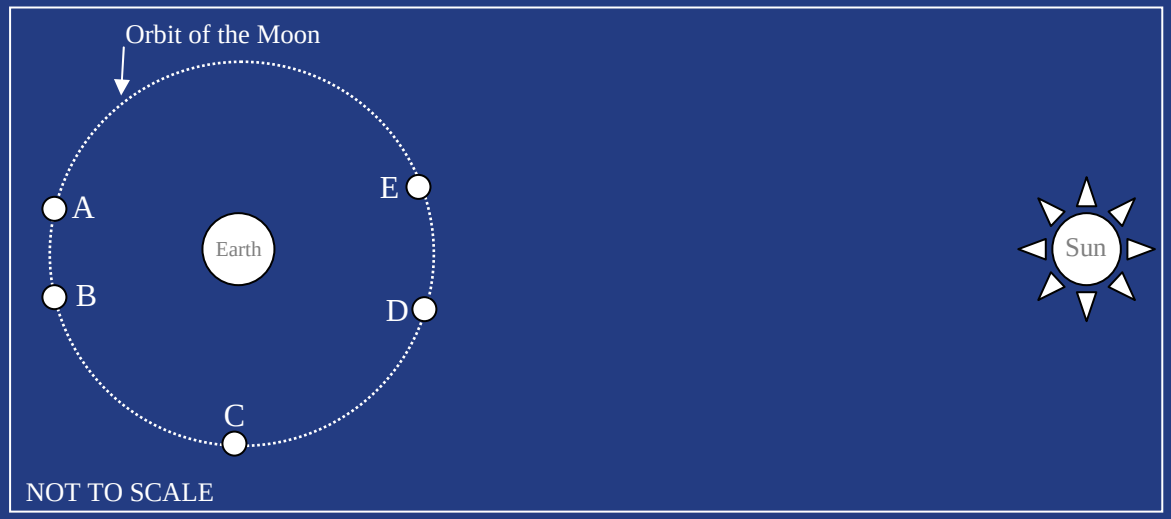
c) high in the southern sky
d) high in the western sky
e) directly overhead

- Before Lecture (N=42): 2% correct

What Causes Moon Phases

The diagram below shows Earth and the Sun as well as five different possible positions for the Moon. Which position of the Moon best corresponds with the phase of the Moon shown in the figure at the right?



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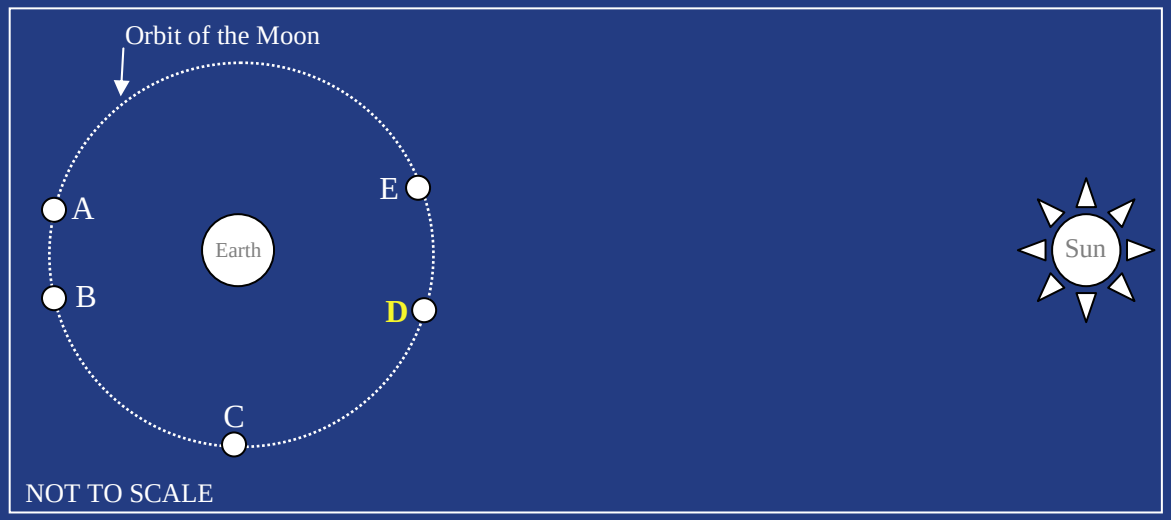

- Before Lecture (N=42): 5% correct

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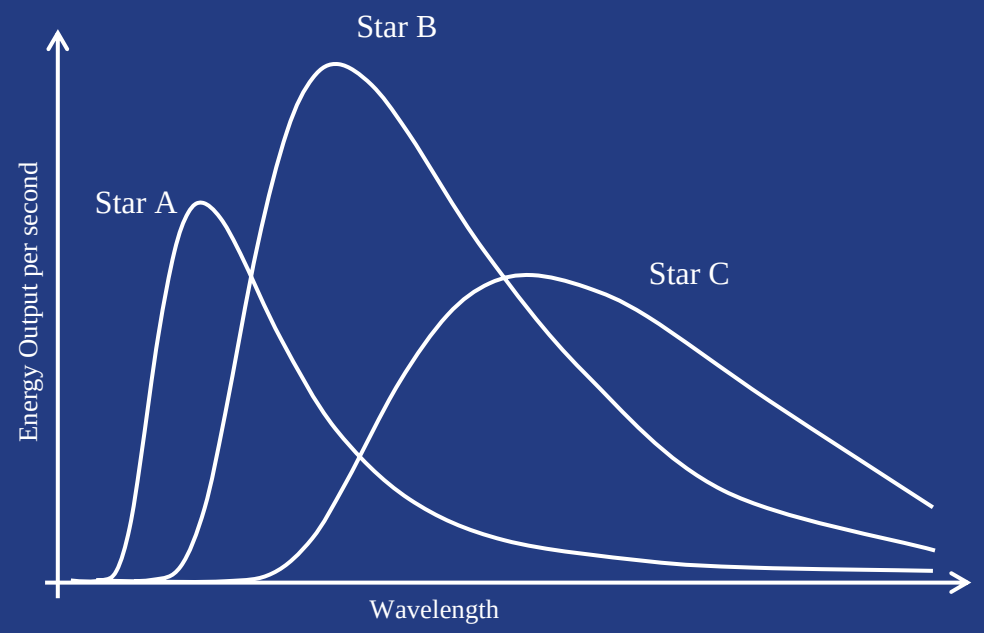
Blackbody Radiation LT

The graph below shows the blackbody spectra for three different stars. Which of the stars is at the highest temperature?

a) Star A

b) Star B

c) Star C



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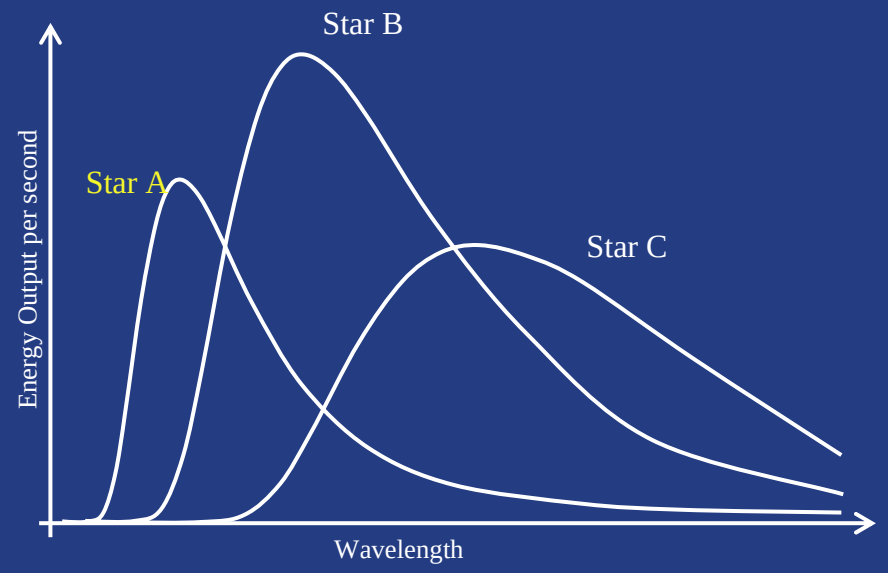

- Before Lecture (N=42): 12% correct

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H-R Diagrams and Spectral Class

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

a) luminosity.

b) temperature.

c) absolute magnitude.

H-R Diagrams and Spectral Class

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

a) luminosity.
b) temperature.
c) absolute magnitude.

- Before Lecture (N=39): 41% correct

Expansion of the Universe

If our universe is expanding, what are the implications for the separation between two stars within our galaxy?

a) The two stars are moving farther apart.
b) The two stars are moving closer together.
c) The two stars are remaining approximately the same distance apart.

Expansion of the Universe

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b) The two stars are moving closer together.
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- Before Lecture (N=39): 19% correct

Looking at Distant Objects

Imagine that you simultaneously receive the satellite transmission of two pictures of two people that live on planets orbiting two different stars. Each image shows the people at their 21st birthday parties. Consider the following possible interpretations that could be made from your observations. Which do you think is the most plausible interpretation?

a) Both people are the same age but at different distances from you.
b) The people are actually different ages but at the same distance from you.
c) The person that is closer to you is actually the older of the two people.
d) The person that is farther from you is actually the older of the two people.

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d) The person that is farther from you is actually the older of the two people.

- Before Lecture (N=39): 53% correct

Assumption #1 - Lecture is ineffective at promoting deep conceptual change.

- Instrument used: A 68 items research based multiple choice questionnaire
- Pre-Course: two forms, A&B, which each contained a subset of questions

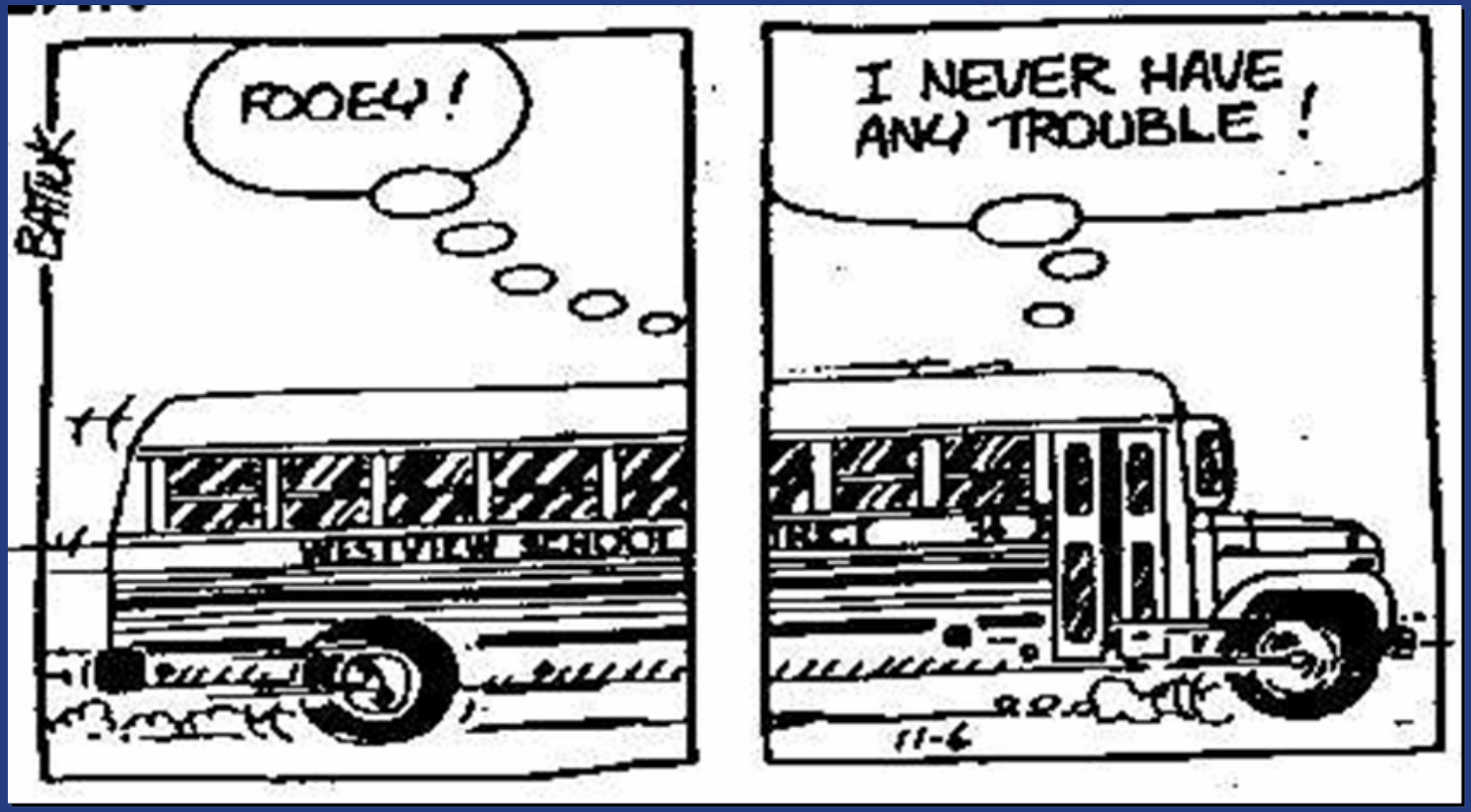
✓ Pre-Course mean: 30% (n_A=39,n_B=42)

So What Can You Do About It?

