Overview: In this session participants will experience several different active learning strategies and implementation techniques designed to improve students learning and make the classroom more intellectually engaging, inclusive and equitable.

Learning Outcomes:
Participants will be able to:
• Identify a wide range of active learning activities
• Describe different implementation techniques and strategies.
• Discuss how active learning activities can be sequenced together to provide an intellectually engaging classroom that promotes students’ learning
About CAE

The Center for Astronomy Education (CAE), directed by Ed Prather and Gina Brissenden (Univ. of Arizona), is devoted to improving teaching and learning in general education, college-level Earth, Astronomy and Space Science (Astro 101) by conducting fundamental research on student beliefs and reasoning difficulties related to astronomy, and instructor implementation difficulties related to teaching astronomy. We use the results of our research to inform the development of research-validated curriculum and assessment materials for use in the Astro 101 classroom. These research-validated curricula & assessment materials frame our professional development CAE Teaching Excellence Workshops for Earth, Astronomy and Space Science instructors. The goal of these professional development workshops is to increase the pedagogical content knowledge of Earth, Astronomy and Space Science instructors and improve implementation of these curricula and assessment materials.

A composite image of stellar cluster NGC 1333. Image Credit: NASA/JPL-Caltech

We Do Workshops

CAE provides many teaching-related professional development workshops throughout the year and across the country. 
Learn more

We Have Stuff for Your Classroom

CAE has a wide variety of instructional and assessment materials ideal for college-level astronomy.
Learn more

Connect with the Greater Astronomy Community

Come join the discussion and connect with other instructors in our Yahoo group Astroinrer@CAE.
Learn more
# Center for Astronomy Education

**Dedicated to improving teaching and learning in Astronomy 101**

### Materials | Publications

#### Instructional and Workshop Materials

**Classroom Instructional Materials**

**Images from Lecture-Tutorials for Introductory Astronomy, Third Edition**

- You will find individual jpeg versions of all the images in Lecture-Tutorials for Introductory Astronomy, Third Edition. You will also find PowerPoint slides of each image grouped by sections in the book.
  - Images from Lecture-Tutorials for Introductory Astronomy, Third Edition (Zip, 41.99 MB)

**Interactive Materials**

- A.B.C.D Voting Card (PDF, 115 KB)

**Studying Exoplanets Curriculum**

- Lecture-Tutorial: Detecting Exoplanets with the Transit Method (DOCKX, 1.71 MB)
- Lecture Slides: Detecting Exoplanets with the Transit Method (PPTX, 2.34 MB)

**Radio Curriculum**

- Lecture-Tutorial: Rotation, Vibration, and Synchrotron Radiation – Astronomical Interactions of Light and Matter (DOCKX, 901 KB)
- Lecture Slides: Rotation, Vibration, and Synchrotron Radiation – Astronomical Interactions of Light and Matter (PPTX, 3.34 MB)
- Assessment Questions: Rotation, Vibration, and Synchrotron Radiation – Astronomical Interactions of Light and Matter (DOCKX, 656 KB)

### Unpublished Reading Tasks

#### Apparent & Absolute Magnitude

- Activity 1 (PDF, 151 KB)
- Activity 2 (PDF, 70 KB)
- Activity 3 (PDF, 90 KB)
- Activity 4 (PDF, 70 KB)

#### Doppler Shift

- Activity 1 (PDF, 145 KB)
- Activity 2 (PDF, 72 KB)
- Activity 3 (PDF, 70 KB)
- Activity 4 (PDF, 58 KB)

#### Gravity

- Activity 1 (PDF, 95 KB)
- Activity 2 (PDF, 240 KB)
- Activity 3 (PDF, 64 KB)
- Activity 4 (PDF, 287 KB)
- Activity 5 (PDF, 195 KB)
- Activity 6 (PDF, 74 KB)
- Activity 7 (PDF, 118 KB)

#### Luminosity of Stars

- Activity 1 (PDF, 64 KB)
- Activity 2 (PDF, 72 KB)
- Activity 3 (PDF, 71 KB)
- Activity 4 (PDF, 67 KB)

#### Phases of the Moon

- Activity 1 (PDF, 102 KB)
- Activity 2 (PDF, 105 KB)
- Activity 3 (PDF, 84 KB)
- Activity 4 (PDF, 121 KB)
- Activity 5 (PDF, 120 KB)

#### The Seasons

- Activity 1 (PDF, 223 KB)
- Activity 2 (PDF, 132 KB)
- Activity 3 (PDF, 154 KB)
- Activity 4 (PDF, 188 KB)
- Activity 5 (PDF, 191 KB)

