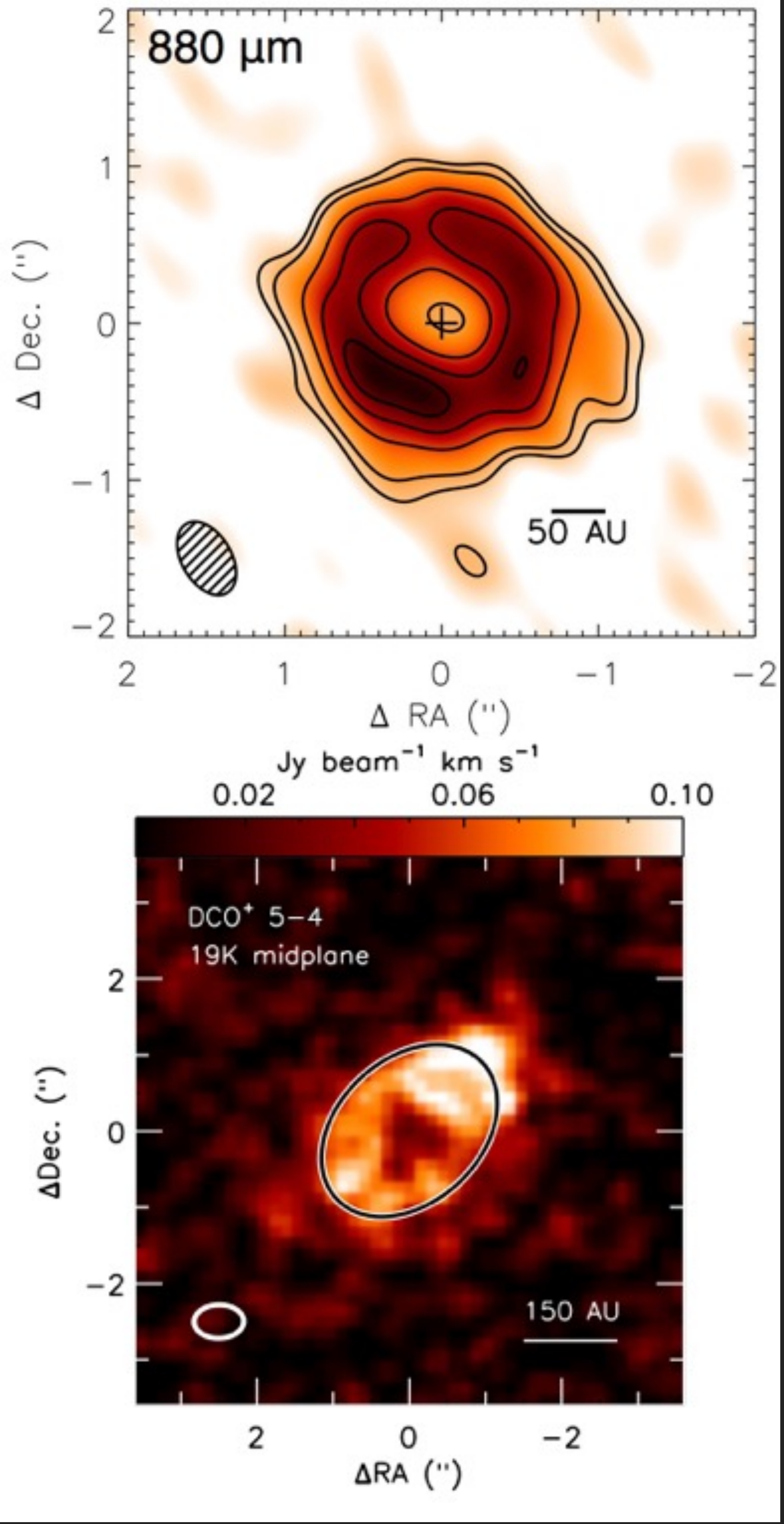
GEOFF MATHEWS

ASTRONOMY FROM THE GROUND UP

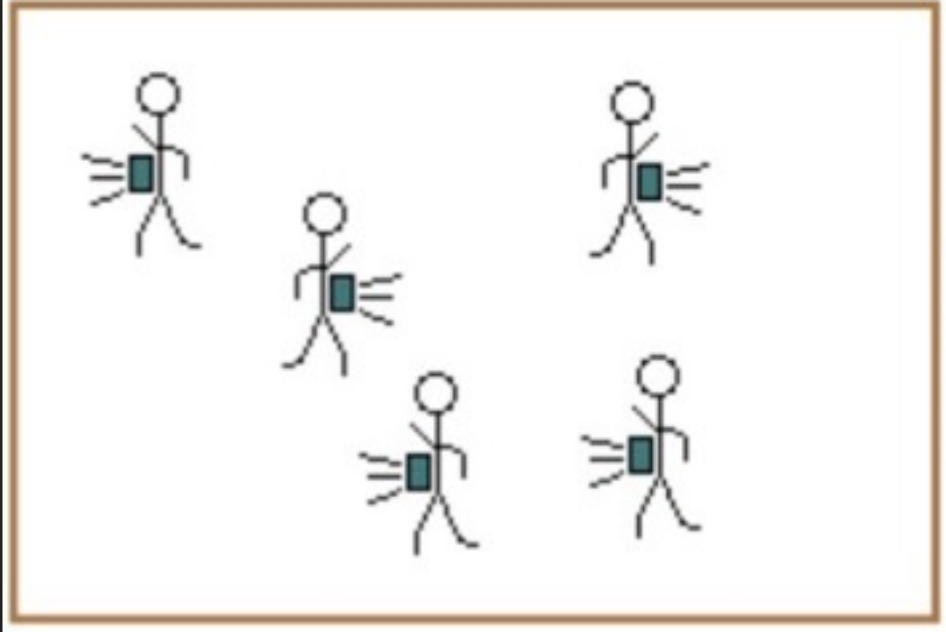
APPLYING THE RESEARCH PROCESS TO UNDERGRADUATE TEACHING

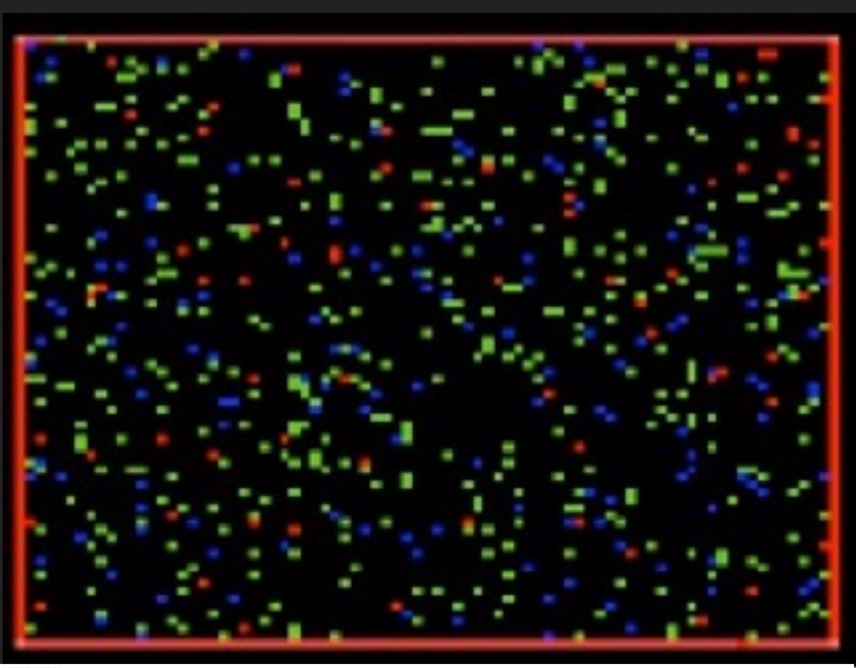


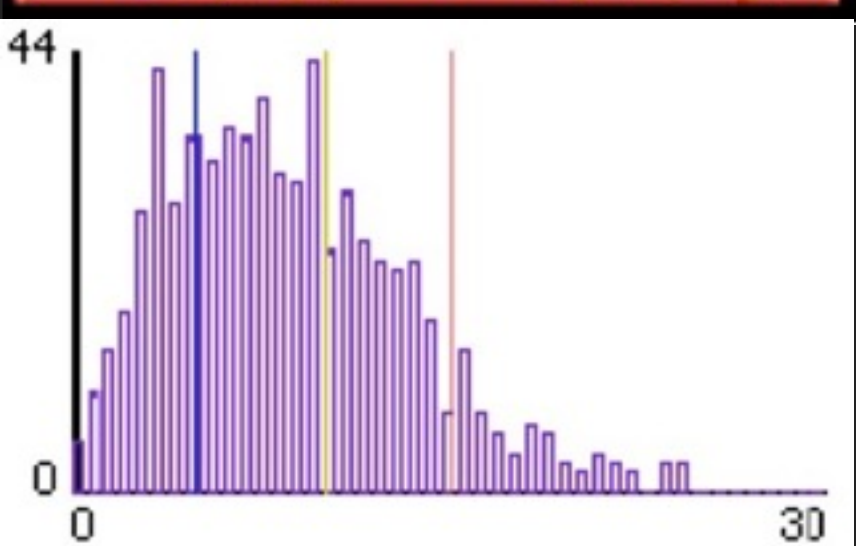
CIRCUMSTELLAR DISKS: BIRTHPLACE OF

PLANETARY SYSTEMS

Mathews et al., 2012, 2013







TEACHING EMERGENT PHENOMENA

MICRO-RULES LEAD TO MACRO-PHENOMENA

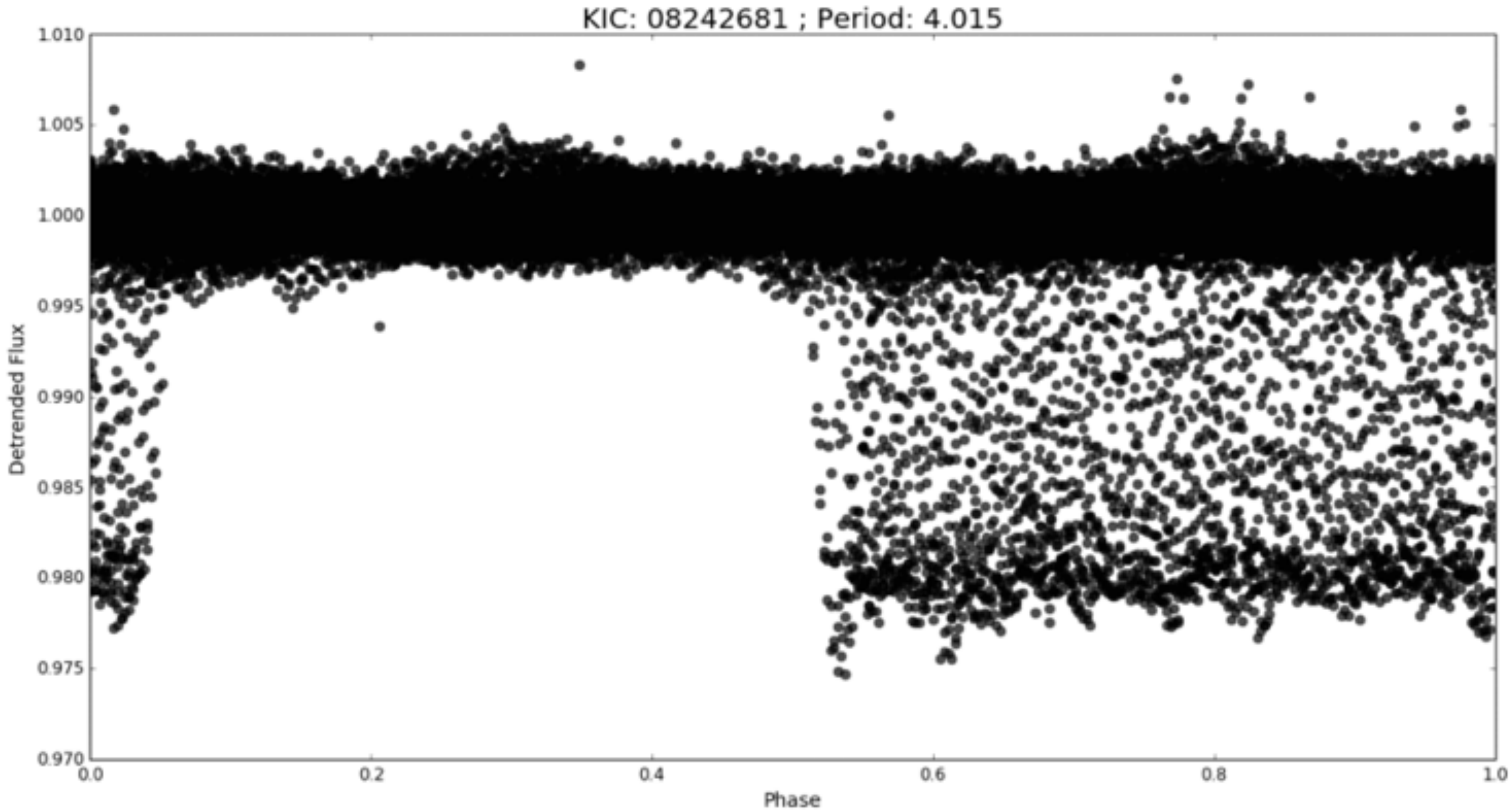
Wilensky & Stroup, 2000

Teaching

Designing new courses

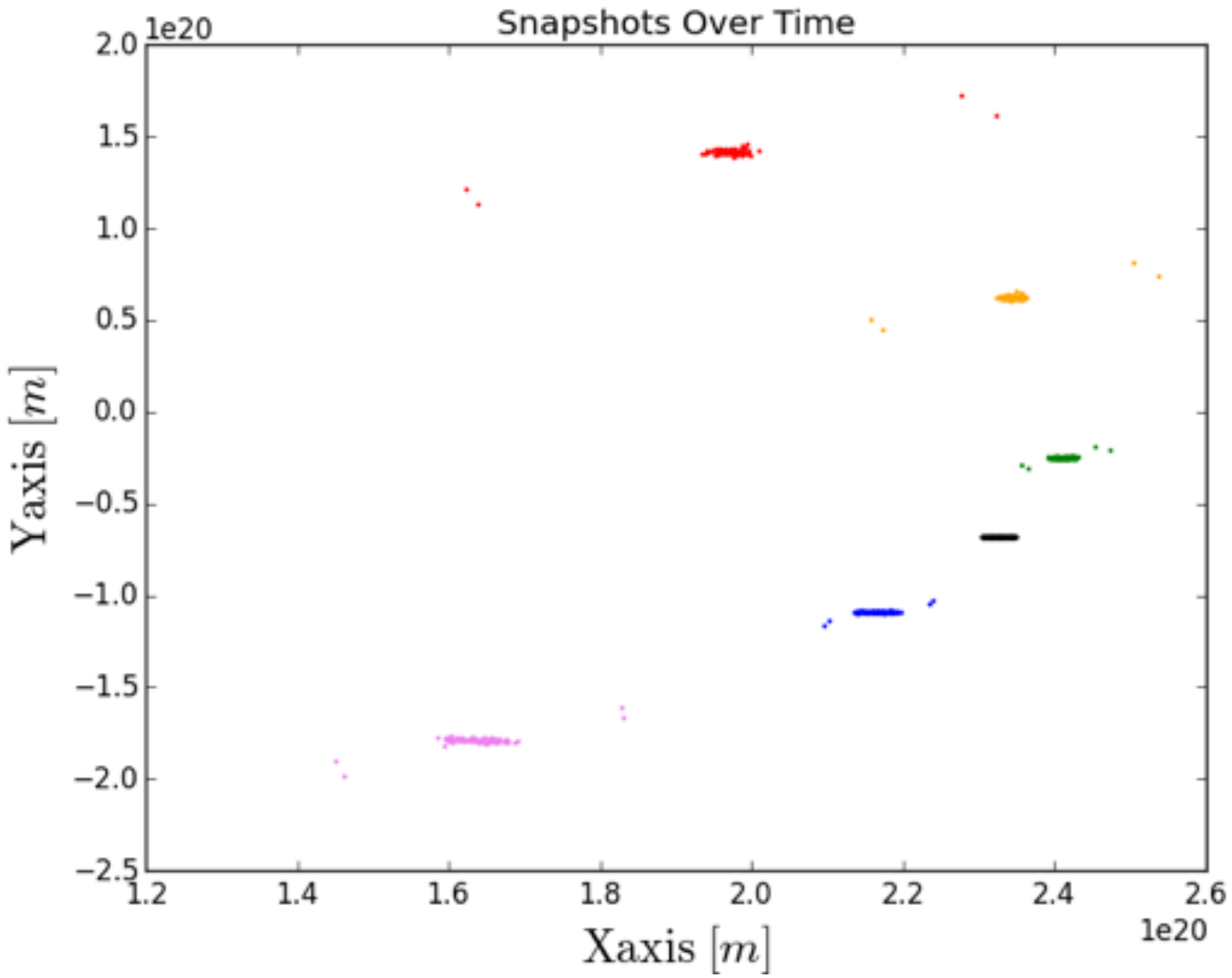
Organizing new undergraduate Astro- program

Assist transition from teaching grads to undergraduate majors



KAIMI KAHIHIKOLO, SOPHOMORE

INTERMITTENTLY ACCRETING BINARIES



JEFFREY KLEYNER, SENIOR

CONVERGENCE AGES OF YOUNG MOVING GROUPS

NATIONAL GUIDANCE ON PHYSICS CURRICULUM

Table A: Course Requirements and Undergraduate Degree Programs (Percentages)

Required Course	Bachelor of Science	Bachelor of Arts	Other Bachelor	**All Programs**
Introductory classical physics	99	99	97	**99**
Intermediate classical mechanics	97	88	87	**95**
Introductory modern physics	95	94	94	**95**
Intermediate electromagnetism	96	88	81	**94**
