The future of STEM education: Preparing the next generation of faculty

Bennett Goldberg

BOSTON UNIVERSITY

The Arguments for Active Learning

Team work

Inquiring minds

Critical thinking

Productive conflict

Social action

Challenge:

The challenge in undergraduate STEM education now lies less in knowing what works and more in getting people to use proven techniques.

- Faculty reward system and time
- Disciplinary traditions
- Institutional structures

Center for the Integration of Research, Teaching and Learning

Mission - To develop a STEM faculty committed to implementing and advancing effective teaching practices for diverse student audiences as part of their professional careers.

Strategy:

Undergraduate STEM Education

Liberal Arts Colleges · 4 SOD · Comprehensive Universities · Two-Year Colleges · Research Universities

~80% of STEM faculty

PhDs from ~100 Research Universities

Strategy: Prepare these future STEM faculty to implement and advance evidence-based teaching practices

Network faculty, staff, and administrators at 12 research universities in the U.S.

C I R T L

CIRTL Core Ideas:

Teaching as Research is the deliberate, systematic and reflective use of research methods to develop and implement teaching practices that advance the learning experiences and outcomes of both students and teachers.

→ STEM professor as change agent

Learning Communities bring together groups of people for shared learning, discovery, and generation of knowledge.

→ Supports institutional growth in teaching and learning

Learning through Diversity capitalizes on the rich array of experiences, backgrounds, and skills among STEM undergraduates and graduates-through-faculty to enhance the learning of all.

→ Excellence and diversity are necessarily intertwined

CIRTL Outcomes:

2700 CIRTL Associates

600 CIRTL Practitioners

150 CIRTL Scholars

MOOC

Individual Participant

MOOC-Centered Learning Community

aka Distributed Flip

aka DOCC

(Not to Scale)

MOOCs as Networks of Local Learning Communities

An Experiment in Preparing Future Faculty

"An Introduction to Evidence-Based Undergraduate STEM Teaching"

@CIRTLMOOC

coursera

2013 - NSF WIDER CFP

Best aspects of the MCLC experience for participants?

MCLC Facilitator Survey (n=24)

Given what you've heard about the MOOC and its MCLCs, what predictions would you make for this experiment?

CIRTL MOOC Outcomes

- Postdocs completed at ~50%
- Grad students completed at ~40%
- Piquing engagement of future faculty!

Metrics and Research Questions:

Measurements:

- Completion rates
- Individual or Group participant
- Intention to complete
- Learning activities during course

Questions:

- Who were high completers and why?
- Does being in a learning community affect completion?
- Does intention impact actual completion?
- Correlations among learning activities

CIRTL MOOC Participation

5908 Enrolled Students

4009 Active Students

566 Statements of Accomplishment

14% Completion Rate

What comes to mind when you hear the word "MOOC"?

MOOC as Course Replacement

MOOC as Educational Outreach

The Arguments for Active Learning

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Effective communities

2030:
The future job market

2030:
The future of education

Inquiring minds

Critical thinking

Indian Nation - 500+ Federally recognized tribes
25% of US Energy Resources
Only 1 faculty in top 50 universities in STEM

Productive conflict

Social action

Grand challenges in science and engineering

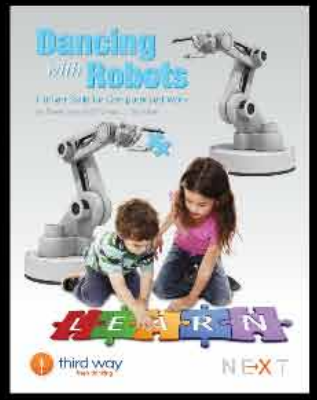
2030:
The future job market

"The human labor market will center on three kinds of work:

solving unstructured problems,

working with new information (including complex communication),

and carrying out non-routine manual tasks."



to sharply increase the fraction of children with the foundational skills needed to develop job-relevant knowledge and to learn efficiently over a lifetime