#### Motion of the City

- Activity 1 (PDF, 55 KB)
- Activity 2 (PDF, 48 KB)
- Activity 3 (PDF, 114 KB)
- Activity 4 (PDF, 35 KB)

#### Stellar Evolution

- Activity 1 (PDF, 75 KB)
- Activity 2 (PDF, 56 KB)
- Activity 3 (PDF, 74 KB)
- Activity 4 (PDF, 76 KB)

#### Stellar Evolution & Lecture Time

- Activity 1 (PDF, 69 KB)

### Size & Scale

- Activity 1 (PDF, 87 KB)
- Activity 2 (PDF, 1.03 MB)
- Activity 3 (PDF, 87 KB)
- Activity 4 (Word, 20 KB)
NSF: Collaboration of Astronomy Teaching Scholars (CATS)

- Leilani Arthurs, UNL
- Duncan Brown, Syracuse Univ.
- Sanlyn Buxner, Univ. of Arizona
- David Consiglio, Bryn Mawr College
- Tim Chambers, U Michigan
- Steve Desch, Guilford Tech. CC
- Doug Duncan, CU Boulder
- Jeffrey Eckenrode, Pacific Science CTR
- Tom English, Guilford Tech. CC
- John Feldmeier, Youngstown State Univ.
- Amy Forestell Bartholomew, SUNY New Paltz
- Rica French, MiraCosta College
- Adrienne Gauthier, Dartmouth
- Pamela Gay, ASP
- Dennis Hands, High Point Univ.
- Kevin Hardegree-Ullman, University of Toledo
- Melissa Hayes-Gehrke, Univ. of Maryland
- Seth Hornstein, CU Boulder
- David Hudgins, Rockhurst Univ.
- Chris Impey, Univ. of Arizona
- Jessica Kapp, Univ. of Arizona
- John Keller, Cal Poly SLO
- Julia Kregenow, Penn State
- Michelle Wooten, Univ. of Alabama
- Kevin Lee, UNL & NSF
- Patrick Len, Cuesta College
- Chris Lintott, Univ. of Oxford
- Michael LoPresto, Henry Ford CC
- Daniel Loranz, Truckee Meadows CC
- Julie Lutz, Univ. of Washington
- Danny Martino, Santiago Canyon College
- Benjamin Mendelsohn, West Valley College
- Ed Montiel, Louisiana State University
- Peter Newbury, Univ. of British Columbia
- Lee Powell, UN Kearney
- Matthew Price, Ithaca College
- Jordan Raddick, Johns Hopkins Univ.
- Alex Rudolph, Cal Poly - Pomona
- Travis Rector, Univ. of Alaska
- Paul Robinson, Westchester CC
- Wayne Schlingman, Ohio State
- Sébastien Cormier, Grossmont College
- Colin Wallace, UNC
- Kathryn Williamson, NRAO
- James Wysong Jr., Hillsborough CC
- Todd Young, Wayne St. College
A little background about me….

• Almost 30 years of research into the teaching and learning of physics and Astronomy
I teach...

...students  ...Physics

Center for Astronomy Education

Dedicated to the professional development of introductory astronomy instructors
Desire for students to learn from time in class
Not Important  ← Desire for class time to be used efficiently  → Very Important
Not Important  ← Desire for control of the classroom’s directions and actions  → Very Important
Not Important  ← Desire for assessments to provide insights and evidence of students’ learning  → Very Important
Not Important  ← Desire for instructional approach to improve issues related to DEI  → Very Important
**Types of Student Inquiry**

By: @trev_mackenzie

**Structured Inquiry**

Students follow the lead of the teacher as the entire class engages in one inquiry together.

**Controlled Inquiry**

Teacher chooses topics and identifies the resources students will use to answer questions.

**Guided Inquiry**

Teacher chooses topics/questions and students design product or solution.

**Free Inquiry**

Students choose their topics without reference to any prescribed outcome.

Inspired by: Fitchman, 2011
This will represent “just the tip of the iceberg” of what it takes to create a highly functioning active learning classroom.
Getting Our “Challenges” on the Table

- Covering all the content
- Time, time, time!
- Department support
- Teaching resources
- Etc…

*The REAL challenge is IMPLEMENTATION!!!!*
On your own, create a list of:

• All of the actions and moves I might do that go beyond lecture.

• NOT a list of named instructional activities.

You have a couple minutes….. GO.
“Most ideas about teaching are not new, but not everyone knows the old ideas.” Euclid (300 B.C.)
Principles of Teaching and Learning:

1. **Prior knowledge and motivation**
   Connect to students’ prior knowledge and motivations to leverage students’ powerful ideas and interests and attend to where they struggle.

2. **Active engagement**
   Use active engagement so that students do the work of making sense themselves and make meaningful connections.