Advanced laboratory	90	74	90	**87**
Quantum mechanics	88	74	65	**84**
Thermal and/or statistical physics	82	57	81	**78**
Mathematical physics	45	38	36	**43**
Optics	46	24	52	**42**
Other physics courses	85	82	87	**84**
Number of survey respondents	387	92	31	**510**

from AAPT Guidelines for Physics Program self-study 2005

AAS CONVENED WORKSHOP REGARDING "ASTRO 101"

Astronomy Education Review

Volume 2, Sep 2003 - Jan 2004
Issue 2

Goals for "Astro 101": Report on Workshops for Department Leaders

by **Bruce Partridge**
Haverford College
George Greenstein
Amherst College

GOALS FOR "ASTRO 101"

1. A cosmic perspective
2. Understand crucial astronomical quantities and appropriate physical laws
3. Physical laws and processes are universal
4. The world is knowable through observations, experiments, and theory
5. Exposure to the types, roles, & degrees of uncertainty
6. Understand evolution of physical systems
7. Some knowledge of related subjects and a set of tool from e.g. mathematics
8. Science as a cultural process
9. Familiarity with the night sky

Partridge & Greenstein 2003

34% RISE IN UNDERGRADUATE ASTRONOMY DEGREES

Trend in astronomy enrollments and degrees, academic years 2004 to 2016.