- Lecture more loudly?

Funky Winkerbean

BY TOM BATIUK



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IF YOU GO FAST ENOUGH, THEY JUST STAY PINNED TO THEIR SEATS!

Celestial Motion of Objects

You observe a star rising directly to the east. When this star reaches its highest position above the horizon, where will it be?

a) high in the northern sky
b) high in the eastern sky
c) high in the southern sky
d) high in the western sky
e) directly overhead

- Before Lecture (N=42): 2% correct

Celestial Motion of Objects

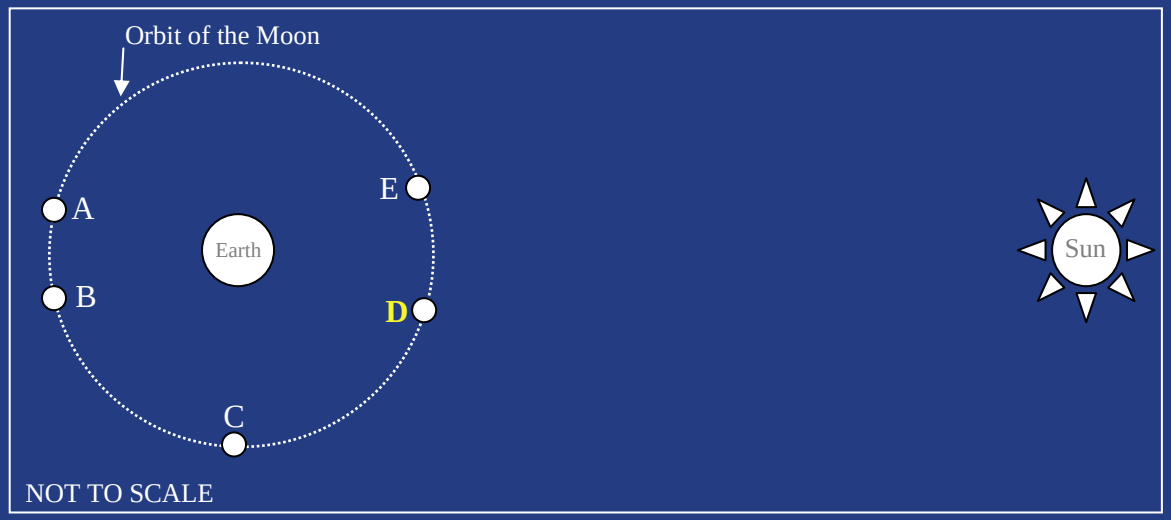
You observe a star rising directly to the east. When this star reaches its highest position above the horizon, where will it be?

a) high in the northern sky
b) high in the eastern sky
c) high in the southern sky
d) high in the western sky
e) directly overhead

- Before Lecture (N=42): 2% correct
- After Lecture (N = 135): 19% correct

What Causes Moon Phases

The diagram below shows Earth and the Sun as well as five different possible positions for the Moon. Which position of the Moon best corresponds with the phase of the Moon shown in the figure at the right?



- Before Lecture (N=42): 5% correct

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What Causes Moon Phases

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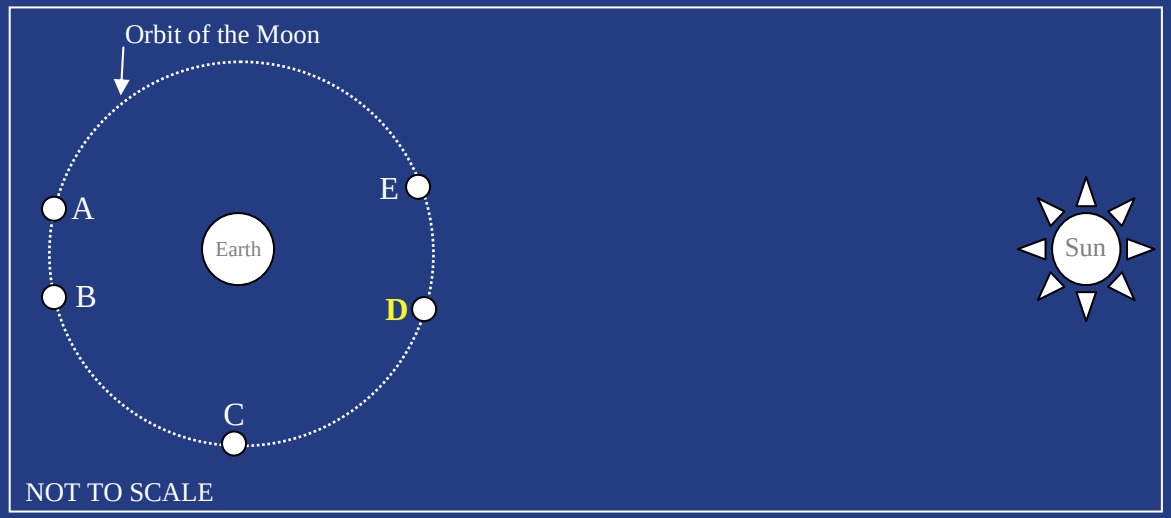


- Before Lecture (N=42): 5% correct
- After Lecture (N=127): 53% correct

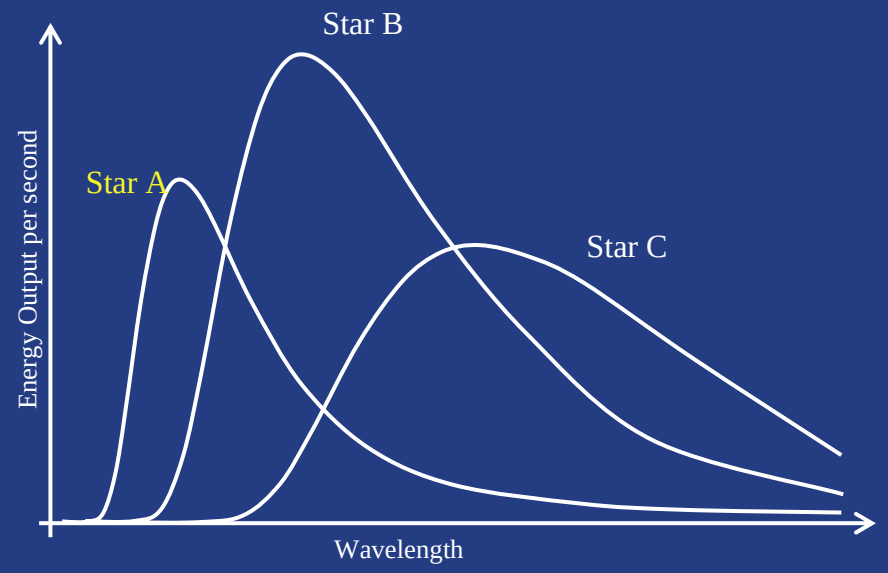
Blackbody Radiation LT

The graph at right shows the blackbody spectra for three different stars. Which of the stars is at the highest temperature?

a) Star A

b) Star B

c) Star C



- Before Lecture (N=42): 12% correct

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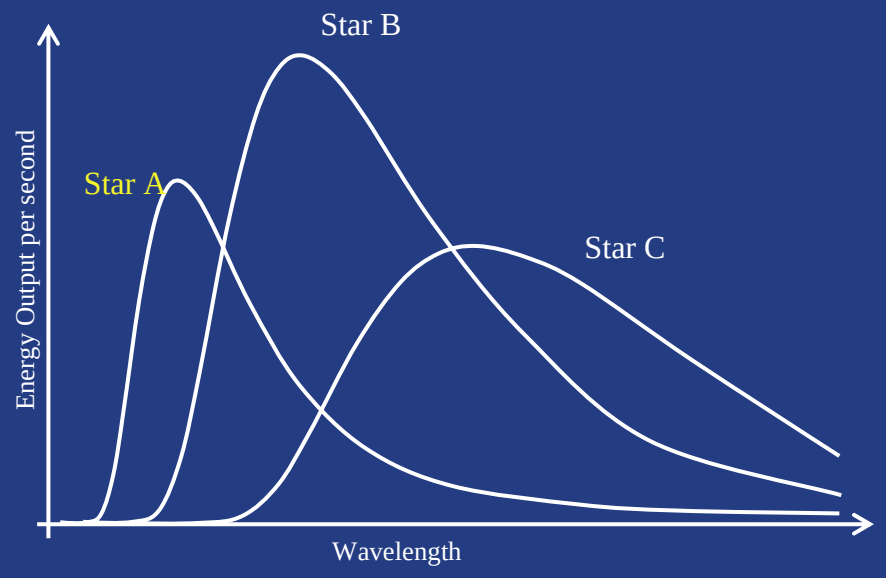

- Before Lecture (N=42): 12% correct
- After Lecture (N=120): 16% correct

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H-R Diagrams and Spectral Class

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

a) luminosity.
b) temperature.
c) absolute magnitude.

- Before Lecture (N=39): 41% correct

H-R Diagrams and Spectral Class

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

a) luminosity.

b) temperature.

c) absolute magnitude.

- Before Lecture (N=39): 41% correct
- After Lecture (N=86): 48% correct

Expansion of the Universe

If our universe is expanding, what are the implications for the separation between two stars within our galaxy?

a) The two stars are moving farther apart.
b) The two stars are moving closer together.
c) The two stars are remaining approximately the same distance apart.

- Before Lecture (N=39): 19% correct

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a) The two stars are moving farther apart.
b) The two stars are moving closer together.
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- Before Lecture (N=39): 19% correct
- After Lecture (N = 85): 27% correct

Looking at Distant Objects

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- Before Lecture (N=39): 53% correct

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d) The person that is farther from you is actually the older of the two people.

- Before Lecture (N=39): 53% correct
- After Lecture (N = 94): 51% correct

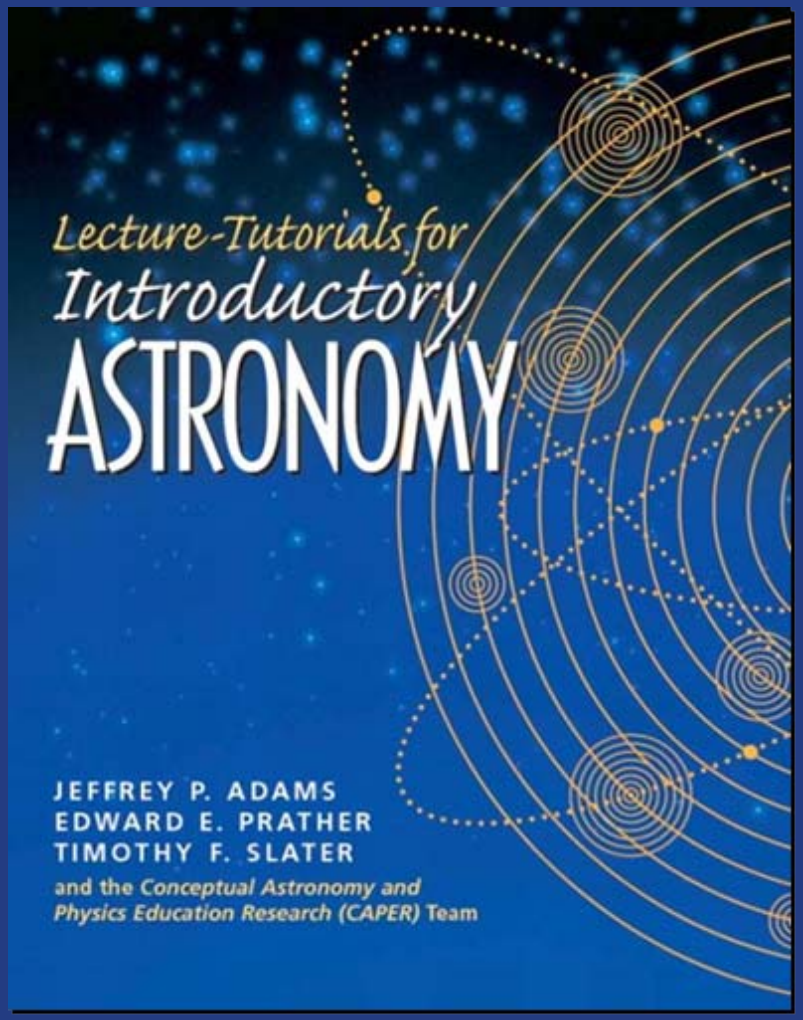
Assumption #1: Lecture is ineffective at promoting deep conceptual change.