3. **Social interaction**
   Use social interaction so that students can verbalize their thinking and coach one another.

4. **Feedback**
   Provide feedback opportunities so that students can reflect on and adjust their learning.

5. **Inclusive classrooms**
   Use inclusive classroom strategies to support learning for the widest variety of students.

6. **Mastery**
   Start simple and build up mastery to scaffold students’ understanding so they can build skills and concepts without cognitive overload.
Centennial Hall Performing Arts Theater at University of Arizona
Zongar Buddhist Institute
Eventually, Billy came to dread his father’s lectures over all other forms of punishment.

“If a Picture is worth a thousand words, then what is a real-world, first-hand, experience worth?

Please participate in the role of a good student!

Don’t get stuck or caught up in OVER-thinking things!!!!!

Eventually, Billy came to dread his father’s lectures over all other forms of punishment.”
What Can I do Besides Lecture to Engage Students in their Learning?

- Ask students questions (not all questions are equal)
- In-class writing (with or without discussion)
  - Muddiest Point
  - Summary of Today’s Main Points
  - Writing Reflections
- Use interactive videos, demonstrations, animations, and simulations
- Think-Pair-Share or Peer Instruction
- Small Group Interactions
  - Concept Maps
  - Case Studies
  - Sorting Tasks
  - Ranking Tasks
  - Lecture-Tutorials
  - Representation Tasks
- Student Debates (individual/group)
- Whole Class Discussions
Todays Topic:
“Detecting Extrasolar Planets with the Doppler Method”

Please pay attention to:

• How collaboration was encouraged and motivated
• How feedback was incorporated
• The wide range of representations employed
• The sequencing of different intellectual tasks
• The different implementation moves used
Debrief....

On your own, create a list of:

- All of the actions and moves I might do that go beyond lecture.
- NOT a list of named instructional activities.

You have a couple minutes..... GO.

Principles of Teaching and Learning:

1. Prior knowledge and motivation
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6. Mastery
   Start simple and build up mastery to scaffold students’ understanding so they can build skills and concepts without cognitive overload.

Given the location marked on the star’s radial velocity curve, at which location in the planet’s orbit would you expect the planet to be?
A little about research results ....
Results from a 6000 student study of Physics Students – *Hake AJP 1998*

\[ g = \frac{\text{post\%} - \text{pre\%}}{100\% - \text{pre\%}} \]

- \( g > 0.7 \) "High"
- \( 0.3 < g < 0.7 \) "Medium"
- \( g < 0.3 \) "Low"

CAE National Study

- Almost 4000 students
- 31 institutions
- 36 instructors
- 69 different sections
  - Section sizes vary from <10 to 180 (now with sections >750!)
\[ <g> = \frac{<\text{post\%}> - <\text{pre\%}>}{100\% - <\text{pre\%}>} \]
\[ g = \frac{\text{post}\% - \text{pre}\%}{100\% - \text{pre}\%} \]
Lower IAS (<25%)  
<g>avg = 0.13

Higher IAS (>25%)  
<g>avg = 0.29
Item Response Theory (IRT)

\[
P(X_{pi} = 1 | \theta_p, b_i) = \frac{\exp[\theta_p - b_i]}{1 + \exp[\theta_p - b_i]}
\]
Demographic Survey

- We also asked 15 demographic questions to allow us to determine how such factors as
  - Gender
  - Ethnicity
  - English as a native language
  - Parental education
  - Overall GPA
  - Major
  - Number of prior science courses
  - Level of mathematical preparation

interact with instructional context to influence student conceptual learning

- This survey also gives us a snapshot of who is taking Astro 101 in the US
• We conducted a full multivariate modeling analysis of our data

• We confirm that the level of interactivity is the **single most important variable** in explaining the variation in gain, even after controlling for all other variables
The results of our investigation reveal that the positive effects of interactive learning strategies apply equally to men and women, across ethnicities, for students with all levels of prior mathematical preparation and physical science course experience, independent of GPA, and regardless of primary language. These results powerfully illustrate that all categories of students can benefit from the effective implementation of interactive learning strategies.
Take Home Messages

• Research-validated active learning strategies can benefit ALL students in ALL classroom environments - BUT

• The quality of our implementation is likely the most deterministic factor toward student achievement
Learning Gains

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<th>Hedges's g</th>
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<tr>
<td>Overall</td>
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% Decrease in Failure Rate

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<th>% Decrease in Failure Rate</th>
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<tr>
<td>Overall</td>
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Numbers indicate # of studies reviewed.

Freeman S et al. PNAS 2014;111:8410-8415

traditional lecture class - mean scores
Help People.

If you can’t help them, at least try not to hurt them.

The Dalai Lama