	Number of astronomy degrees			Undergraduate astronomy major enrollments		Graduate astronomy student enrollments	
Academic Year	Bachelors	Exiting Masters	PhDs	Juniors	Seniors	1st-year	Total
2004-05	343	27	91	437	584	212	999
2005-06	351	30	119	511	565	188	1,026
2006-07	336	18	125	379	569	206	1,077
2007-08	327	36	161	364	536	193	1,081
2008-09	322	29	141	388	515	215	1,065
2009-10	382	23	156	382	605	193	1,083
2010-11	408	47	160	450	637	202	1,156
2011-12	385	35	152	487	666	224	1,122
2012-13	386	35	155	484	694	233	1,134
2013-14	428	28	147	530	711	183	1,118
2014-15	459	22	130	561	780	187	1,108
2015-16				604	782	198	1,137

Nicholson & Mulvey, 2016, AIP

WHAT SHOULD BE TAUGHT?

Student Learning Outcomes

1. Laws of Physics - Explain the physical laws and concepts of classical mechanics, thermodynamics and statistical mechanics, electromagnetism, optics, relativity, and quantum mechanics.
2. Astronomical Objects - Describe the nature, structure, distribution, and formation of astronomical objects, including planets, stars, and galaxies, and the history of the universe.
3. Physical laws in Astronomy - Demonstrate an appreciation of the universality of physical laws and apply these laws to explain phenomena in astronomical systems and the universe
4. Astrophysical Problems - Formulate astrophysical problems in mathematical terms and use analytic and numerical methods to obtain solutions
5. Scientific Method - Use the scientific method to ask meaningful questions, to design experiments to address these questions, to acquire and critically analyze the data, and to draw appropriate conclusions.
6. Scientific Communications - Communicate research design and results effectively in both written and oral formats.
7. Observational Properties - Define and interpret the observational properties of astronomical objects
8. Astronomical data reduction - Reduce astronomical images and spectra using standard analysis software, and measure observational properties from reduced data.
9. Observing methods - Propose, plan, and conduct astronomical observations with professional telescopes
10. Astronomical literature - Use sources from astronomical literature, databases, and on-line catalogs to obtain relevant information about astronomical objects and theories.

WHAT SHOULD BE TAUGHT?

Student Learning Outcomes

1. Laws of Physics - Explain the physical laws and concepts of classical mechanics, thermodynamics and statistical mechanics, electromagnetism, optics, relativity, and quantum mech
2. Astro
astron
3. Phys
laws
4. Astro
analy
5. Scien
exper
appro
6. Scien
writt
7. Obse
objec
8. Astro
analy
9. Obse
profe
10. Astro
catalo

3. Physical laws in Astronomy -

Demonstrate an appreciation of the universality of physical laws and apply these laws to explain phenomena in astronomical systems and the universe

Subject	Introduction	Basic Usage	Mastery
Orbital motion	Kepler's Laws. Newton's version of Kepler's 3rd law. Circular orbits with a negligible mass.	General 2-body problem. Perturbations; secular evolution.	Non-Keplerian potentials; orbital invariants
Continuum mechanics	Hydrostatic equilibrium: atmospheres.	Hydrostatic equilibrium: planetary & stellar interiors.	Solar & stellar winds; time-dependent problems; shocks.
Matter & Radiation	Stefan-Boltzmann & Wien's laws. Qualitative description of Interaction of light & matter	Planck function and Rayleigh-Jeans approximation; hydrogen levels; line formation in LTE.	Non-LTE systems; astrophysical masers.
Nuclear Reactions	alpha and beta decay. Fusion and fission	Hydrogen and helium burning. CNO cycle vs PP	Reaction networks; R and S process.
Chemistry	Temperature and pressure conditions for molecular stability	Conditions for formation	Molecules as probes of physical conditions

Mathews et al. 2015, IAU General Assembly

WHAT SHOULD BE TAUGHT?

Student Learning Outcomes

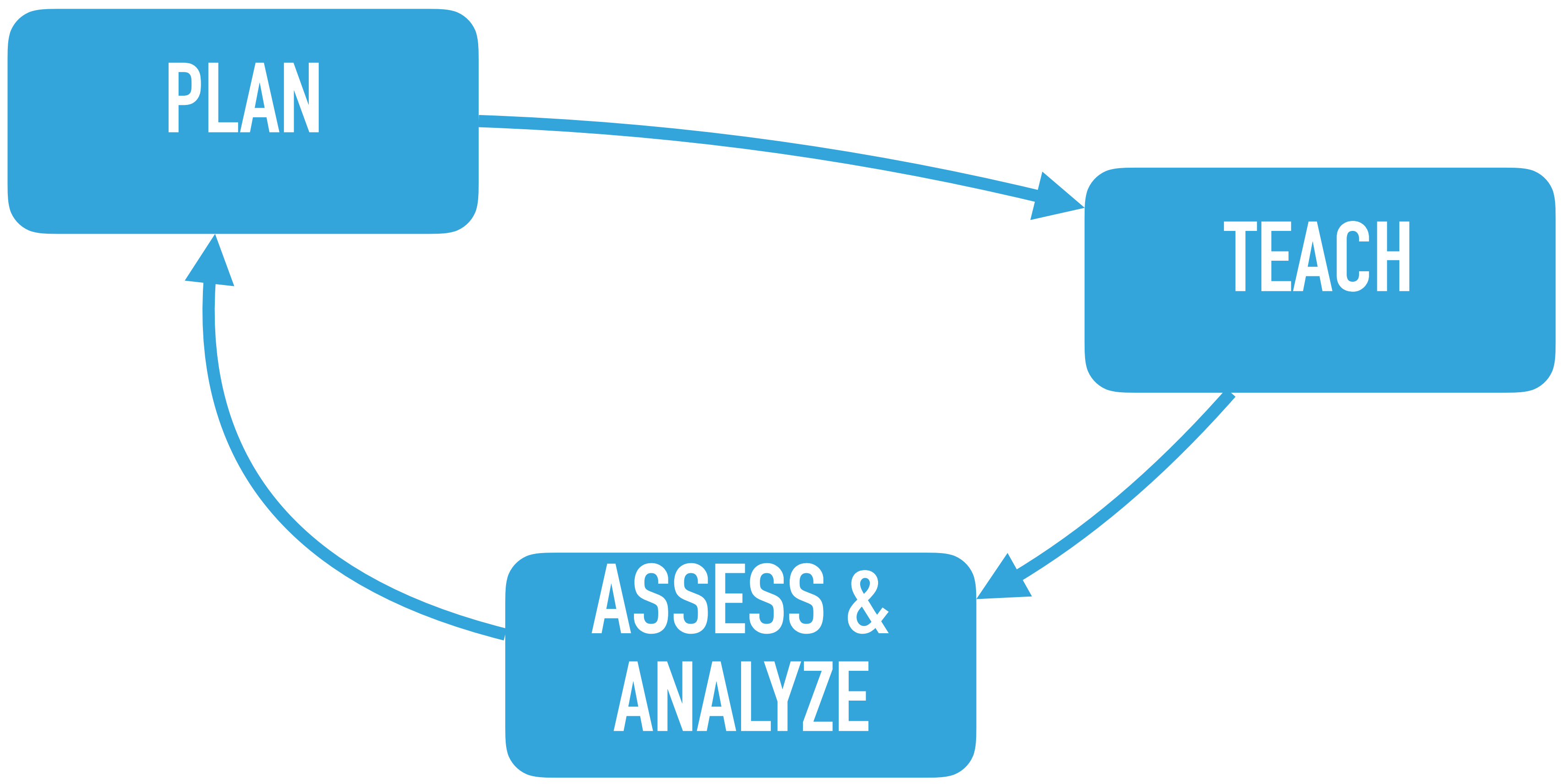
1. Laws of Physics - Explain the physical laws and concepts of classical mechanics, thermodynamics and statistical mechanics, electromagnetism, optics, relativity, and quantum mech
2. Astro astron
3. Phys laws
4. Astro analy
5. Scien exper appro
6. Scien writte
7. Obse objec
8. Astro analy
9. Obse profe
10. Astro catalo

3. Physical laws in Astronomy -

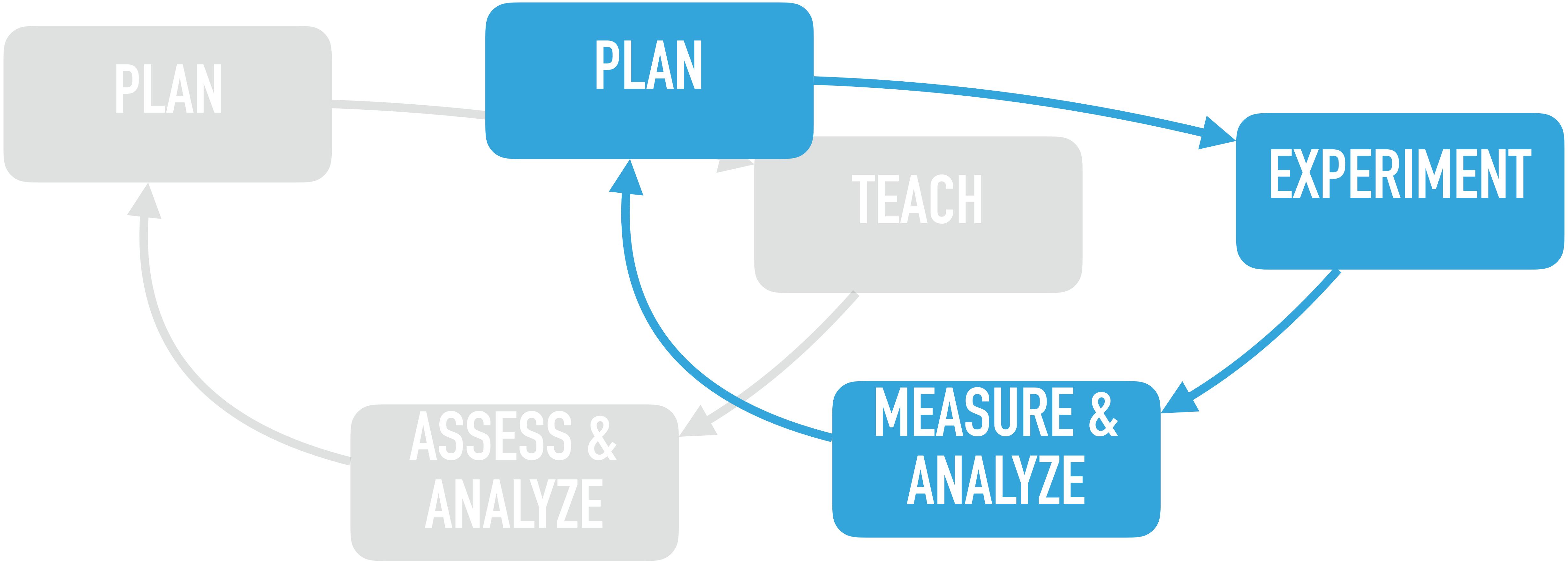
Demonstrate an appreciation of the universality of physical laws and apply these laws to explain phenomena in astronomical systems and the universe