Murnane and Levy

The future job

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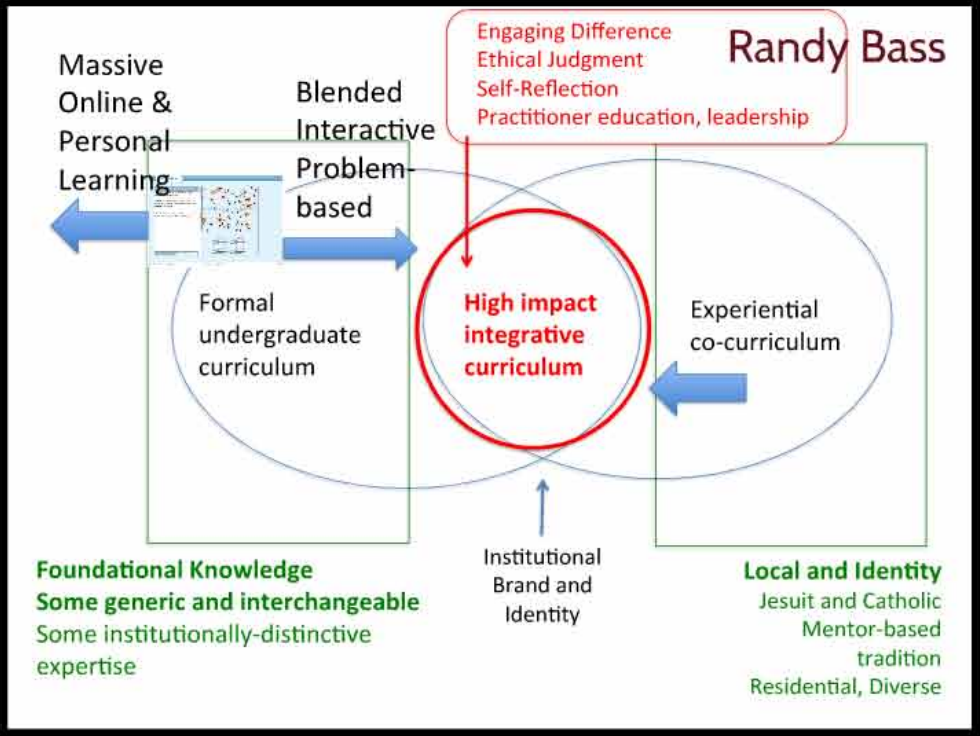
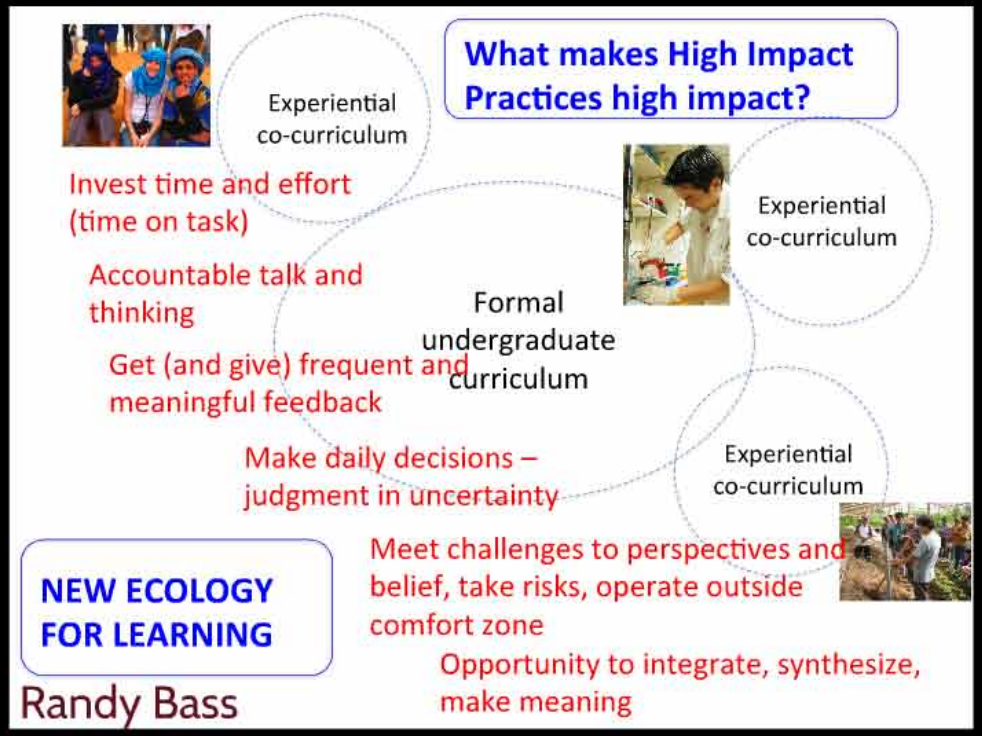
2030:
The future of education





The Arguments for Active Learning

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The Five Dysfunctions Model by Patrick Lencioni

Social action

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tructured approaches to teaching are effecti