- Instrument used: A 68 items research based multiple choice questionnaire
- Pre-Course: two forms, A&B, which each contained a subset of questions
- Post-Lecture: questions administered in subsets that directly reflected topic of lecture

Pre-Course mean: 30% (nA=39,nB=42)
Post-Lecture mean: 52% (n ~ 100)

So What Can You Do About It?

- Lecture more loudly?
- It's *not what the instructor does* that matters; rather, it is *what the students do* that matters
- Create a learner-centered environment that promotes the intellectual engagement of your students
- For large-enrollment lectures, we created *Lecture-Tutorials for Introductory Astronomy*



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Development of **Lecture-Tutorials** *for Introductory Astronomy*

- Based on the topics faculty most often cover
- Require 15-minutes and are designed for easy implementation into existing traditional lecture courses
- Socratic-dialogue driven, highly-structured collaborative learning activities designed to:
  - elicit misconceptions
  - confront naïve, incomplete, or inaccurate ideas
  - resolve contradictions
  - demonstrate the power of *THEIR* conceptual models

Idealized Classroom Implementation

- Professor lectures for approximately 20 minutes
- Students are posed a conceptually challenging question on the presented lecture material
- If less than 50% can answer it correctly, then the class breaks into teams of two and work through the lecture-tutorial activity
- Professor “debriefs” the activity interactively highlighting the difficulties in reasoning and common problems
- Professor returns to lecture mode for remaining time

Drum roll please

Lecture-Tutorial

Motion

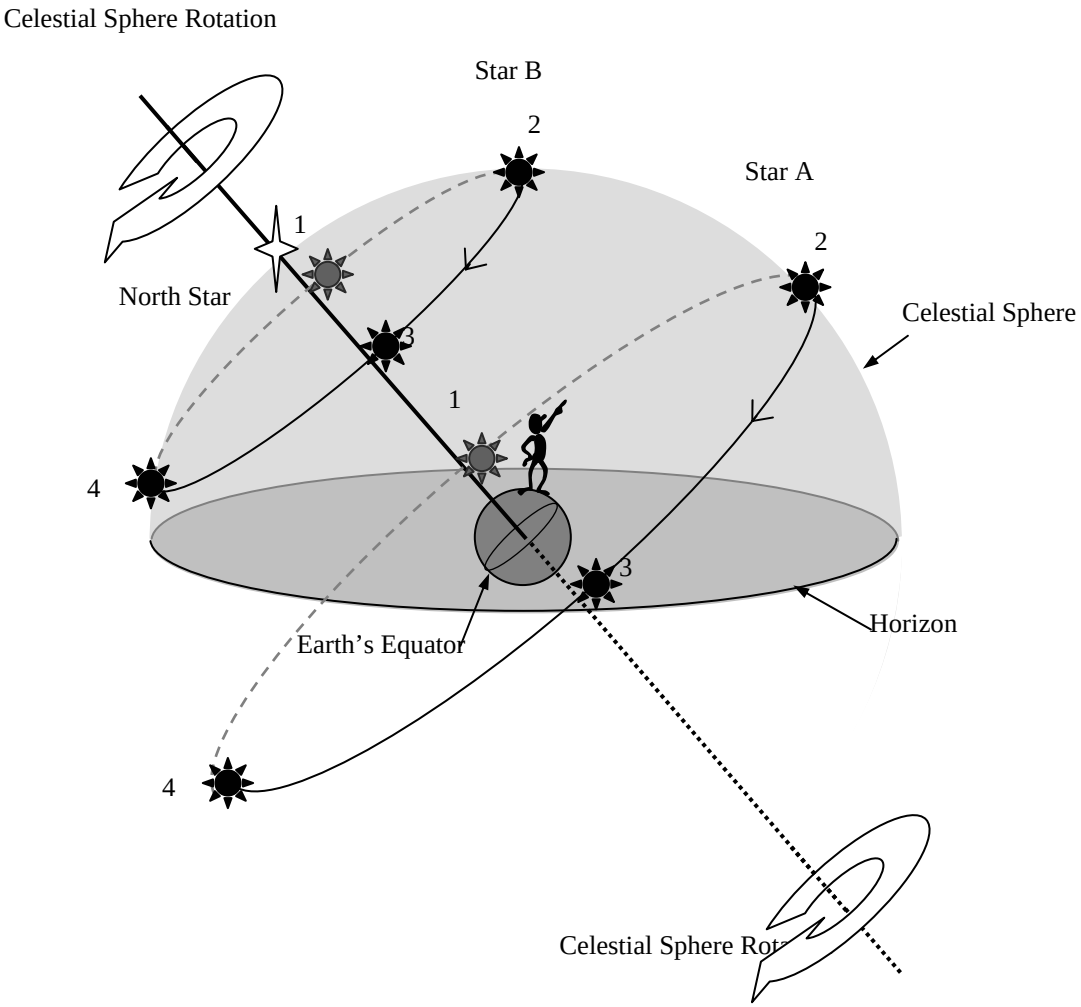

Figure 1

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Part I: Looking North

You are in the northern hemisphere at 6 PM. Looking north, the sky appears as shown in Figure 1. The positions and motions of the stars in Figure 1 can be understood by imagining yourself as the observer at the center of the **celestial sphere** as shown in Figure 2. In the celestial sphere model, the Earth is stationary and the stars are carried on a sphere that rotates about an axis through the North Star.

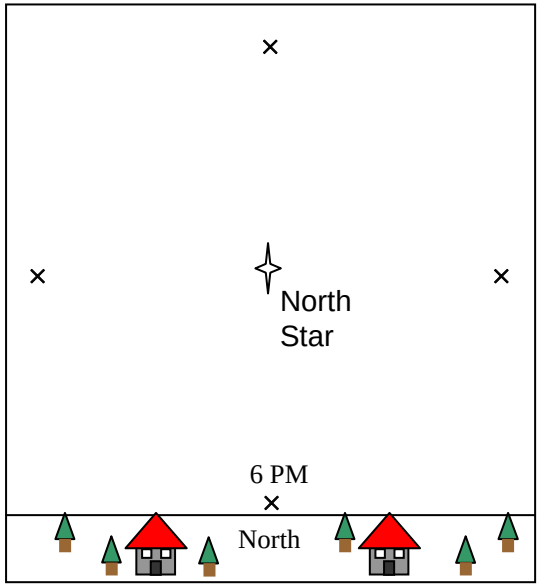


Figure 1

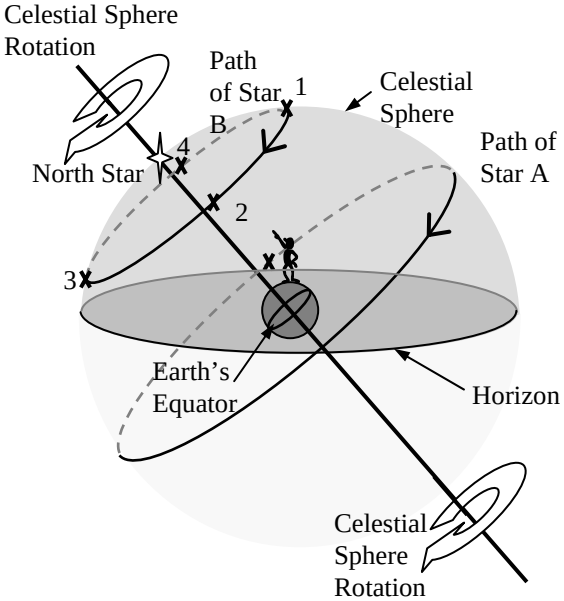
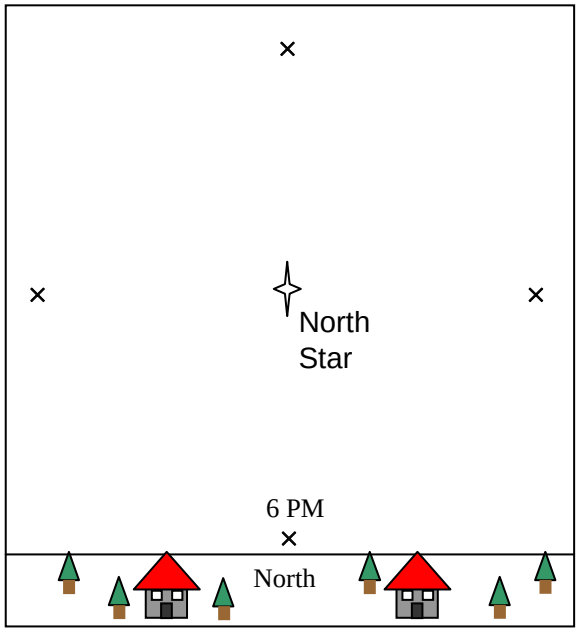
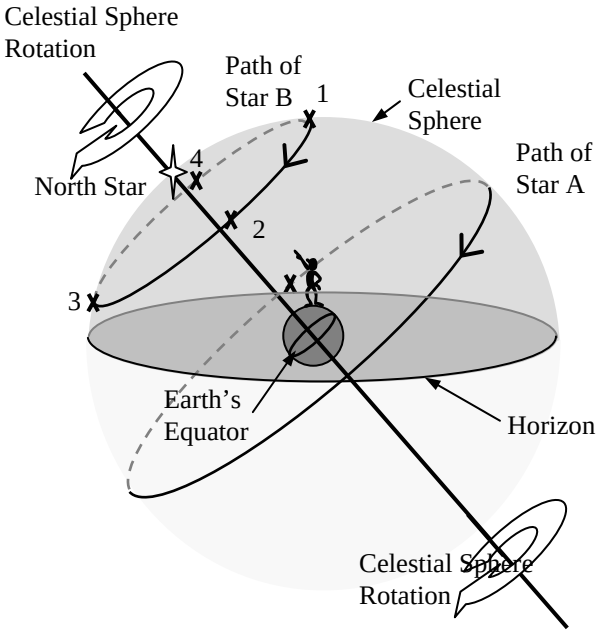


Figure 2

The ×'s in both figures represent the positions through which star B will pass during the course of one revolution of the celestial sphere. Ignore star A until question 5.

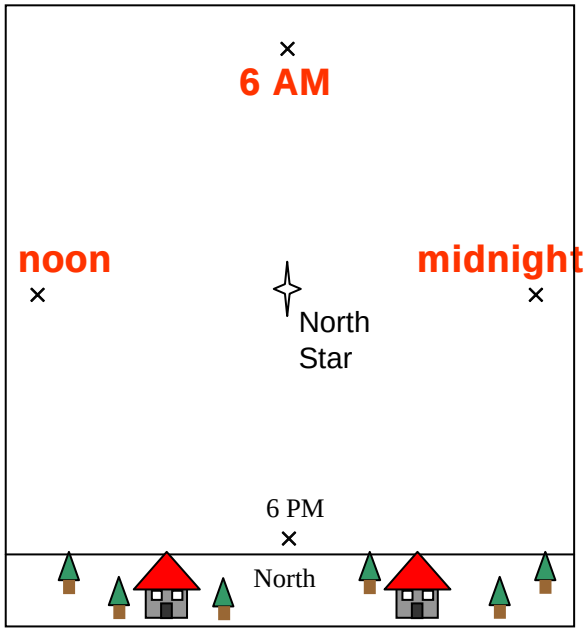


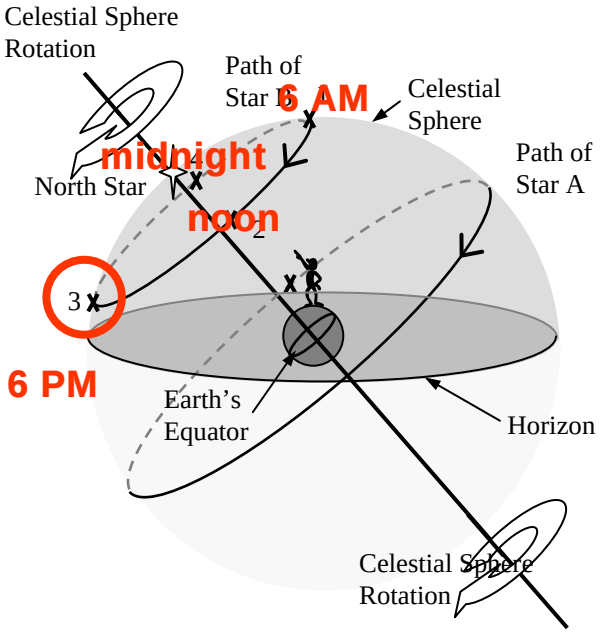


1) Note in Figure 1 the position of Star B at 6 PM. Circle the numbered position (1, 2, 3, or 4) in Figure 2 that corresponds to the location of star B at 6 PM.