Subject	Introduction
Orbital motion	Kepler's Laws version of Kep Circular orbits negligible mas
Continuum mechanics	Hydrostatic ec atmospheres.
Matter & Radiation	Stefan-Boltzm laws. Qualitat description of light & matter
Nuclear Reactions	alpha and beta Fusion and fis
Chemistry	Temperature a conditions for stability

Subject	Orbital motion
Introduction	Kepler's Laws. Newton's version of Kepler's 3rd law. Circular orbits with a negligible mass.
Basic Usage	General 2-body problem. Perturbations; secular evolution.
Mastery	Non-Keplerian potentials; orbital invariants

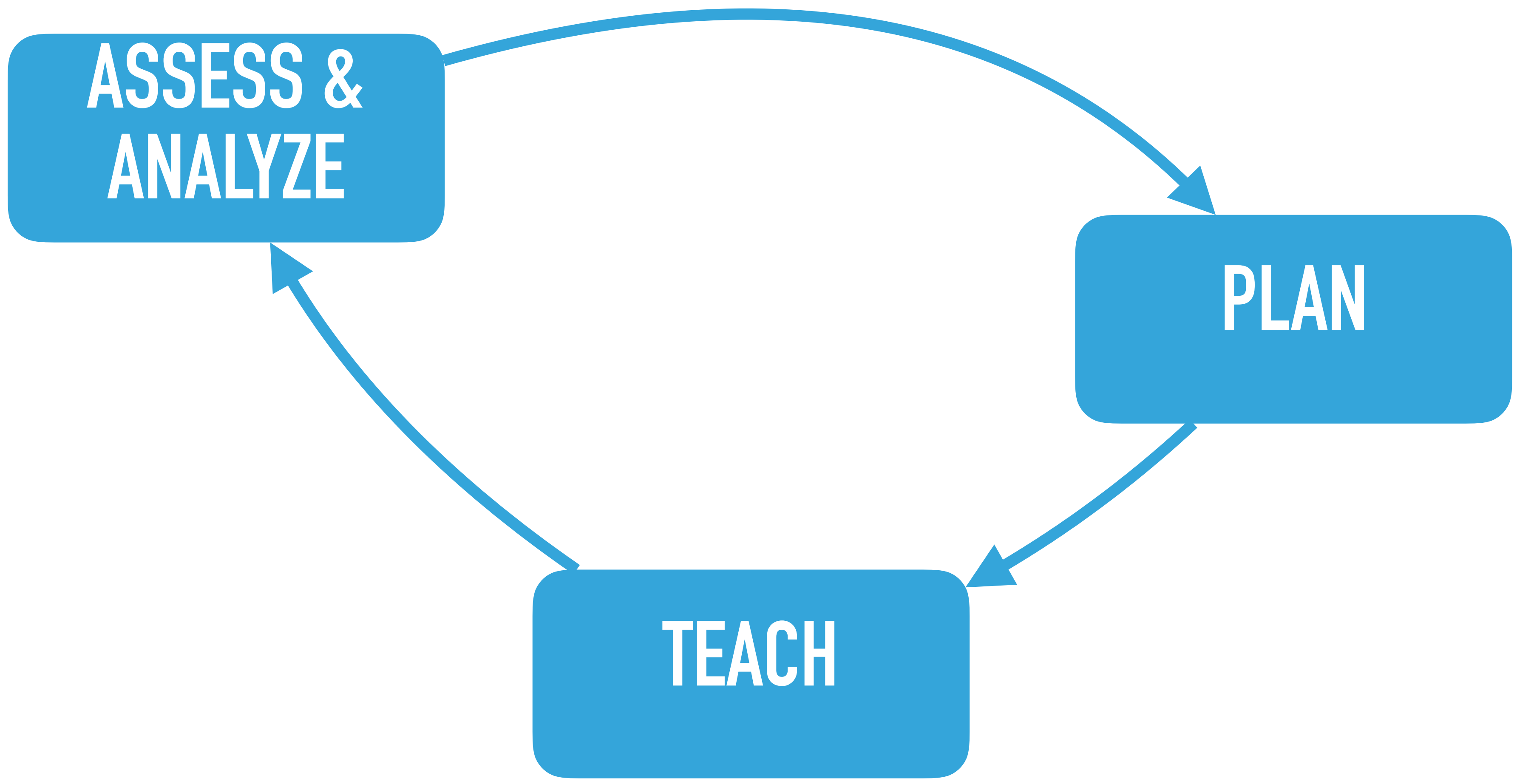


ASSESSMENT CYCLE

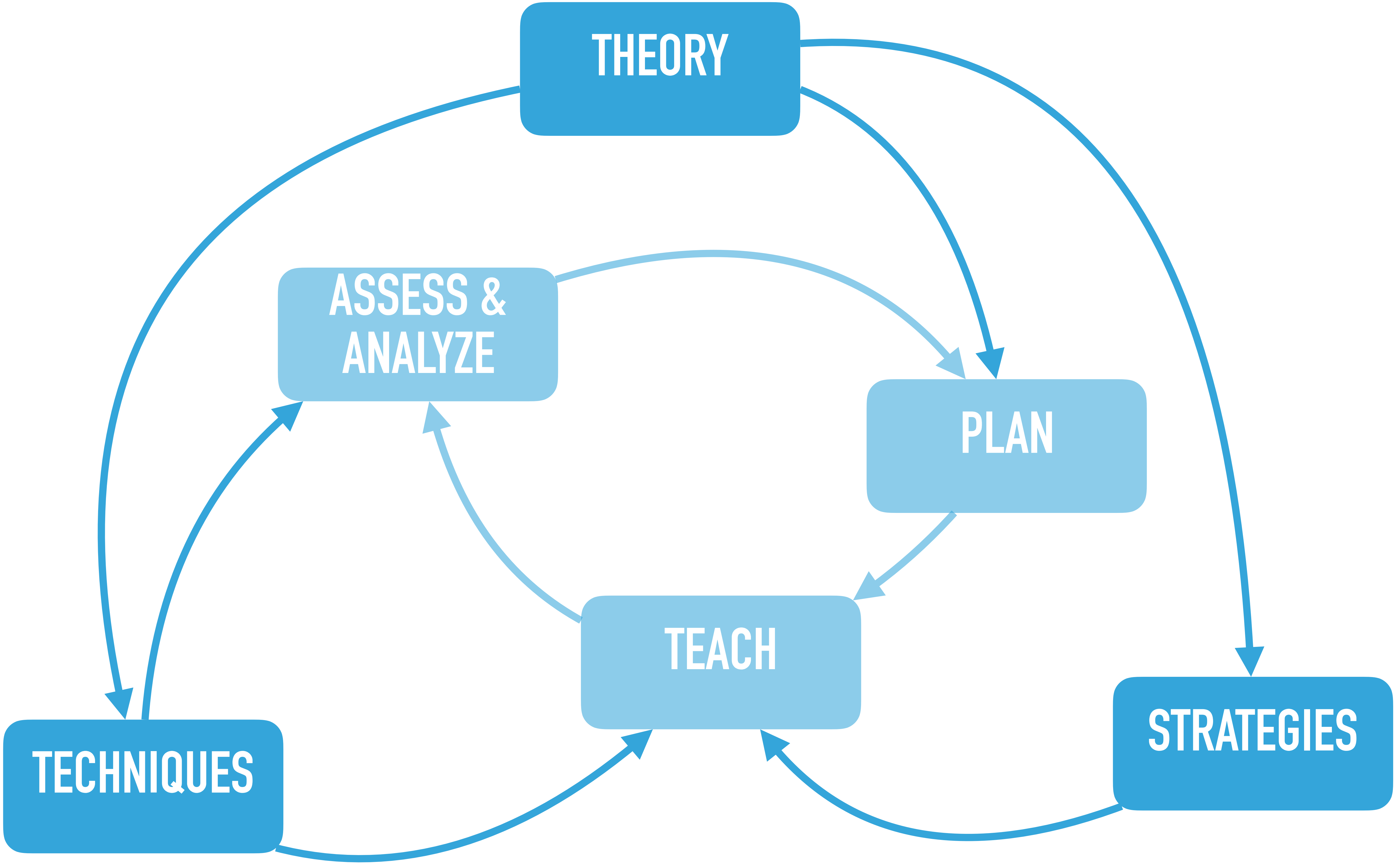


ANALOG TO SCIENCE CYCLE

ASSESSMENT CYCLE



ASSESSMENT CYCLE


THEORY
ASSESS & ANALYZE
PLAN
TEACH
TECHNIQUES
STRATEGIES

THREE THINGS TO REMEMBER

A (GROSSLY OVERSIMPLIFIED) THEORY OF EDUCATION