Meta-analysis of 250 Studies of Active Learning

PNAS

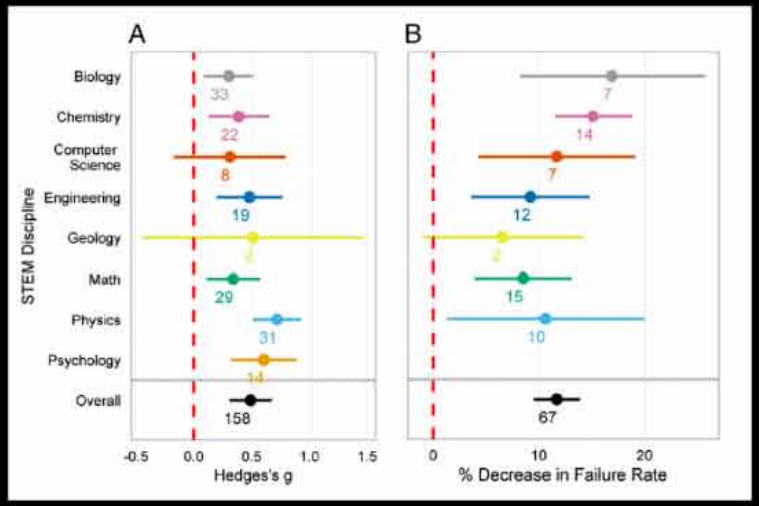
Active learning increases student performance in science, engineering, and mathematics

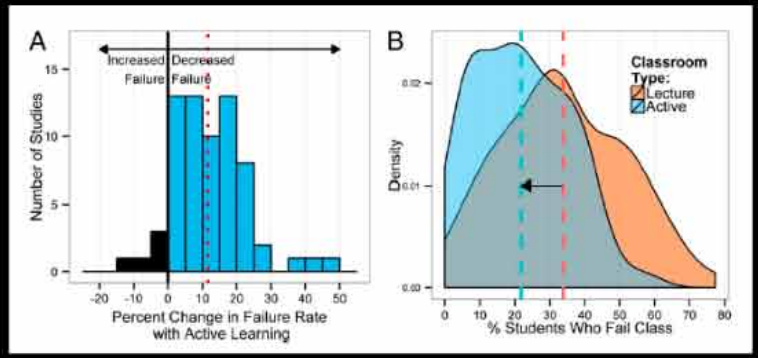
Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

[a]Department of Biology, University of Washington, Seattle, WA 98195; and [b]School of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported 225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementa-





Significance

The President's Council of Advisors on Science and Technology has called for a 33% increase in the number of science, technology, engineering, and mathematics (STEM) bachelor's degrees completed per year and recommended adoption of empirically validated teaching practices as critical to achieving that goal. The studies analyzed here document that active learning leads to increases in examination performance that would raise average grades by a half a letter, and that failure rates under traditional lecturing increase by 55% over the rates observed under active learning. The analysis supports theory claiming that calls to increase the number of students receiving STEM degrees could be answered, at least in part, by abandoning traditional lecturing in favor of active learning.

Challenge:

The challenge in undergraduate STEM education now lies less in knowing what works and more in getting people to use proven techniques.

- Fairweather 2008
- PCAST 2012

- Faculty reward system and time
- Disciplinary traditions
- Institutional structures

Center for the Integration of Research, Teaching and Learning

CIRTL

Mission - To develop a STEM faculty committed to implementing and advancing effective teaching practices for diverse student audiences as part of their professional careers.

- Disciplinary traditions
- Institutional structures

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What CIRTL Is About

College of Idaho

Ain Shams Univ., Cairo

University of Illinois Urbana-Champaign

Ball State University

Purdue University

University of Maryland Eastern Shore

University of Wisconsin - Rock County

Lawrence University

Augustana College

North Carolina State University

University of Dubuque

University of Louisville

Madison Area Technical College

Tufts University

www.cirtl.

Strategy:

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4,500

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C I R T L

Network: Faculty, staff, and administrators at 22 research universities in the U.S.

> 20% of US STEM PhD Production

Network expansion to >50% of US STEM PhD Production

CIRTL Core Ideas:

Teaching-as-Research: is the deliberate, systematic, and reflective use of research methods to develop and implement teaching practices that advance the learning experiences and outcomes of both students and teachers.

→ STEM professor as change agent

Learning Communities: bring together groups of people for shared learning, discovery, and generation of knowledge.

→ Supports institutional growth in teaching and learning

Learning-through-Diversity: capitalizes on the rich array of experiences, backgrounds, and skills among STEM undergraduates and graduates-through-faculty to enhance the learning of all.