2) The rotation of the celestial sphere carries star B around so that it returns to the same position at about 6 PM the next evening. Label each of the (x's in both figures with the approximate time at which star B will arrive (e.g., the location you circled in question 1 will labeled "6 PM").

3) Using Figure 2, describe the direction you have to look to see Star B at 6 AM.

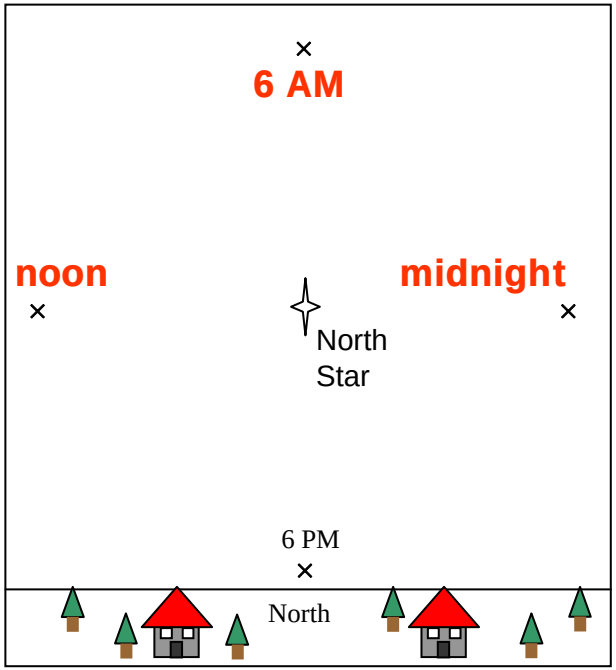


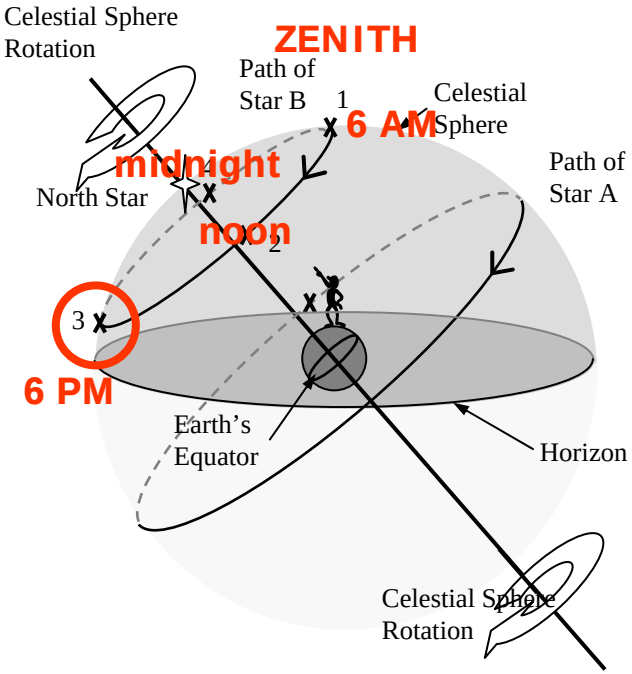


1) Note in Figure 1 the position of Star B at 6 PM. Circle the numbered position (1, 2, 3, or 4) in Figure 2 that corresponds to the location of star B at 6 PM.

2) The rotation of the celestial sphere carries star B around so that it returns to the same position at about 6 PM the next evening. Label each of the (x's in both figures with the approximate time at which star B will arrive (e.g., the location you circled in question 1 will labeled "6 PM").

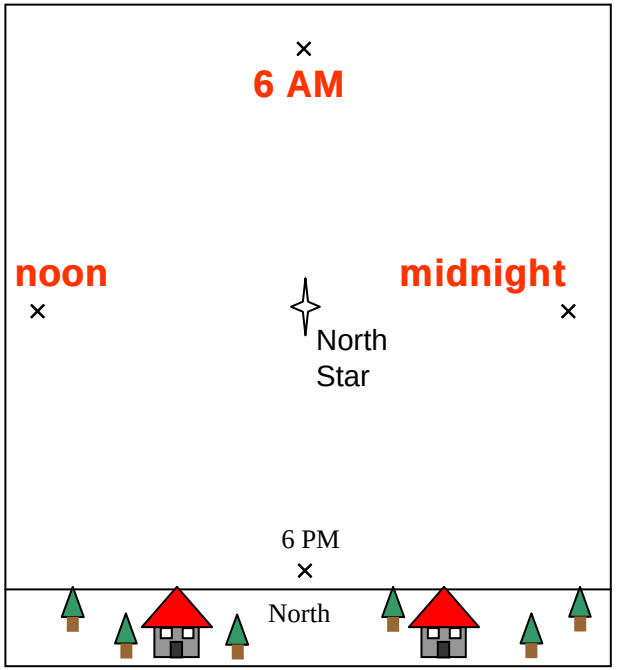
3) Using Figure 2, describe the direction you have to look to see Star B at 6 AM. **overhead**

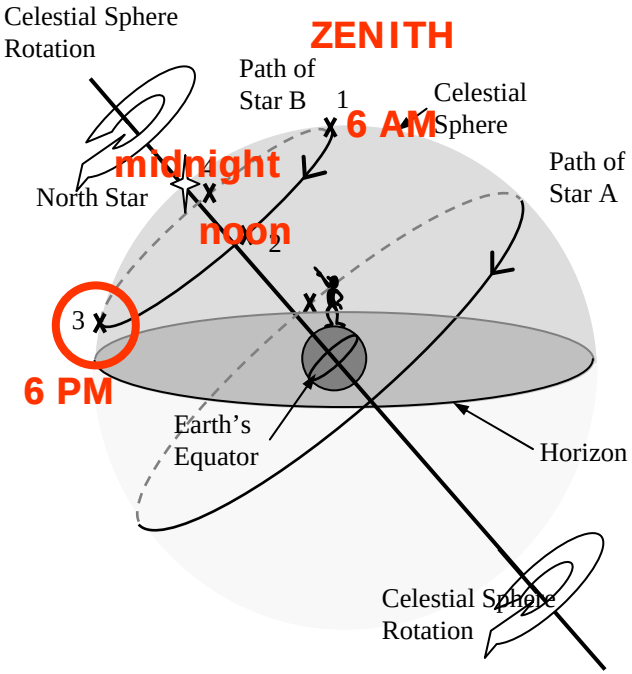




4) The position directly overhead is called the **zenith**. Label the direction of the zenith on Figure 2. How does the direction of the zenith compare to the direction that you identified in question 3? .

5) Using Figure 2, describe in words the position of Star A half way between rising and setting. High in the southern sky.





6) In Figure 1, use a dotted line to draw the entire path that Star B takes over the course of 24 hours. Next, draw an arrowhead on the path you just drew to represent the direction Star B would be moving when at each of the four locations marked with an ×. Check your answers with a nearby group.

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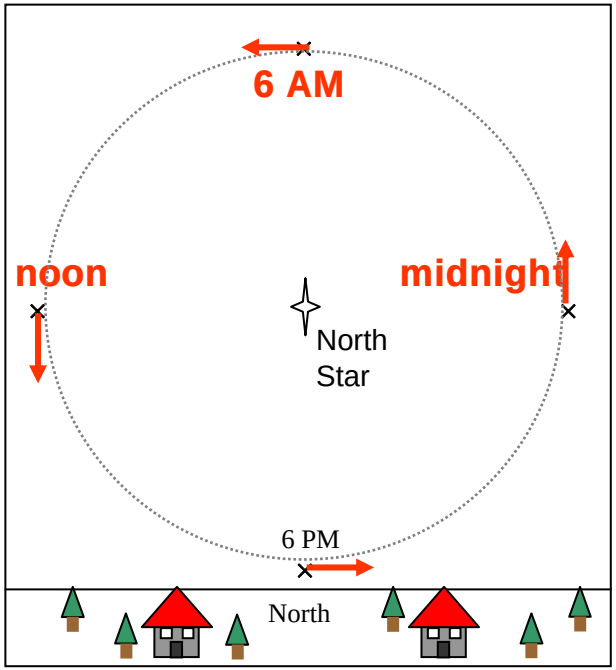

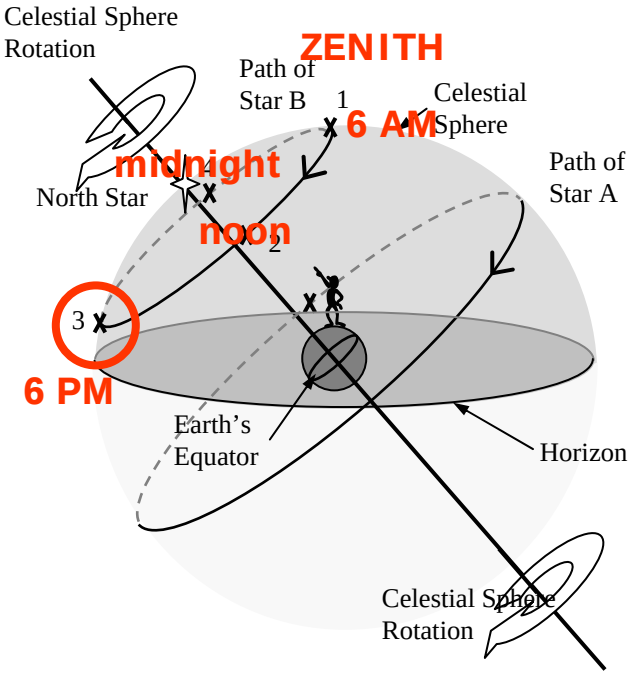

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Figure 3 extends your view along the eastern horizon showing the positions of stars A and B at 6 PM.

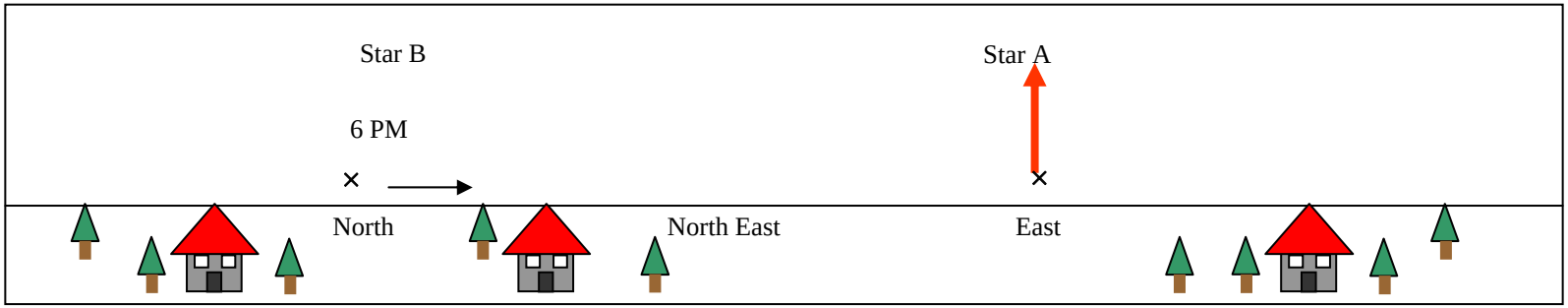

Figure 3

7) Recall that in question 5, you found that Star A ends up high in the southern sky half way between rising and setting (and therefore never passes through your zenith). Draw a straight arrow at the x in the east in Figure 3 showing the direction the star moves as it rises. Studying Figure 2 can also help clarify your answer.

8) Two students are discussing the direction of motion of a star rising directly in the east.

Student 1: *Stars move east to west so any star rising directly in the east must be moving straight up so that it can end up in the west. If the arrow were angled, the star would not set in the west.*

Student 2: *I disagree. From Figure 2, the path of Star A starts in the east, swings through the southern sky yet still sets in the west. To do this it has to move toward the south as it rises so I drew my arrow angled to the right.*

Do you agree with Student 1, Student 2, both, or neither? Why?

Figure 3 extends your view along the eastern horizon showing the positions of stars A and B at 6 PM.