MOTIVATION AND ENGAGEMENT ARE PREREQUISITES FOR LEARNING

HUMANS LEARN BY DOING

TEACHING IS A FEEDBACK SYSTEM: YOU AND YOUR STUDENTS NEED DATA

Elements of motivation

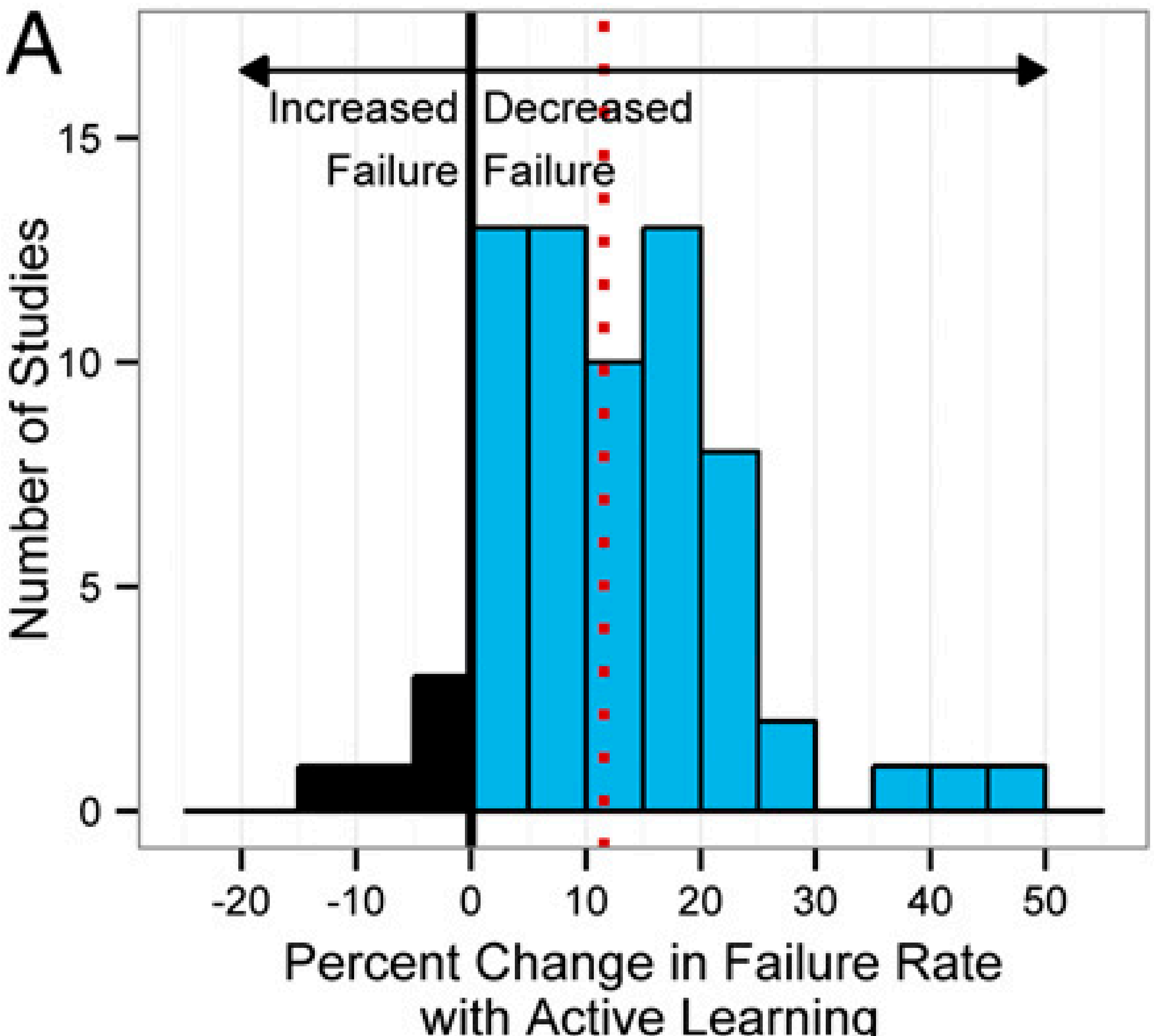
Student's Efficacy* is	Environment is NOT SUPPORTIVE		Environment is SUPPORTIVE	
	DON'T see value	SEE value	DON'T see value	**SEE value**
Low	Rejecting	Hopeless	Rejecting	Fragile
High	Evading	Defiant	Evading	**Motivated**

*Self-efficacy: one's belief in one's ability to succeed

Ambrose et al., 2010

Slide from Feb. 21, 2017 presentation by Sara Harris & Sarah Bean Sherman, from the Carl Wieman Science Education Initiative, University of British Columbia. Used with permission.

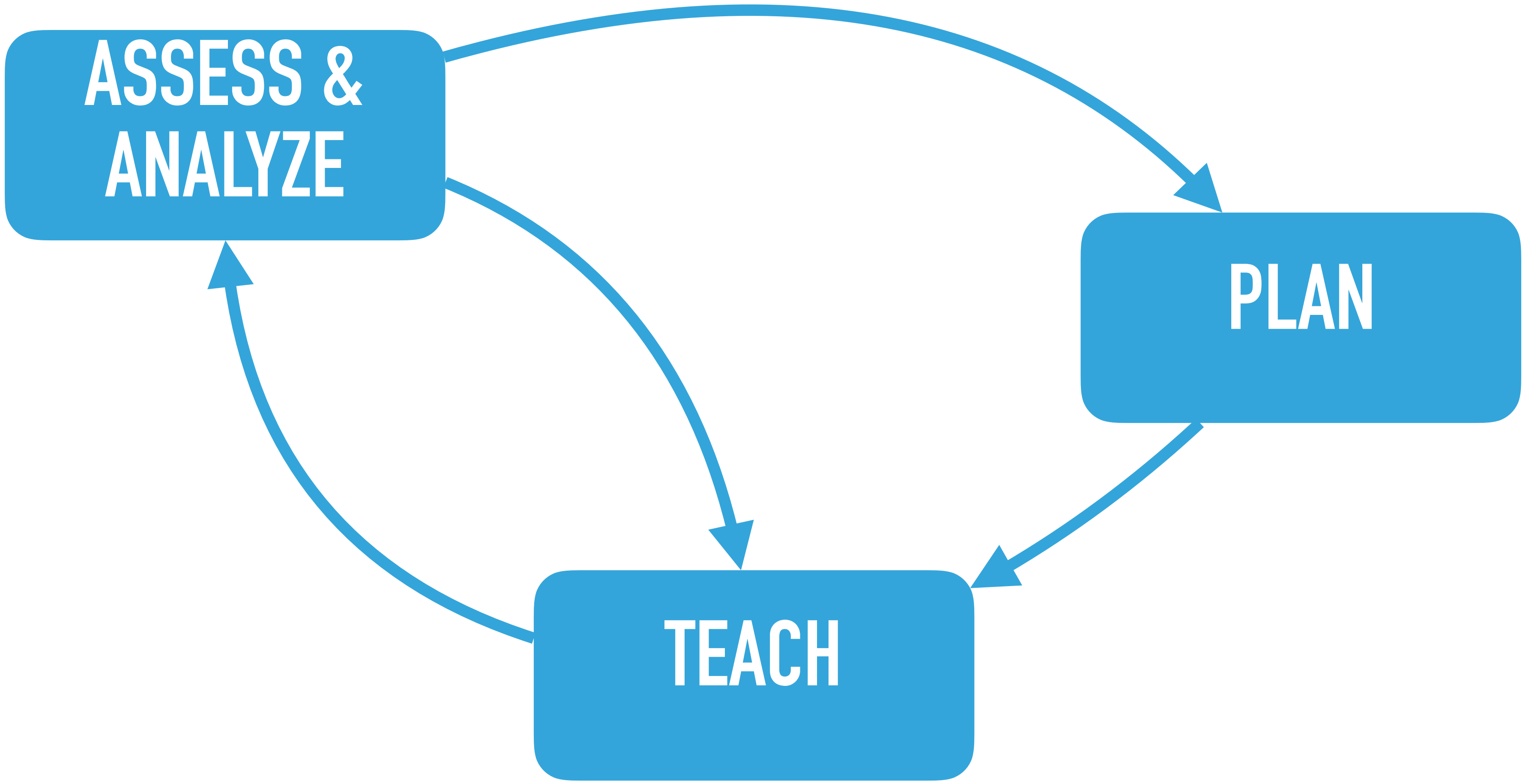
HUMANS LEARN BY DOING (AKA "ACTIVE LEARNING")



- group problem solving
- in-class tutorials / worksheets
- individual responses to in-class questions
- peer instruction
- studio / workshop