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Network Design:

- Central hub with resources, organization, governance
- Local Learning Communities at every Network institution
- Common student learning outcomes!
- Cross-network courses, workshops, coffee-hours, in-person meetings

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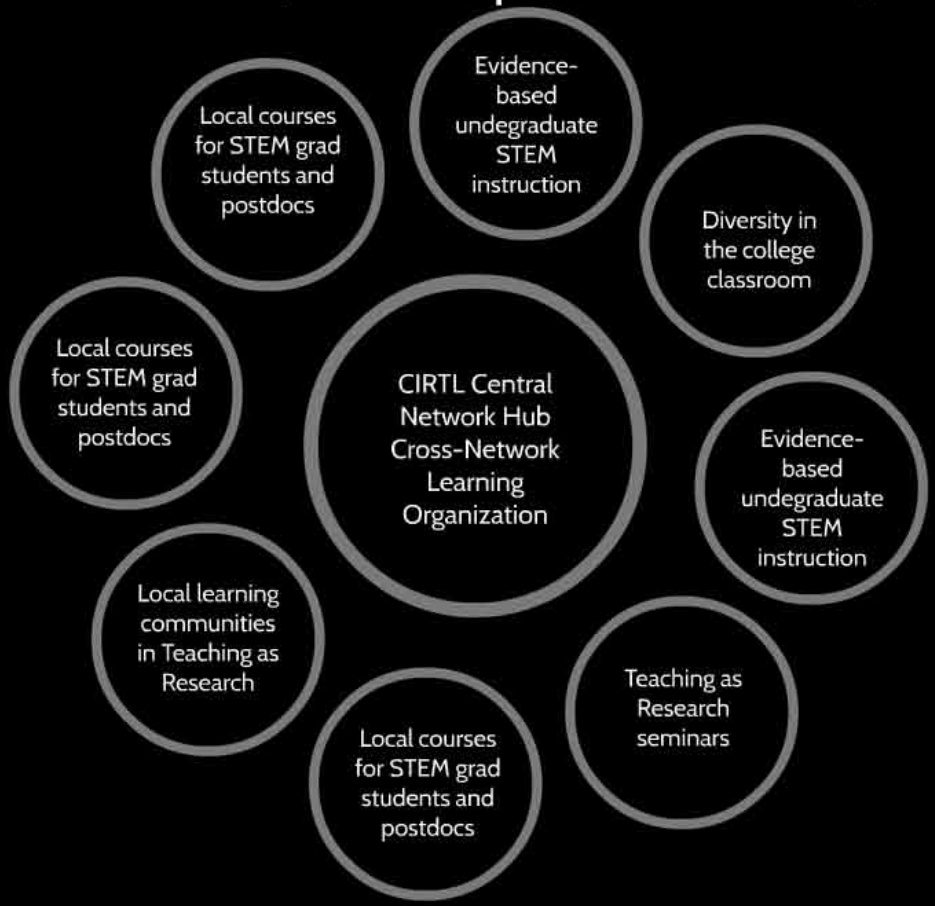
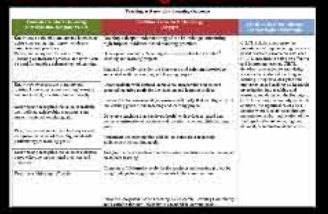


Common Learning Outcomes



Common Learning Outcomes

Teaching as Research – Learning Outcomes

Associates can do the following: (Describe and Recognize Value)	Practitioners can do the following: (Engage)	Scholars can do the following: (Advance and Disseminate)
Know that a body of literature and knowledge exists concerning high-impact, evidence-based teaching practices.	Develop a deeper understanding of the knowledge concerning high-impact, evidence-based teaching practices.	CIRTL Scholars recognize the importance of implementing evidence-based practices associated with each CIRTL core idea to being an effective and improving teacher. CIRTL Scholars have added to knowledge about evidence-based teaching and learning. They have designed and implemented a Teaching-as-Research investigation into teaching and learning, and defended the findings to CIRTL learning-community peers. In addition, the significance of CIRTL Scholar work is established through presentation and/or publication of the findings to all-university, regional, national, or international audiences.
Define and recognize the value of the Teaching-as-Research process, and how it can be used for ongoing enhancement of learning.	Develop and execute a Teaching-as-Research plan for a limited [1] teaching and learning project: Find and critically consider **the literature and existing knowledge** associated with the teaching and learning project. Create realistic well-defined, achievable, measurable and student-centered **learning goals** for the teaching and learning project. Find or develop assessment (**measurement**) tool(s that are aligned with the learning goals of the teaching and learning project. Develop a teaching plan (an **hypothesis)** with evidence-based and inclusive instructional practices and materials to accomplish learning goals. Implement the teaching plan and collect some **data** regarding achievement of learning goals. **Analyze** the data and draw evidence-based conclusions about the impact on student learning. Complete a **full-inquiry cycle** for the teaching and learning project by using findings to suggest improvements to the above actions.	
Know how to access the literature and existing knowledge about teaching, learning and assessment, in a discipline or broadly.		
Describe and recognize the value of realistic well-defined, achievable, measurable and student-centered learning goals.		
Describe several assessment techniques and recognize the value of their alignment with particular types learning goals.		
Describe and recognize the value of evidence-based effective instructional practices and materials.		
Describe a "full-inquiry" cycle		
	Show the integrated use of Teaching-as-Research, Learning Community and Learning-through-Diversity to accomplish learning goals.	