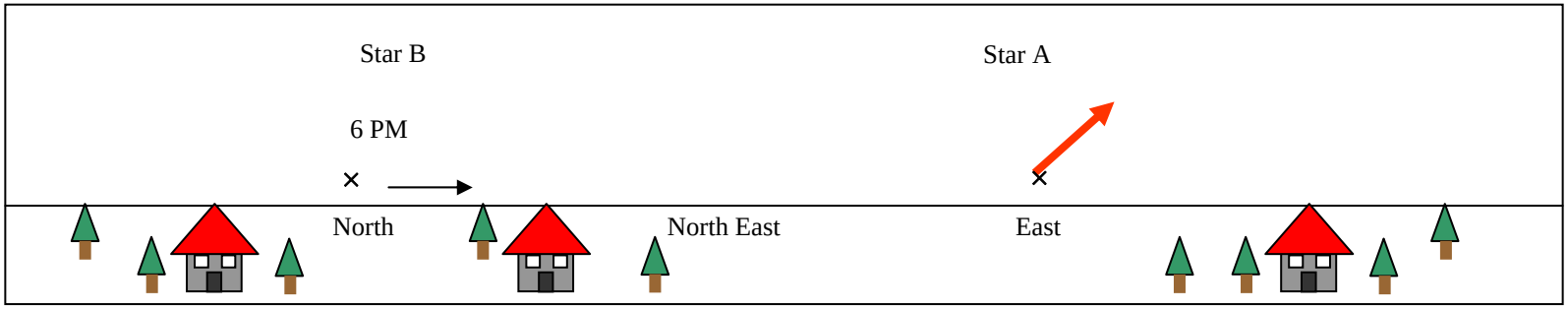

Figure 3

7) Recall that in question 5, you found that Star A ends up high in the southern sky half way between rising and setting (and therefore never passes through your zenith). Draw a straight arrow at the x in the east in Figure 3 showing the direction the star moves as it rises. Studying Figure 2 can also help clarify your answer.

9) Imagine you could see Star B at noon. Fifteen minutes later, in what direction will Star B have moved? Explain your reasoning.

10) Consider the student comment below.

Student: *The amount of time that all stars are visible above the horizon is 12 hours because it takes 12 hours for a star to rise in the east and then set in the west.*

Do you agree or disagree with this student statement? Why?

11) Consider the following debate between two students regarding the motion of the Sun and constellations shown in Figures 4 and 5.

Student 1: *We know the Sun rises in the east and moves through the southern part of the sky and then sets in the west. Eight hours after sunrise, it makes sense that the Sun will have moved from being on the eastern horizon near the constellation Cancer to being located high in the southwestern sky near the constellation Aries.*

Student 2: *You're forgetting that the stars and constellations also move from the east through the southern sky and to the west just like the Sun. So, the Sun will still be near Cancer eight hours later. So Figure 5 is drawn incorrectly. It should show that the constellations have all moved like the Sun, so Cancer would also be located high in the southwestern sky, with the Sun, eight hours later.*

Do you agree or disagree with either or both of the students? Why? Check your answers with a nearby group.

Topics

- Light and EM Spect.
- Trig. Parallax
- Cosmology and B.B.
- Telescopes and Star Maps
- Solar System
- Our Sun
- Solar System Motion
- Moon Phases
- Stellar Evolution
- Char. of Milky Way
- Celestial Sphere
- Stellar Magnitudes
- Stellar Spectra

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- **Moon Phases**
- Stellar Evolution
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- Stellar Spectra

Topics

- Cause of Moon Phases
- Predicting Moon Phases

Consider the following debate between two students about the cause of the phases of the Moon.

Which, if either, do you agree with and why?

Student 1: *The phase of the Moon depends on how the Moon, Sun and Earth are aligned with one another. During some alignments only a small portion of the Moon's surface will receive light from the Sun, in which case we would see a crescent moon.*

Consider the following debate between two students about the cause of the phases of the Moon. Which, if either, do you agree with? Why?

Student 1: *The phase of the Moon depends on how the Moon, Sun and Earth are aligned with one another. During some alignments only a small portion of the Moon's surface will receive light from the Sun, in which case we would see a crescent moon.*

Student 2: *I disagree. The moon would always get the same amount of sunlight it's just that in some alignments Earth casts a larger shadow on the Moon. That's why the Moon isn't always a full moon.*

What Do You Do During a Small Group Activity?

- This is the chance to actually get to talk with your students about concepts.
- Ask two nearby groups if they are getting the same answer and to account for any differences.
- Ask a group if there were any other possible answers that someone might come up with.
- Pull in non-participants by asking them why the group answered the way that they did and if he agrees with them.
- Offer additional questions that help students engage with the concepts.
- Circle the wagons afterward (*i.e., debrief*)

Always in pursuit of the ***TEACHABLE MOMENT***

Predicting Moon Phases

Which of the following is possible?

a) a waxing crescent Moon on the eastern horizon just after sunset.

b) a waning gibbous on the western horizon just after sunset.

c) a waning crescent Moon on the eastern horizon just before sunrise.

d) a full Moon on the western horizon at sunset

e) a first quarter moon rising at dawn.

Predicting Moon Phases

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e) a first quarter moon rising at dawn.

Modern Topics too!!

- Milky Way Scales
- Expansion of the Universe
- Looking at Distant Objects

An Abridged Lecture-Tutorial Example from Looking at Distant Objects

7. The telescope image at the right was taken of the Andromeda Galaxy, which is located 2.5 million ly away from us. Is this an image showing how the Andromeda Galaxy looks right now, how it looked in the past, or how it will look in the future? Explain your reasoning.

An Abridged Lecture-Tutorial Example from Looking at Distant Objects

8. Imagine that you were observing a distant star that was located in a galaxy 100 million ly away from you. By analysis of the starlight received, you are able to tell that the image we see is of a 10 million year old star. You are also able to predict that the star will have a lifetime of 50 million years, at which point it will end in a catastrophic supernova.

a) How old does the star appear to us here on Earth?

b) How long will it be before we receive the light from the supernova event?

c) Has the supernova already occurred? If so, when did it occur?

Assumption #2: *Lecture-Tutorials* can intellectually engage students at a level that is more effective than traditional lecture at promoting deep conceptual change.

- Post *Lecture-Tutorial*: questions administered in subsets
  - ✓ Pre-Course mean: 30% (nA=39,nB=42)
  - ✓ Post-Lecture mean: 52% (n ~ 100)

Celestial Motion of Objects

You observe a star rising directly to the east. When this star reaches its highest position above the horizon, where will it be?

a) high in the northern sky
b) high in the eastern sky
c) high in the southern sky
d) high in the western sky
e) directly overhead

- Before Lecture (N=42): 2% correct
- After Lecture (N = 135): 19% correct

Celestial Motion of Objects

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c) high in the southern sky
d) high in the western sky
e) directly overhead

- Before Lecture (N=42): 2% correct
- After Lecture (N = 135): 19% correct
- After Lecture Tutorial (N=134): 66% correct

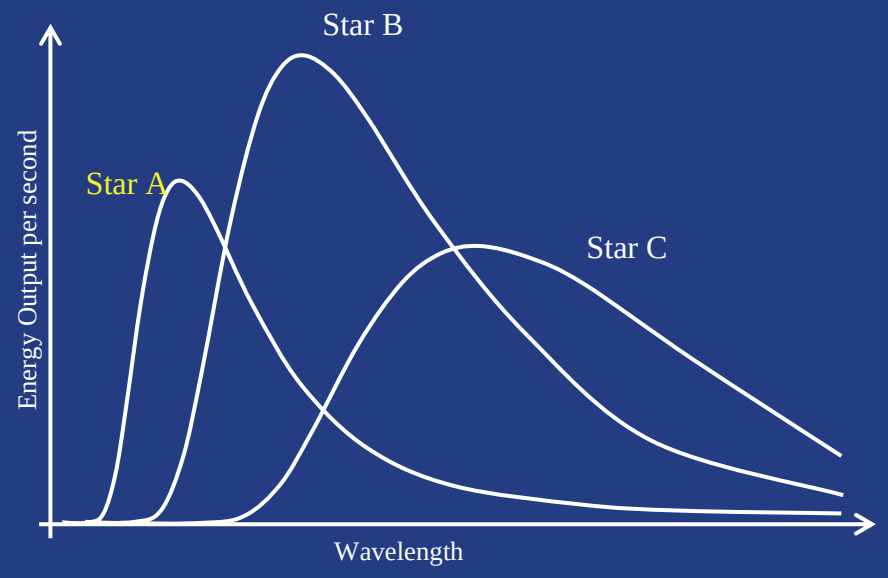
Blackbody Radiation LT

The graph at right shows the blackbody spectra for three different stars. Which of the stars is at the highest temperature?

a) Star A

b) Star B

c) Star C



- Before Lecture (N=42): 12% correct
- After Lecture (N=120): 16% correct

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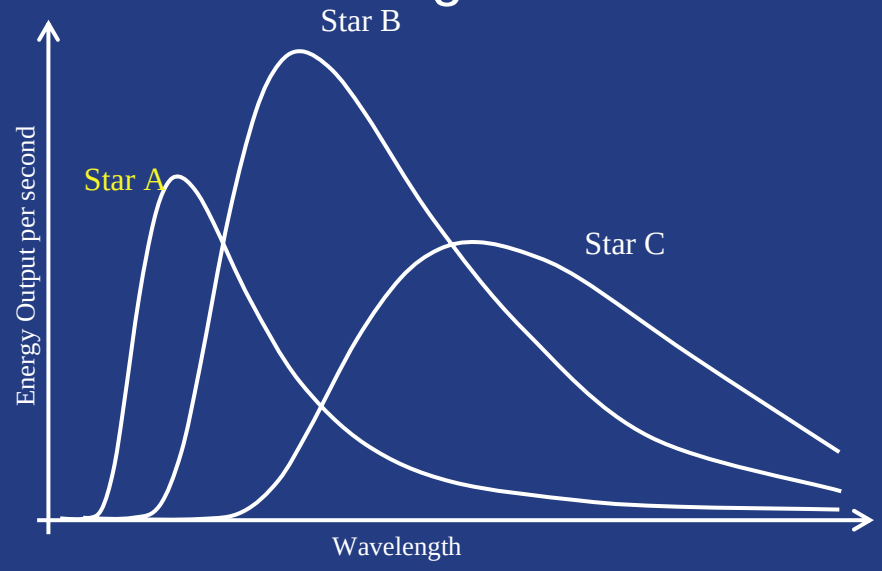
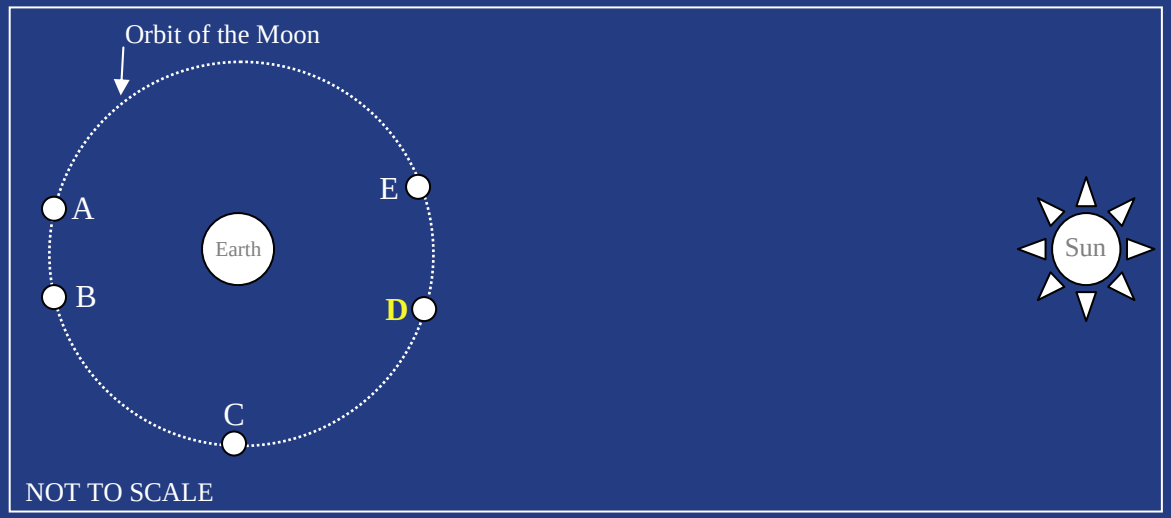


- Before Lecture (N=42): 12% correct
- After Lecture (N=120): 16% correct
- After Lecture Tutorial (N=80): 80% correct

What Causes Moon Phases

The diagram below shows Earth and the Sun as well as five different possible positions for the Moon. Which position of the Moon best corresponds with the phase of the Moon shown in the figure at the right?