Freeman et al. 2014

TEACHING IS A FEEDBACK SYSTEM



MAXIMIZE SELF-EFFICACY, USEFUL ACTIVITY, AND FEEDBACK

Strategies

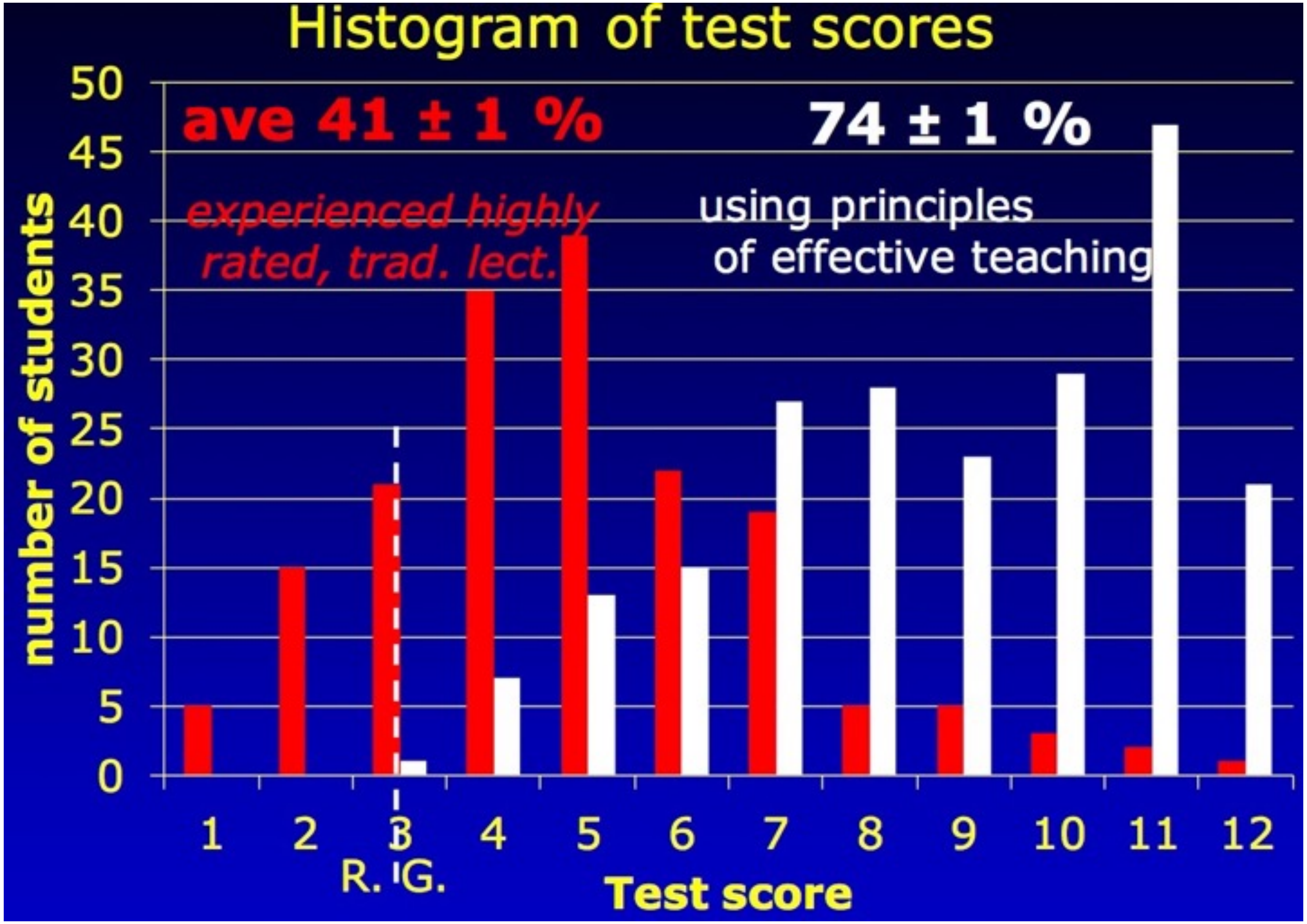
- Backwards-design from course goals (Wiggins & McTigh, 1998)
- Spiral and strand (Snider 2004)
- Formative assessment (Black & William, 1998)

MAXIMIZE SELF-EFFICACY, USEFUL ACTIVITY, AND FEEDBACK

Techniques

- Peer instruction (Mazur & Somers 1999)
- Lecture tutorials (Prather et al., 2004)
- Pre-reading with pre-test (Heiner, Banet, & Wieman 2014)

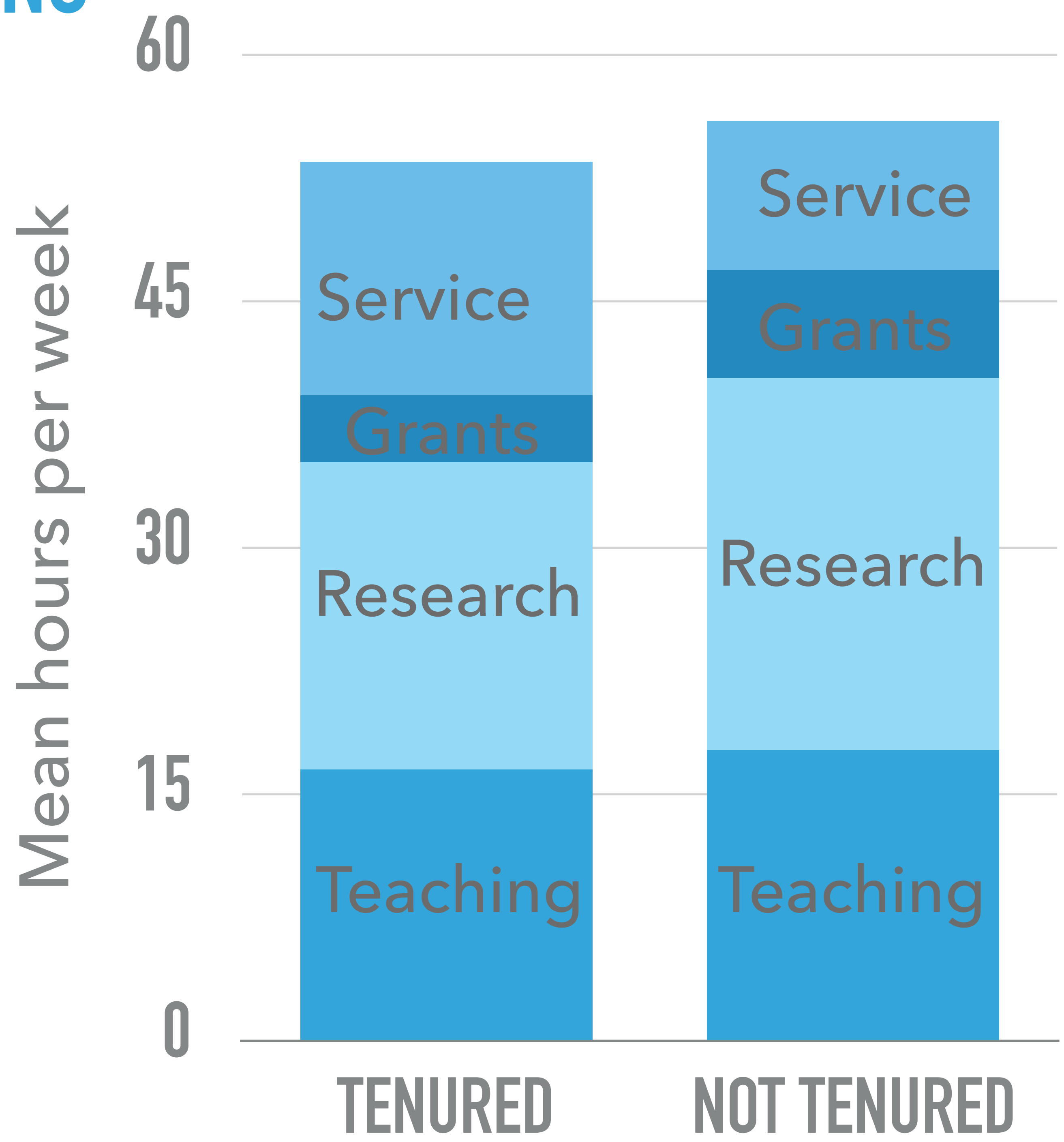
IMPROVEMENTS ARE NECESSARY AND POSSIBLE



Carl Wieman talk at UH Manoa, Feb. 4, 2016

BARRIERS TO EFFECTIVE TEACHING

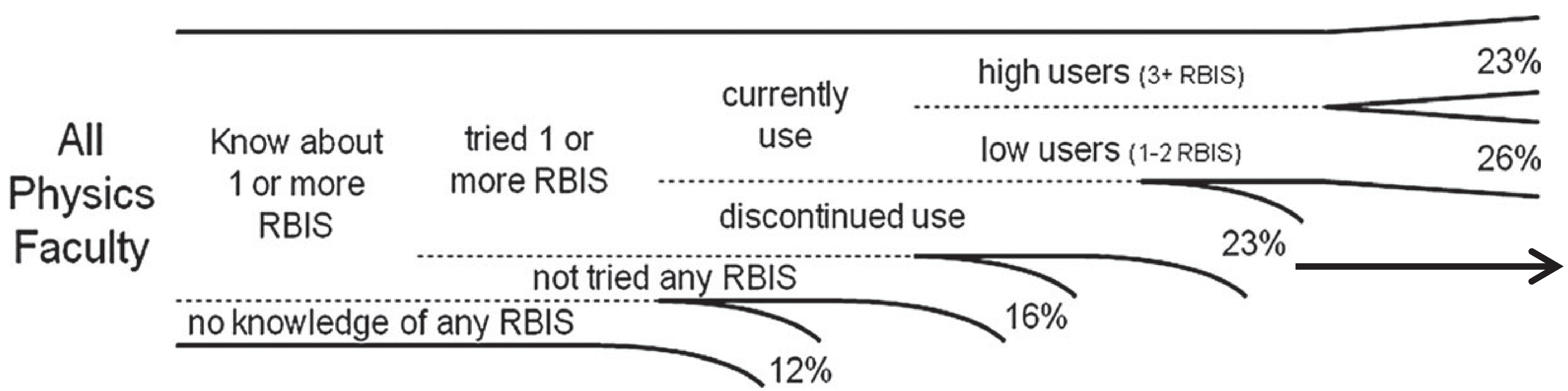
- 17 hours per week on teaching
- Lack of training
- Lack of incentives
- Professional identity
- Low status



Link et al. 2008, Brownell & Tanner 2012

SO HOW DO WE IMPROVE TEACHING?