CIRTL Outcomes:

CIRTL Outcomes – Early-Career Faculty

Participants use skills in other than classroom settings.

- Lab supervision, mentoring, and advising
- Outside academia working with clients

-Benbow, Byrd and Connolly 2011
-Connolly et al. 2012

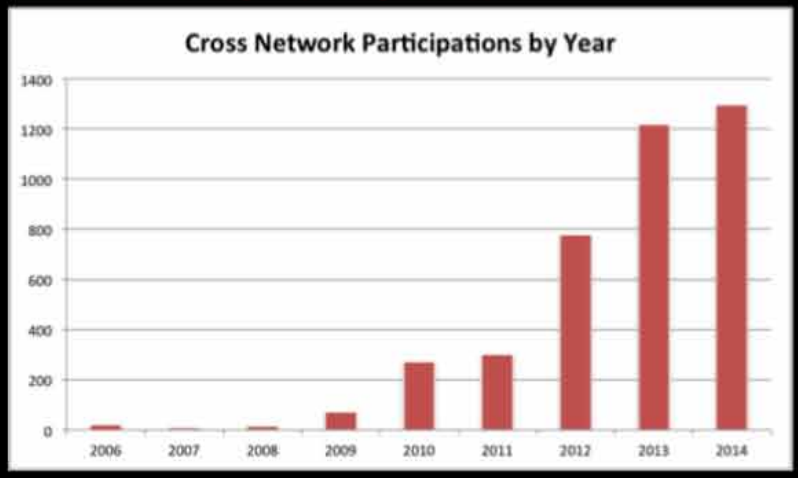
Programs help those looking for academic jobs.

- Sense of readiness for academic jobs
- Apply for a wider range of positions
- Knowledgeably discuss teaching in job interviews

Programs support early career success.

- Begin quickly in new positions
- Fostered fast starts in research programs
  - faster to first grant

Growth in participation



Longitudinal study of outcomes

Participants later use skills and concepts known to improve student learning.

-Benbow, Byrd and Connolly 2011
-Connolly et al. 2012

76% had found ways to apply gained knowledge and skills in their early careers.

In order of frequency of response, participants report:

- Delivering instruction that increases student engagement
- Using outcomes-based design; learning goals in course planning
- Methods of ongoing assessment aligned with learning goals.
- Ways to include diverse student perspectives

Participants cite integrating teaching and scientific research as valuable currently.

CIRTL Goal (2015-16)

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150 CIRTL Scholars

Faculty

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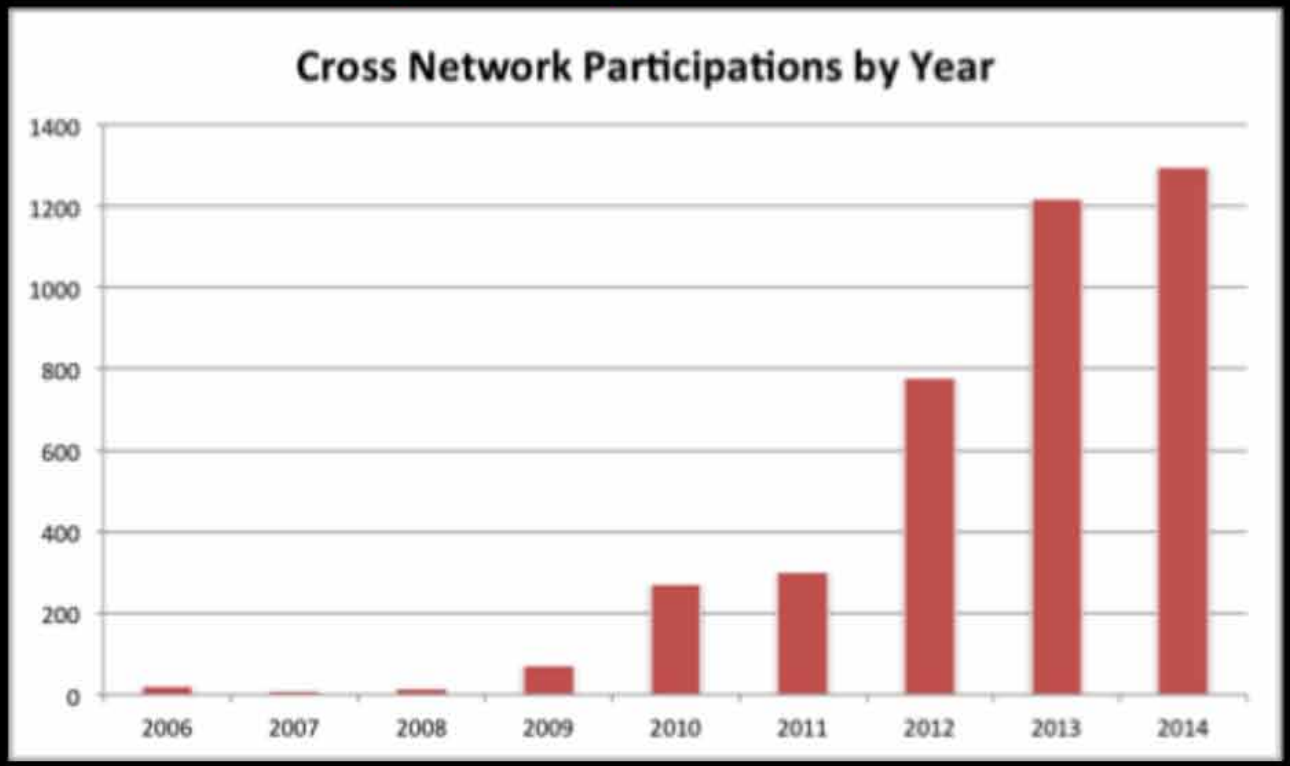