- Before Lecture (N=42): 5% correct
- After Lecture (N=127): 53% correct

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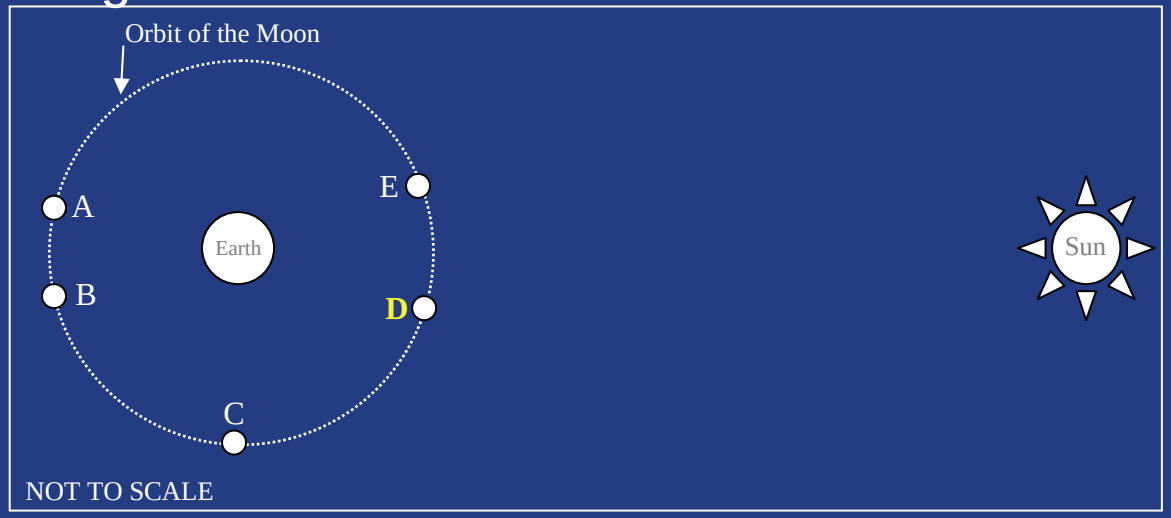

- Before Lecture (N=42): 5% correct
- After Lecture (N=127): 53% correct
- After Lecture Tutorial (N=104): 72% correct

H-R Diagrams and Spectral Class

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

a) luminosity.

b) temperature.

c) absolute magnitude.

- Before Lecture (N=39): 41% correct
- After Lecture (N=86): 48% correct

H-R Diagrams and Spectral Class

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

a) luminosity.

b) temperature.

c) absolute magnitude.

- Before Lecture (N=39): 41% correct
- After Lecture (N=86): 48% correct
- After Lecture Tutorial (N=83): 73% correct

Expansion of the Universe

If our universe is expanding, what are the implications for the separation between two stars within our galaxy?

a) The two stars are moving farther apart.
b) The two stars are moving closer together.
c) The two stars are remaining approximately the same distance apart.

- Before Lecture (N=39): 19% correct
- After Lecture (N = 85): 27% correct

Expansion of the Universe

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b) The two stars are moving closer together.
c) The two stars are remaining approximately the same distance apart.

- Before Lecture (N=39): 19% correct
- After Lecture (N = 85): 27% correct
- After Lecture Tutorial (N=75): 56% correct

Looking at Distant Objects

Imagine that you simultaneously receive the satellite transmission of two pictures of two people that live on planets orbiting two different stars. Each image shows the people at their 21st birthday parties. Consider the following possible interpretations that could be made from your observations. Which do you think is the most plausible interpretation?

a) Both people are the same age but at different distances from you.
b) The people are actually different ages but at the same distance from you.
c) The person that is closer to you is actually the older of the two people.
d) The person that is farther from you is actually the older of the two people.

- Before Lecture (N=39): 53% correct
- After Lecture (N = 94): 51% correct

Looking at Distant Objects

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d) The person that is farther from you is actually the older of the two people.

- Before Lecture (N=39): 53% correct
- After Lecture (N = 94): 51% correct
- After Lecture Tutorial (N=77): 77% correct

Assumption #2: *Lecture-Tutorials* can intellectually engage students at a level that is more effective than traditional lecture at promoting deep conceptual change.

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  - ✓ Post-Lecture mean: 52% (n ~ 100)
  - ✓ Post-Lecture Tutorial: 72% (n ~ 100)

Qualitative Results
(focus group)

Students believe that the tutorials are one of the greatest strength of the class

- *"I liked the Tutorial, they were very helpful. I am not a science person but feel that I learned a lot from them.*
- *"Why don't all professors use tutorials during class?"*
- *"The student interaction and tutorials are a very effective approach to both teaching and learning. I guarantee most students will retain most of this course."*

Qualitative Results
(interview)

"And then the tutorials? I don't know who ever thought of that. But it's really how classes should be taught….The tutorials [review concepts] because they break it down. You start with something so simple…and then it slowly gets to more." –Marti

Qualitative Results
(interviews)

"I know the worksheets are real helpful. I found it sometimes hard to talk to as many people as I wanted to talk to and finish the worksheet in time." – Joe

But wait there is more!!

For those of you who prefer to emphasize quantitative or mathematical reasoning we have created - Ranking Tasks for Introductory Astronomy

Critical Questions

- What are your beliefs about teaching and learning that guide your instruction?
- How do YOU want your students to be different as a result of the experiences you design?
- What do we know about how STUDENTS learn?
- What are some strategies and resources to actively engage students in learning?
- What evidence would you accept that students made significant gains in conceptual, attitudinal, and skill domains?

What Do I Do During a Small Group Activity?

- This is the chance to actually get to talk with your students about concepts.
- Ask two nearby groups if they are getting the same answer for #3.
- Ask a group if there were any other possible answers to #6.
- Pull in non-participants by asking them why the group answered #9 the way that they did and if he agrees with them.
- Offer additional questions that help students engage with the concepts.
- Circle the wagons afterward (*i.e., debrief*)

What Do I Do During a Small Group Activity?

- This is the chance to actually get to talk with your students about concepts.
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Always in pursuit of the ***TEACHABLE MOMENT***

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- Circle the wagons afterward (*i.e., debrief*)

Some Benefits to Doing Activities in Groups

- Capitalize on students in your class who like to socialize
- Revisit complicated concepts in ways besides lecture
- Actually talk to your students about concepts
- Emphasize learning during class time
- Demonstrate to students that science is about doing stuff, not memorizing lists of facts
- Less papers to grade if you have them turn in one paper per group

Critical Questions

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Case Study

- Read the “Number 2” case study from the *Case Studies Booklet for Introductory Science Teaching*.
- Before you talk to your neighbor, write down two possible responses that you might give to Jeff as his *educational therapist* .

Do they understand?

Critical Questions

- What are your beliefs about teaching and learning that guide your instruction?
- How do YOU want your students to be different as a result of the experiences you design?
- What do we know about how STUDENTS learn?
- What are some strategies and resources to actively engage students in learning?
- What evidence would you accept that students made significant gains in conceptual, attitudinal, and skill domains?

Improving Testing and Grading in ASTRO 101

WHAT IS ASSESSMENT?

- What is assessment?

THE IMPORTANCE OF GRADES: A HUMAN CONTINUUM

Let's form a single line of individuals from one end of the room to the other.

To the **front-most** should be individuals who believe grading is primarily a waste of time, is not worth the hassle and discomfort caused by student questions, and who would even prefer to work in one of the several institutions that don't even give letter grades.

To the **back-most** should be individuals who think grading is a very valuable use of your time, students benefit greatly from grades, and that education cannot possibly work without them.

Talk to the people next to you to be sure you know if you should be standing to their right or to their left. Pay careful attention to your own beliefs and experiences. Don't forget to introduce yourself.

The Montillation of Traxoline

(attributed to the insight of Judy Lanier)

It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then brachter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

Directions: Answer the following questions in complete sentences. Be sure to use your best handwriting.

1. What is traxoline?
2. Where is traxoline montilled?
3. How is traxoline quaselled?
4. Why is it important to know about traxoline?

What Does it Mean to Really Understand a Concept?

The student needs to be able to:

- State it
- Explain it explicitly
- Apply it appropriately
- Reason with it
- Generalize with it
- Integrate it with related concepts

Bloom's Taxonomy of Educational Objectives for Knowledge-Based Goals

Level of Expertise

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

Bloom's Taxonomy of Educational Objectives for Knowledge-Based Goals

Level of Expertise	Description of Level
Knowledge	Recall, or recognition of terms, ideas, procedure, theories, etc.
Comprehension	Translate, but not transfer to other situations, closer to literal translation.
Application	Apply abstractions, general principles, or methods to specific concrete situations.
Analysis	Separation of a complex idea into its constituent parts as well as between relevant and extraneous variables.
Synthesis	Create ideas from multiple sources.
Evaluation	Make judgments of ideas using external evidence.

Bloom's Taxonomy of Educational Objectives for Knowledge-Based Goals

Level of Expertise	Description of Level	Example of Measurable Outcome
Knowledge	Recall, or recognition of terms, ideas, procedure, theories, etc.	Student can name the components of a simple clock.
Comprehension	Translate, but not transfer to other situations, closer to literal translation.	Student knows the purpose of each component of a simple clock.
Application	Apply abstractions, general principles, or methods to specific concrete situations.	Student describes how changing gears impact accuracy
Analysis	Separation of a complex idea into its constituent parts as well as between relevant and extraneous variables.	Given an inaccurate clock, the student can design experiments to determine the cause of the malfunction.
Synthesis	Create ideas from multiple sources.	Given a collection of clock parts, the student can design a clock that meets given specifications.
Evaluation	Make judgments of ideas using external evidence.	Given several novel alarm clock designs, the student can articulate the advantages and disadvantages of designs.

Transferring Your Own Goals Into Measurable Student Outcomes

Working with the person next to you, agree upon a Knowledge-Based goal that is important to both of you (maybe one from your top three goals list?).

Using the Bloom's Taxonomy blank worksheet in your packet, create a measurable student outcome for each level of Bloom's Taxonomy.

Bloom's Taxonomy of Educational Objectives for Knowledge-Based Goals

Level of Expertise
Knowledge
Comprehension
Application
Analysis
Synthesis
Evaluation

- Which of these levels was the easiest to create a measurable student outcome for?
- Which of these levels was the hardest to create a measurable student outcome for?
- What about the time it takes students to answer these questions? How about to grade?
- How might this translate to creating homework tasks and test questions?

Bloom's Taxonomy of Educational Objectives for Knowledge-Based Goals

Level of Expertise	Description of Level	Example of Measurable Outcome
Knowledge	Recall, or recognition of terms, ideas, procedure, theories, etc.	Student states when the first day of Spring is.
Comprehension	Translate, but not transfer to other situations, closer to literal translation.	Student describes what the summer solstice means.
Application	Apply abstractions, general principles, or methods to specific concrete situations.	Student explains why seasons reversed in the southern hemisphere.
Analysis	Separation of a complex idea into its constituent parts as well as between relevant and extraneous variables.	Student can analyze what Earth's seasons would be like if its orbit was perfectly circular.
Synthesis	Create ideas from multiple sources.	Given a description of a planet's seasons, student can propose plausible orbital and tilt characteristics.
Evaluation	Make judgments of ideas using external evidence.	Student can distinguish what would be the important, and irrelevant, variables for predicting seasons on a newly discovered planet.

Field Tested Learning Assessment Guide (FLAG)

www.flaguide.org

- NSF-supported collaborative project of the National Institute for Science Education (housed at Univ. Wisconsin)
- Includes classroom-ready examples, theoretical foundation, and personal testimonials about strengths and weaknesses of a variety of strategies

www.flaguide.org

- Multiple Choice Tests
- Short Answer and Essay Tests
- Homework Sets and Papers
- Mathematical Thinking Tasks and Context Rich Problems
- Concept Maps
- Presentations

- Performance Assessment
- Portfolio Assessment
- Attitude Surveys
- Student Self-Assessment of Learning Gains
- Conceptual Diagnostics Tests

Field-Tested Learning Assessment Guide from the National Institute for Science Education

Taking a Small Step Toward Change:

Improving Your Multiple-Choice Test

Assessment Drives Student Learning:

The challenge of creating multiple-choice tasks lies in moving beyond rote memorization, and basic recognition of names, to the analysis of complex ideas, and the synthesis of concepts, to create new ideas.

Bottom Line:

Poorly constructed multiple-choice items often have the unintended effect of helping the students who do not understand select the correct answer and the students who do understand select incorrect answers.

Correcting Common Errors in Constructing Multiple-Choice Items

- **Focus on more than vocabulary.** Otherwise, students will only memorize the bold-faced words (don't laugh, this strategy works in far too many classes!).
- **Include only one central idea in each test item.** Otherwise, you won't know which part the students don't understand.
- **Don't increase the difficulty** of an item by being ambiguous or using vocabulary. Rather, increase the difficulty level of items by making the options more similar.
- **Make questions independent from other items.** Otherwise, you'll give the answers to one question in another question.