CONTINUED PROFESSIONAL DEVELOPMENT IS NEEDED



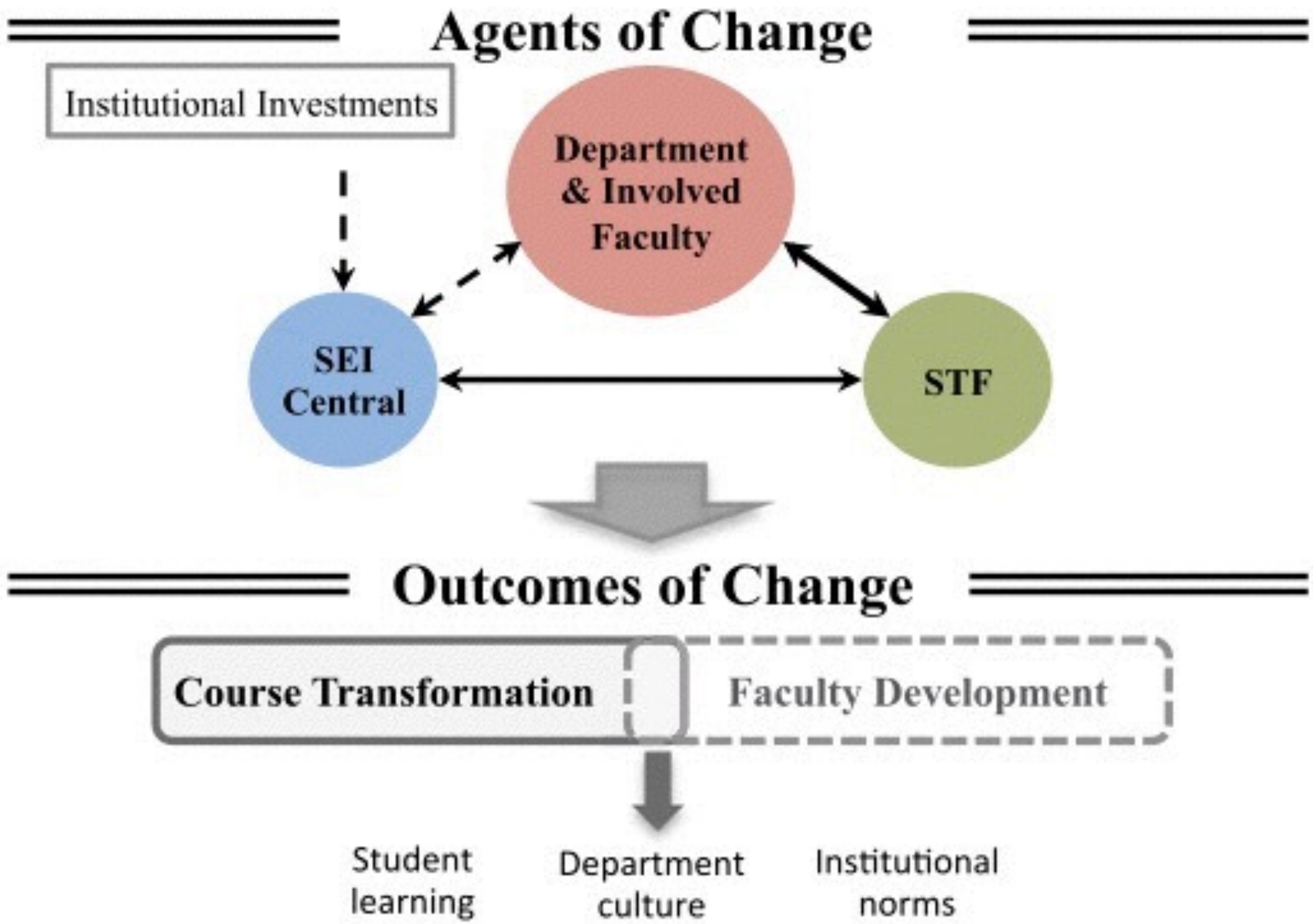
~1/3 of those who try a RBIS discontinue use

Dancy, Henderson, & Turpen 2016

…FACULTY WHO IMPLEMENT AN INNOVATION WITHOUT ADEQUATE AWARENESS OF THE RECOMMENDED USE ARE LIKELY TO ENCOUNTER DIFFICULTIES AND (OR) NOT SEE THE PROMISED SUCCESS OF THE INNOVATION.