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Longitudinal study of outcom

2013 - NSF WIDER CFP

"WIDER seeks to **substantially increase the scale** of application of highly effective methods of STEM teaching and learning in institutions of higher education, by employing instructional materials and methods that have a convincing evidentiary basis of effectiveness."

MICHIGAN STATE UNIVERSITY

Henry (Rique) Campa

WISCONSIN

Robert (Bob) Mathieu
Katherine (Kitch) Barnicle

VANDERBILT UNIVERSITY

Derek Bruff

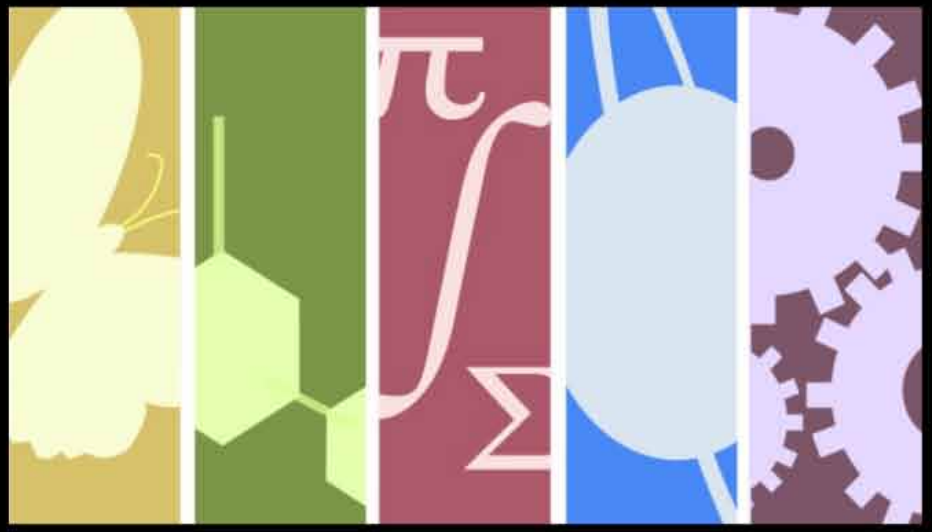
BOSTON UNIVERSITY

Bennett Goldberg

NSF Grant #1347605

MOOCs as Networks of Local Learning Communities

An Experiment in Preparing Future Faculty



"An Introduction to Evidence-Based Undergraduate STEM Teaching"
@CIRTLMOOC

coursera

1 - Principles of Learning
Derek Bruff
Vanderbilt U.

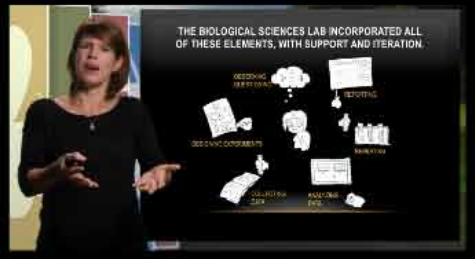
2 - Learning Objectives
Stephanie Chasteen
U. Colorado - Boulder

3 - Assessment
Angela Little
U. California - Berkley

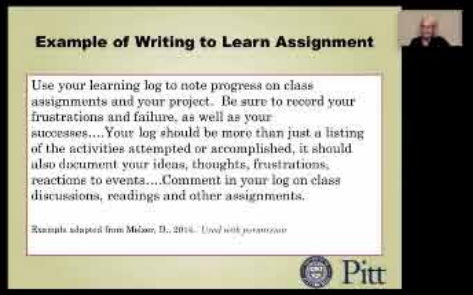
4 - Cooperative Learning
Rique Campa
Michigan State U.