Correcting Common Errors in Constructing Multiple-Choice Items

- If a concept is really important, there should be **multiple questions** about it so that students who really understand have more chances to demonstrate it.
- Always have someone **proofread** your items and tell you what they think the right answers are!
- **Keep questions short**, otherwise you'll test reading ability rather than science understanding.
- As **amateur test writers**, we often make A or B correct more frequently than C or D. In other words, tell students if they don't know the right answer, and they are just going to guess anyway, DO NOT guess C or D.

ARE YOU TESTING CONCEPTUAL UNDERSTANDING OR READING ABILITY?

Shorter stems and even shorter response choices are preferable. Emphasize important words such as NOT, EXCEPT, and ALWAYS in all caps.

A bad example:

The Stefan-Boltzmann law can describe the relationship among the variables of a star's luminosity, surface area, and temperature. Consider two stars, Alpha Orion and Beta Orion, which have different colors, and, of course, different temperatures. If they were to have identical luminosities, which they do not, which of the following would NOT be true:

A) the two stars, although being at different distances and having different apparent magnitudes, would have the same absolute magnitude.

B) the two stars, having the same luminosity, would have different peak wavelengths and, correspondingly different temperatures.

DO YOU GIVE CLUES TO THE CORRECT ANSWER IN YOUR QUESTION?

Items need to be carefully reviewed so that they probe student understanding rather than their ability to eliminate distractors.

A bad example:

WHICH GALAXY DO WE LIVE IN?

A) ANDROMEDA NEBULA
B) LOCAL GROUP
C) MILKY WAY GALAXY
D) NONE OF THESE

Construct items so that students can know, basically, what a question is probing by only reading the stem.
For instance, try to avoid using the stem construction:

A bad example:

Which of the following is correct?

A. The bigger the mass of the planet the bigger the force of gravity.

B. The bigger the mass of the planet the smaller the force of gravity.

C. The force of gravity is independent of the mass of the planet.

D. The nearer the planet is to the Sun the bigger is the force of gravity.

ARE YOU TESTING WHAT IS REALLY IMPORTANT TO YOU?

If you can only have 100 questions on your final exam, do they represent the enduring knowledge you really want your students to retain five years from now?

A bad example:

Isaac Newton wrote:

a) the Almagest

b) in pig latin and finger paints

c) De Revolutionibus Orbium Celestium

d) Dialogo Dei Due Massimi Sistemi

e) Philosophiae Naturalis Principia Mathematica

Propose A Way To Improve This Item

If you analyze the light emitted from a low density object (such as a cold cloud of interstellar gas), which type of spectrum do you see?

A. dark line absorption spectrum
B. bright line emission spectrum
C. continuous spectrum

What Do Item Difficulty Scores Tell Us?

Item difficulty values indicate what percentage of students get the answer correct:

EXAMPLE: An item difficulty greater than 0.70 means that more than 70% of the students answered the question correctly, implying that this was a recall question or that the correct answer was obvious.

What Do Item Discrimination (Biserial-R) Scores Tell Us?

Item discrimination values range from –1.0 to +1.0 and values near zero suggest that students that score high on the test overall may, or may not, be getting a particular item correct

EXAMPLE: An item discrimination score of +0.10 suggests that both high scoring and low scoring students answer this item correctly. If the item difficulty is high (+0.9), then the item is probably easy. If the item difficulty is low (-0.9), then the high scoring students are probably reading too much into the question and low scoring students are probably guessing answers

Handling Tough Questions

- I thought you wanted me to choose answer B because …
- I think this is a trick question …
- The test took far too long …
- English is not my first language and I need to use a dictionary …
- I have to miss the exam because …

Handling Tough Questions

- When will grades be posted …
- I need to have extra time …
- I studied all week for this exam and I still failed …
- What do I need to get on the final exam to earn a B? …
- Do you grade on the curve?
- This test was unfair because …

High Performance Grading for Busy Faculty

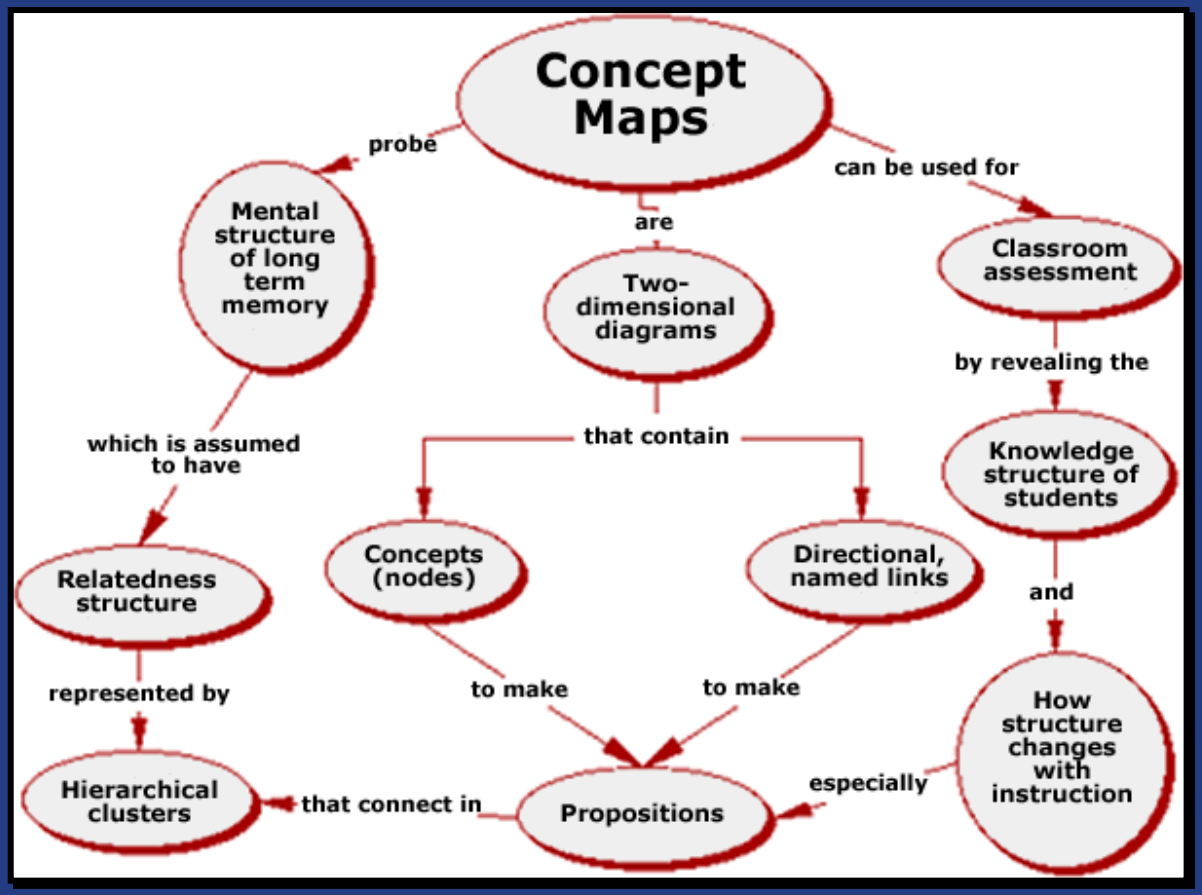
- Score 2: Essentially correct and meets expectations
- Score 1: Needs improvement (you need to look carefully at the key and perhaps see me)
- Score 0: No meaningful attempt
- Score 3: Wow, clearly exceeds expectations

High Performance Grading for Busy Faculty

- *Score 3: Wow, clearly exceeds expectations*
- *Score 2: Essentially correct and meets expectations*
- *Score 1: Needs improvement*
  (you need to look carefully at the key and perhaps see me)
- *Score 0: No meaningful attempt*

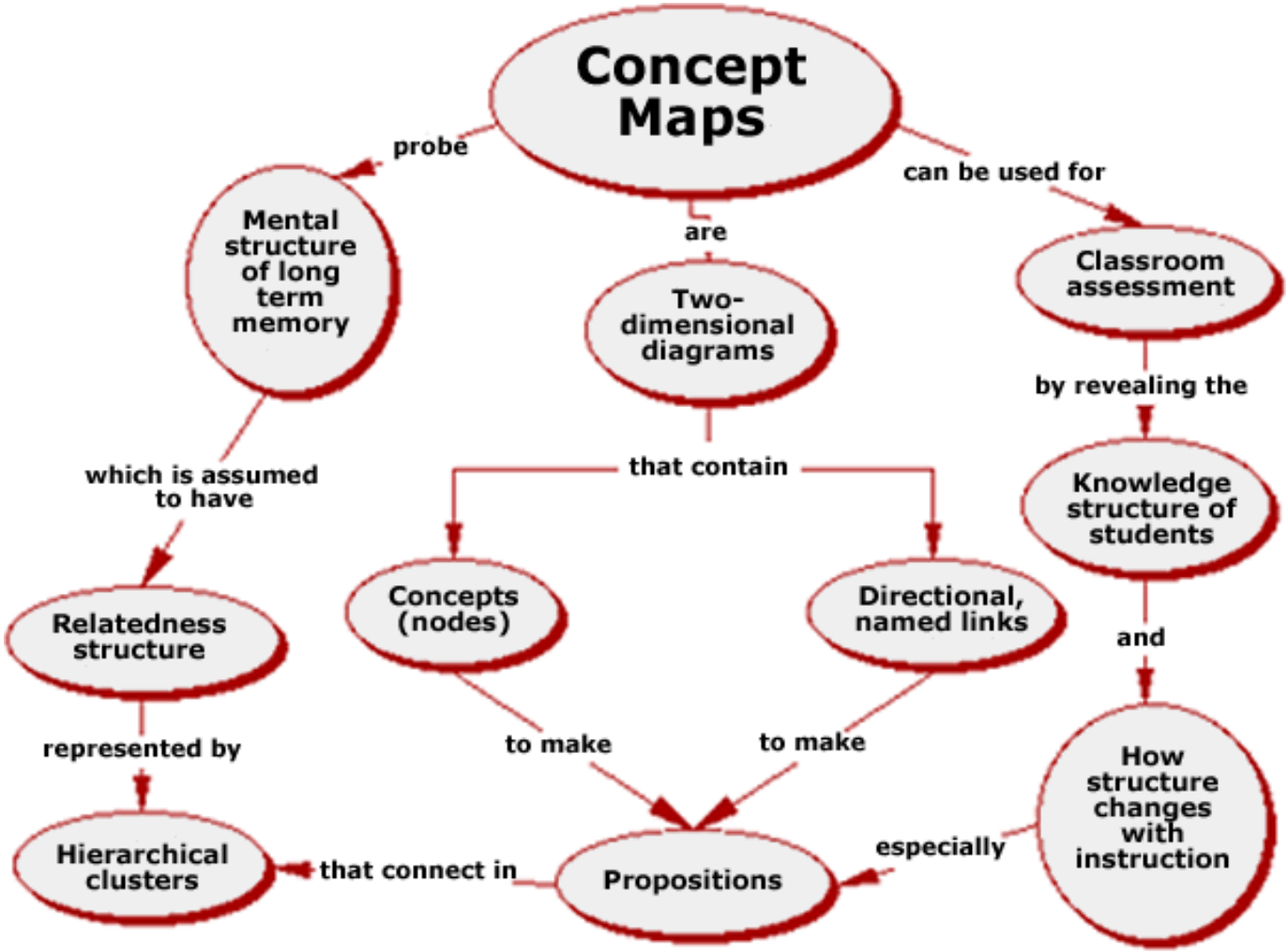
- **Tells students if they need to see the key**
- **But wait, I got a 2/3 or 66% - I failed!!**
- **If you get all "2" scores or above, you get an A!**
- **e.g., for 10 assignments, if you get eight "2" scores and no zeros you get a B**
- **e.g., if you get eight "2" scores, you get a C**

Taking a Bigger Step Toward Change:
Concepts Maps



Taking a Bigger Step Toward Change:

Concepts Maps



Stars Fill-In Map

Name:_____

Map 2 Answer List

A. composition
B. lifetimes
C. stellar evolution
D. continuous
E. luminosity
F. flux
G. stellar parallax
H. binary stars
I. temperature