Dancy, Henderson, & Turpen 2016

WIEMAN SCIENCE EDUCATION INITIATIVE MODEL



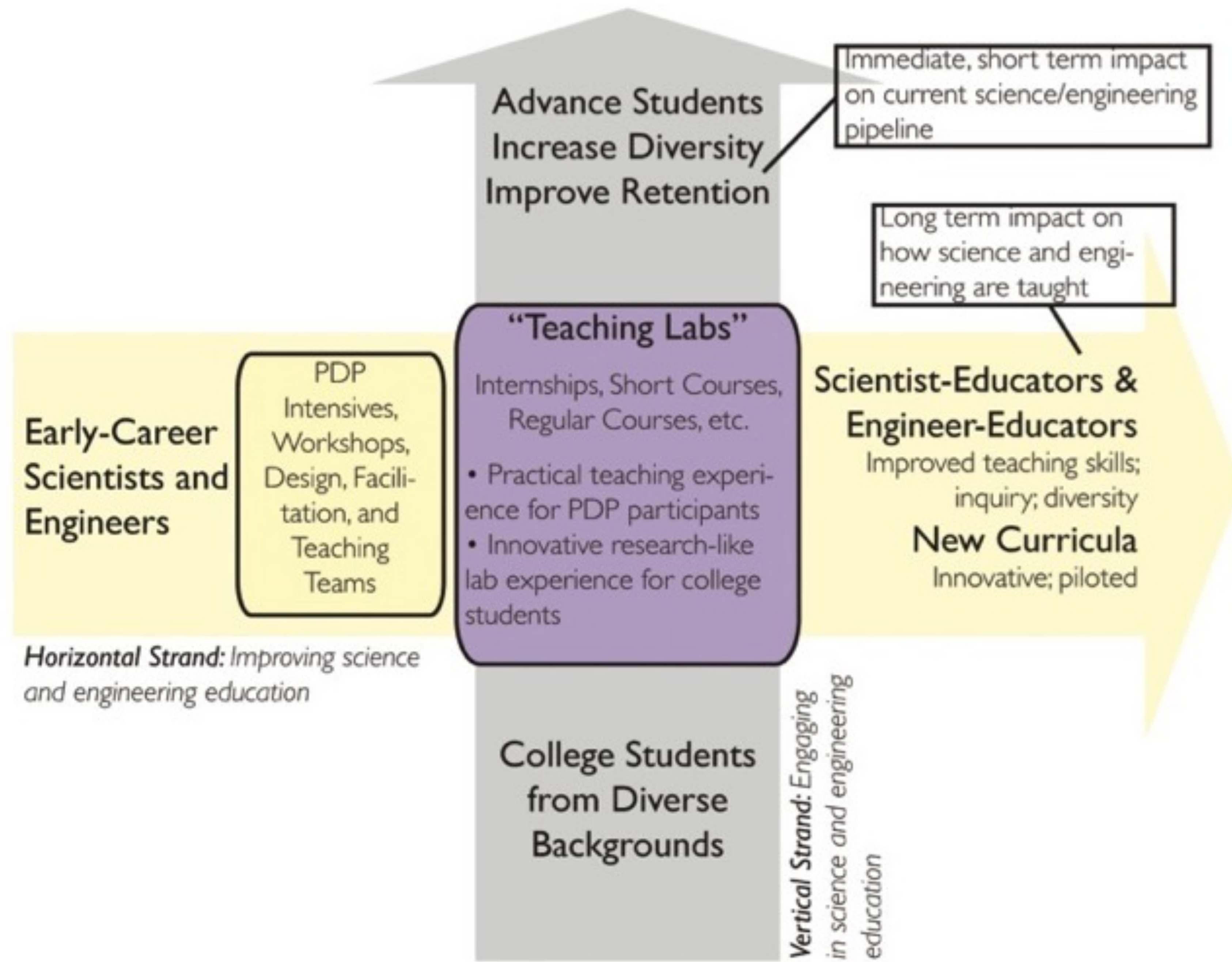
Chasteen et al., 2015

MANOA CENTER FOR TEACHING EXCELLENCE

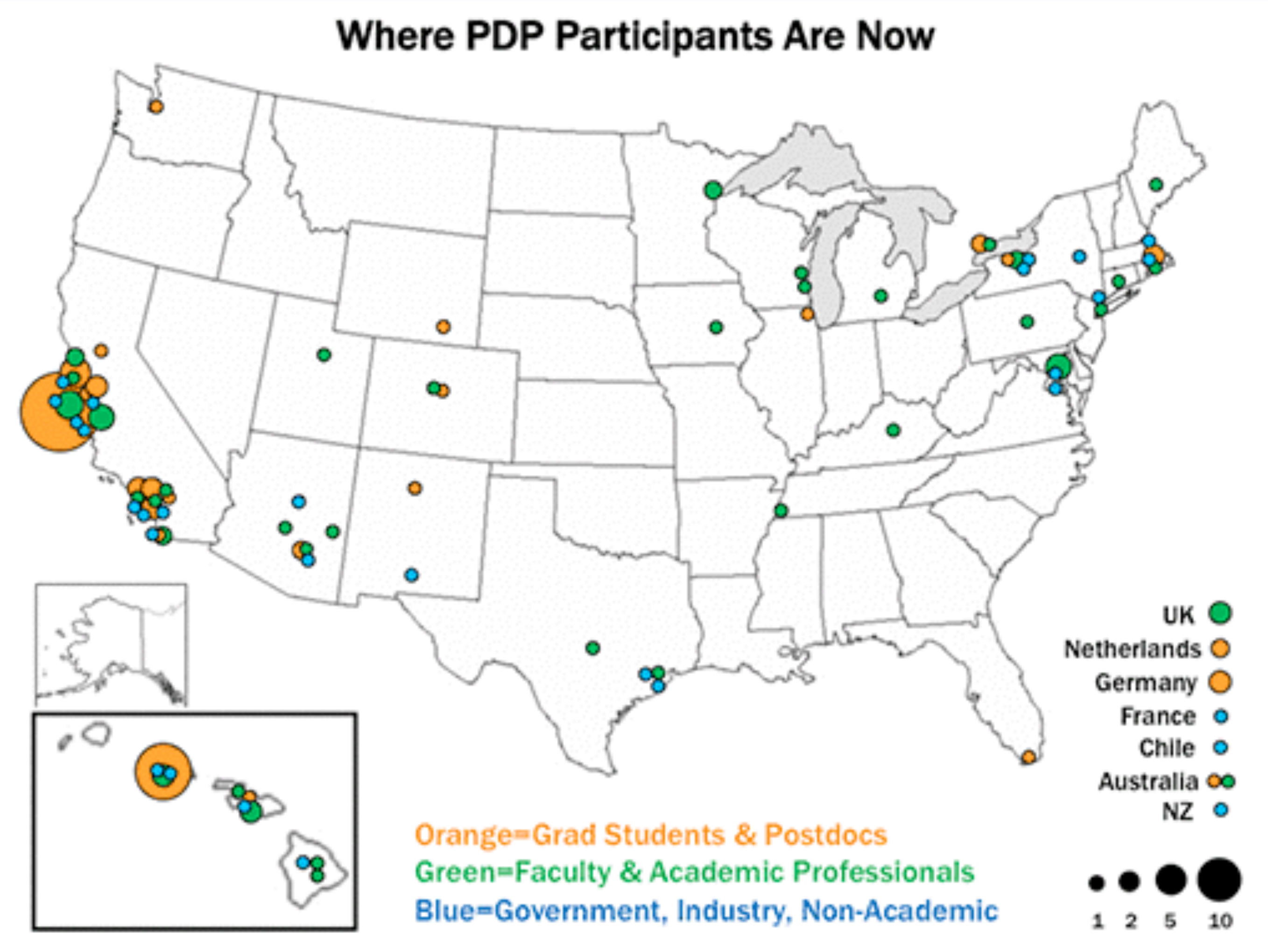
- Teaching assessment, by schedule
- Designing Effective Writing Assignments (April 11)
- Flipping the classroom (April 4)
- Undergrad Research Project Design and mentoring skills (March 30)
- Using polling in teaching (March 14)
- Inside the Master Teacher's Studio (Feb. 15)

IMPROVING TEACHERS BEFORE THEY ARE TEACHERS (ISEE PDP)

- ~100 hours effort
- Inquiry
- Diversity & equity
- Assessment



Hunter et al., 2010



"THERE ARE NOW 38 PDP ALUMNI IN LONG-TERM ACADEMIC POSITIONS ACROSS 15 STATES."

ISEE PDP

http://isee.ucsc.edu/programs/pdp/

PAST EFFORTS AT IFA, AND FUTURE RECOMMENDATIONS

PAST EFFORTS

- Astro-Coffee talks to share high impact teaching techniques
- Colloquium to introduce backwards-design and curriculum map
- Monthly “teachers’ lunch”
- Pre-semester planning meetings
- Individual coaching

High ROI teaching

- Write the final first. Then work backwards from there to the beginning of the course
- Design assignments that have the students practice what you want them to be able to do
- Ask at least two questions per hour, multiple choice and/or think-pair-share (what would happen if X changes… how would you begin modeling X… what would be a good next step…)
- Look past your expert blind spot - why is your topic worth learning (why is it cool, or what cool thing will it enable students to do later). What are potential bottlenecks?

MORE TIME, BUT MORE EFFECTIVE

- Focus class on **Practice with Feedback** on reasoning
- Shift extension and elaboration topics to homework

I think of it this way:

$$\text{Learning} = \int \text{Teaching} \times \text{Retention}$$

If improvements in retention outweigh losses
in breadth of coverage, that's a win

Feb. 2016

CLASS PLANNING

1. ID student difficulties with concepts and math applications
2. **Explicit learning goals** - Students Will Be Able To… (SWBAT)
3. Lectures, with interspersed interactive elements
   - **Conceptual questions with peer instruction**
   - **Targeted questions to develop specific skills, particular math usage**
4. Homework, with metacognitive questions
   - explicitly require connection of abstract to physical context
   - ask students to predict what answer should be
   - require students to first estimate and approximate

Chasteen, Pollack, Pepper, & Perkins 2012

GOALS

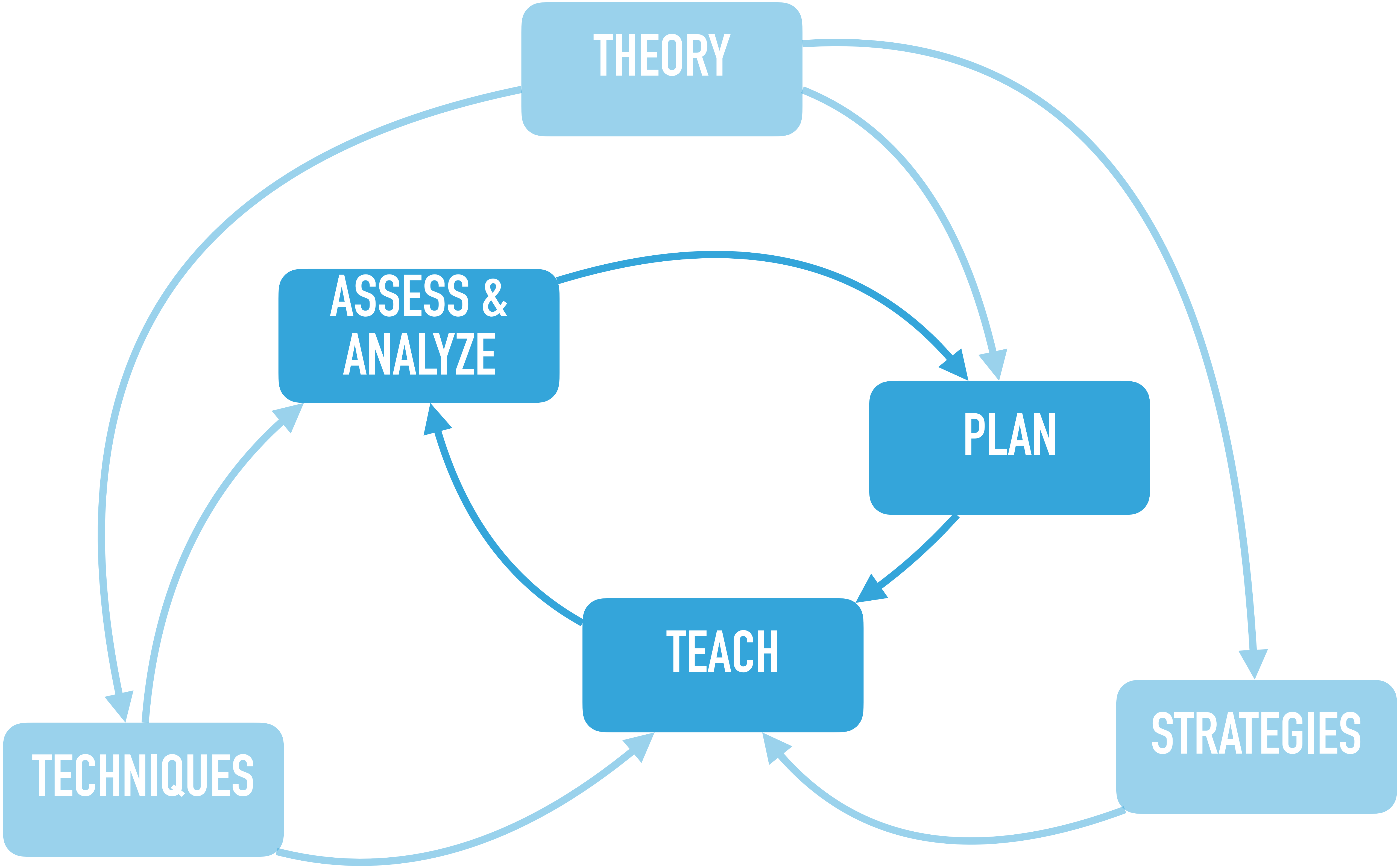
1. Understand how your course helps students meet program learning goals
2. Develop at least one end-of-course assessment question (or some other form of assessment)
3. Outline two activities to prepare students to do well on that question
4. Have tools to complete #2 & 3 for other course goals

WHAT WILL WE ACCOMPLISH TODAY?

- Generate and classify project ideas
- Outline one potential project, and list content, practice, and attitude learning goals
- Plan initial training
- Organize regular interactions

FUTURE RECOMMENDATIONS

- Offer training to incoming faculty (UCSC ISEE PDP or Yale Center for Teaching and Learning)
- Offer training to current faculty, too!
- Integrate faculty in program level assessment cycle, in finite, focused ways:
  - yearly: curriculum map and course alignment
  - pre-semester goal setting and back-design
  - post-semester debrief / briefing for the following instructor
- Engage faculty in scholarly discussions of teaching on a regular basis
- Teaching trained post-doc with focus on faculty professional development (CWSEI model)


THEORY
ASSESS & ANALYZE
PLAN
TEACH
TECHNIQUES
STRATEGIES