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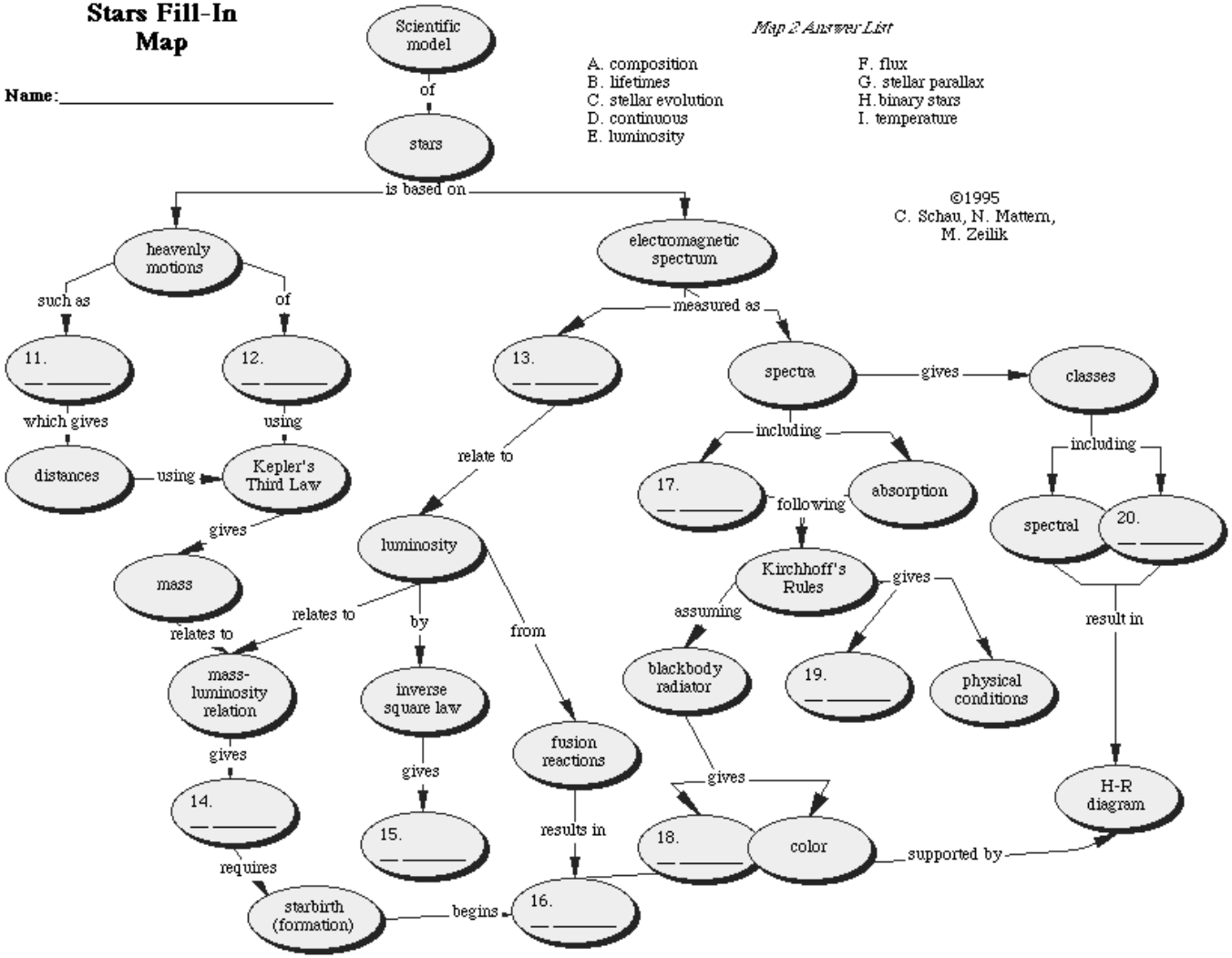

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Working in Groups to Create a Collaborative Concept Map: Seasons

Collaborative Group Roles

Leader: Keep everyone in your group focused on the question at hand.

Recorder: Form group consensus; write down your group's answers.

Skeptic: Make sure your group has looked at all angles of your question.

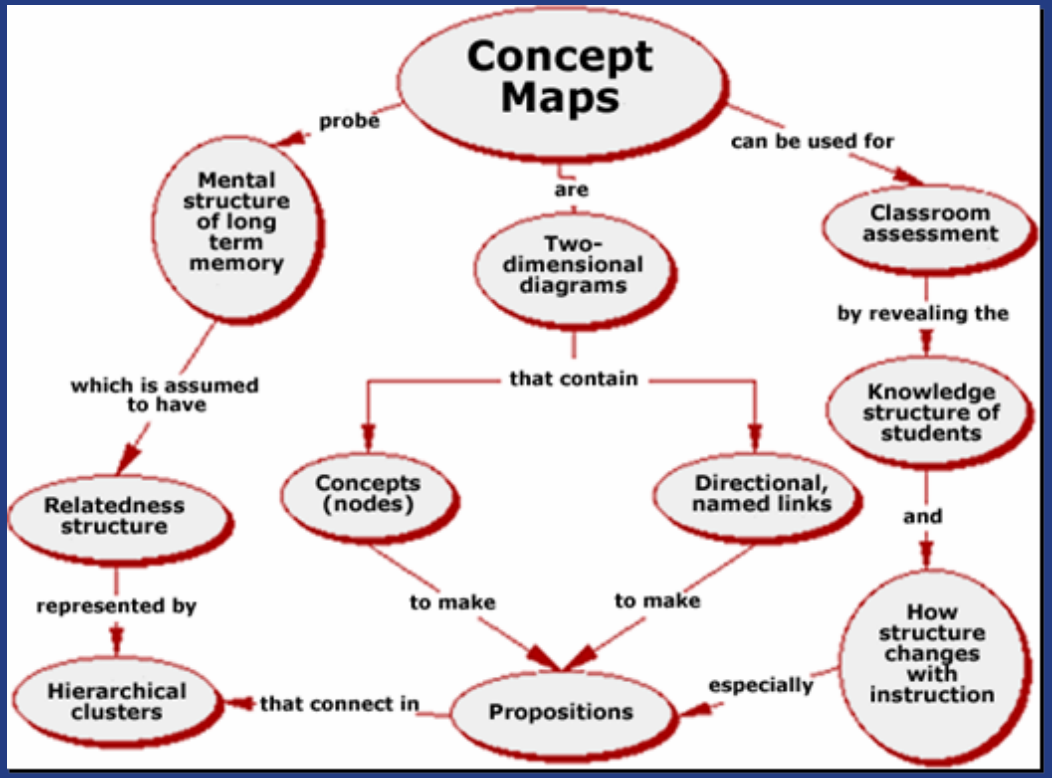
Explorer: Are there other answers that would be better than the one's you're discussing?

Your Task:

- Create a Concept Map of SEASONS.
- When you have created your map, reproduce it on an overhead so we can see the similarities and differences between our maps.

Taking a Bigger Step Toward Change:

Concepts Maps



- Collaborative
- Fill-In
- Select and Fill-In
- Selected Terms
- Seeded Terms
- Guided Choice

Taking a Bigger Step Toward Change:

Portfolio Assessment

- A purposeful collection of student work
- Provides a forum for cataloging long term growth
- Emphasizes student responsibility for demonstrating mastery

Taking a Bigger Step Toward Change: *Portfolio Assessment*

DEMONSTRATE MASTERY OF THE FOLLOWING:

•a cosmic perspective -- a broad understanding of the nature, scope and evolution of the Universe, and where the Earth and Solar System fit in

•the notion that physical laws and processes are universal

•some knowledge of related subjects (e.g., gravity and spectra from physics) and a set of useful “tools” from related subjects such as mathematics

•an acquaintance with the history of astronomy and the evolution of scientific ideas (science as a cultural process)

•familiarity with the night sky and how its appearance changes with time and position on Earth

Taking a Bigger Step Toward Change: Three Types of **Portfolio Assessment**

Showcase Portfolios
e.g., best work, most interesting, most important, most improved, most disappointing, and a personal statement

Checklist Portfolios
e.g., 10 correctly worked problem sets, two magazine article summaries, two laboratory reports, and two examinations in addition to self-reflection paragraphs where the student decides which objectives most closely fit which assignments.

Open-Format Portfolios
Students submit anything they wish to be considered as evidence for mastery of a given list of learning objectives.

Taking a Bigger Step Toward Change: *Portfolio Assessment*

Grading Criteria: Each individual piece of evidence will be graded according to the following scale:

Score 0: No evidence - the evidence is not present, it is not clearly labeled, or there is no rationale or self-reflection.

Score 1: Weak evidence - the evidence is presented is inaccurate, implies misunderstandings, has insufficient rationale or insufficient self-reflection.

Score 2: Adequate evidence - the evidence is presented accurately with no errors nor misunderstandings implied, but the information is dealt with at the literal definition level with no integration across concepts. Opinions presented are not sufficiently supported by referenced facts or facts are presented without clear relevance to opinions or positions.

Score 3: Strong Evidence - the evidence is presented accurately and clearly indicates understanding by integration across concepts. Opinions and positions are clearly supported by referenced facts.

Taking a Bigger Step Toward Change: *Portfolio Assessment*

Grade	Rubrics
A	Strong (3) or adequate (2) evidence in all 10 objectives
B+	Strong (3) or adequate evidence(2) in 8 of 10, but no 1s or 0s;
B	Adequate (2) evidence in 8 objectives
C+	Two-Thirds of objectives are adequate or higher, with no 0 scores
C	Two-Thirds of objectives are adequate or higher, with only one 0f
D+	Strong or adequate evidence on half of objectives
D	One-third of objectives are less than adequate
F	One-half of objectives are less than adequate

Submission and Possession of Evidence: *Submission of evidence for mastery of each objective is to be done during laboratory class meetings and the portfolios will be securely maintained in the laboratory. It is your responsibility to see that your portfolio is current and accurate. No late submissions will be accepted. Any submissions remotely suspected of plagiarism will receive a score of 0.*

Taking a Bigger Step Toward Change: *Performance Assessment*

Your task is to set up and align the 8” telescope, find three different sky objects, and accurately describe some aspects of these objects that astronomers consider to be important.

Grading Rubric

Level 3: Student completes all aspects of task quickly and efficiently and is able to answer questions about the equipment used and objects observed beyond what is obvious. The tasks are: (a) align telescope mount with north celestial pole; (b) align finder telescope with primary telescope; (c) center on target object; (d) select and focus appropriate eyepiece; (e) provide information about the target beyond the literal descriptive level; and (f) answer questions about the target correctly.

Level 2: Student completes all aspects of task and provides descriptive information about the equipment and objects observed.

Level 1: Student is not able to complete all aspects of task or is not able to sufficient provide information about the equipment used or objects observed.

Level 0: No attempt or meaningful effort obvious.

No evidence(0) Approaches goal(1) Meets goal(2) Exceeds goal(3)

1. Method of Research: Identifies the information and steps needed to solve the problem.

0 1 2 3

2. Appropriate Use of Equipment and Apparatus: Demonstrates the correct application and cautious use of equipment and apparatus to meet this standard.

0 1 2 3

3. Accuracy and Precision: Demonstrates the ability to make accurate measurements to appropriate precision and to judge the reasonableness of the results.

0 1 2 3

4. Comprehension: Properly applies concepts and formulas related to phenomena.

0 1 2 3

5. Calculations: Properly uses mathematics and mathematical conversions (as needed) to solve the problem.

0 1 2 3

6. Laboratory Report: Communicates conclusions in a complete, clear, and organized way using illustrations.

0 1 2 3

Note: Adapted, with permission, from T.F. Slater and J.M. Ryan (1993). Laboratory performance assessment. *The Physics Teacher, v. 31*, no. 5, pages 306 - 309.

Tips from the Trenches

- Students have been conditioned to try to figure out what will be on our tests rather than to learn the material. Talk about what your tests are like and what your expectations are.
- Testing is anxiety-producing for students. Some compassion is warranted.
- Student perceptions of “fairness” are paramount. Do your best to publicly correct your mistakes.
- Summarize the number of As, number of Bs, etc. after the exam. Students can clearly see where they rate relative to the rest of the class.
- Discuss grades in private. Students can be particularly aggressive when they first find out they have received a lower-than-expected grade.

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- Multiple Choice Tests
- Short Answer and Essay Tests
- Homework Sets and Papers
- Mathematical Thinking Tasks and Context Rich Problems
- Concept Maps
- Presentations

- Performance Assessment
- Portfolio Assessment
- Attitude Surveys
- Student Self-Assessment of Learning Gains
- Conceptual Diagnostics Tests

Field-Tested Learning Assessment Guide from the National Institute for Science Education

As Yet Unanswered Burning Questions

Ted.Slather@as.arizona.edu

- caper@as.arizona.edu *for more information*
- Additional lecture tutorials
- Ranking tasks
- Syllabi
- Test bank

http://astronomy101.jpl.nasa.gov

Critical Questions

- What are your beliefs about teaching and learning that guide your instruction?
- How do YOU want your students to be different as a result of the experiences you design?
- What do we know about how STUDENTS learn?
- What are some strategies and resources to actively engage students in learning?
- What evidence would you accept that students made significant gains in conceptual, attitudinal, and skill domains?

Learner Centered Astronomy

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