5 - Peer Instruction
Bennett Goldberg
Boston University

6 - Lecturing
Derek Bruff
Vanderbilt U.



7 - Inquiry-Based Labs
Cynthia Brame
Vanderbilt U.



8 - Writing to Learn
Janet Littrell
U. Pittsburgh

9 - Problem-Based Learning
Rique Campa
Michigan State U.

10 - Inclusive Teaching
Trey Mack
Vanderbilt U.

11 - Student Motivation
Derek Bruff
Vanderbilt U.

Intros & Outros
Trina McMahon, UW-Madison
Derek Bruff, Vanderbilt U.

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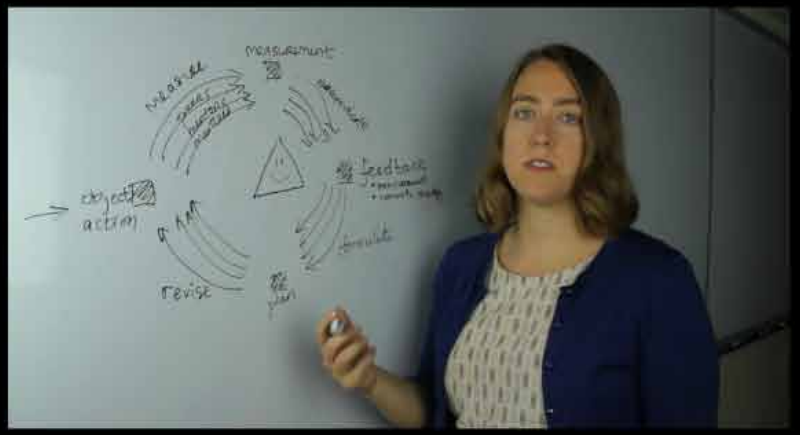

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YouTube

dvancing effective teaching
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practices.

CIRTL

Excellence an

MOOC

Individual Participant

Facilitator's Guide
- Module learning goals
- Description of module content
- Suggested in-person activities

Discussion Highlights
Questions & Perspectives
Course Feedback

MOOC-Centered
Learning Community

aka Distributed Flip
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See http://derekbruff.org/?p=2938.

(Not to Scale)

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CIRTL MOOC Outcomes

Neda Derakhshani
Chris Dellarocas

C increased your completion by
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- Grad students completed at ~40%
- Meeting large need of future faculty!

Metrics and Research Questions:

Measurements:

- Completion rates

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37% Male

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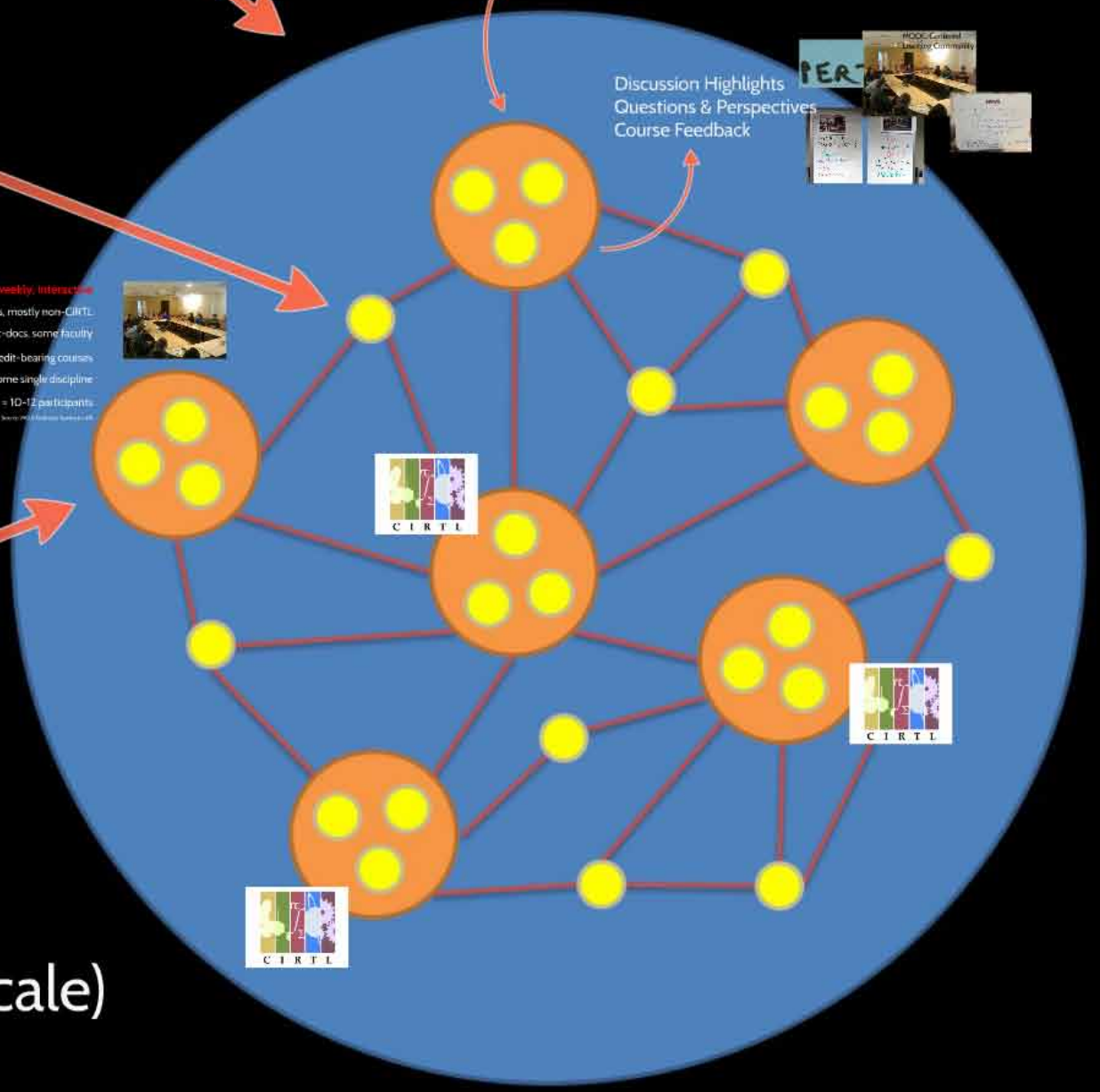

(Not to Scale)

CIRTL MOOC Outcomes

Neda Derakhshani

MCLCs - in-person, weekly, interactive

>45 hosting institutions, mostly non-CIRTL

Mostly grad students and post-docs, some faculty

Some offered as part of credit-bearing courses

Most were multi-disciplinary, some single discipline

Average size = 10-12 participants

Source: MCLC Facilitator Survey (n=24)

Faciltator's Guide

- Module learning goals
- Description of module content
- Suggested in-person activities

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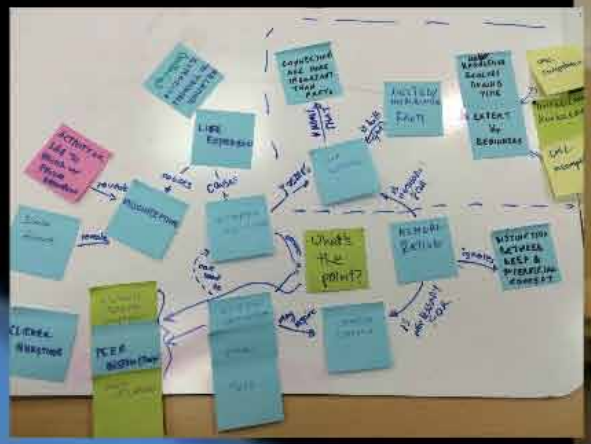
MOOC-Centered Learning Community



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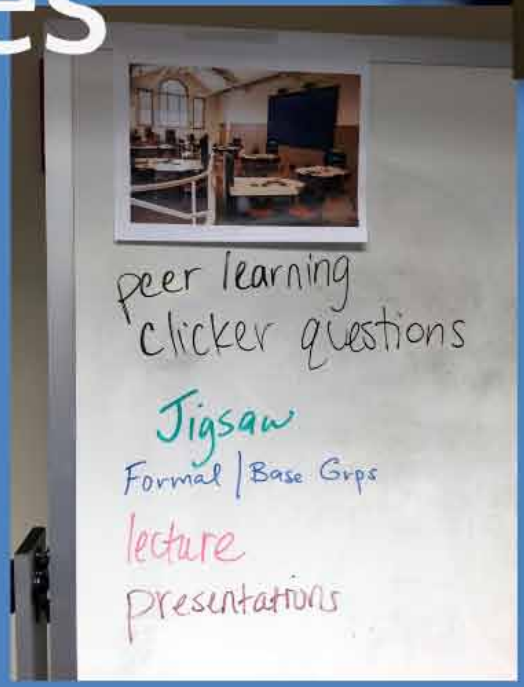

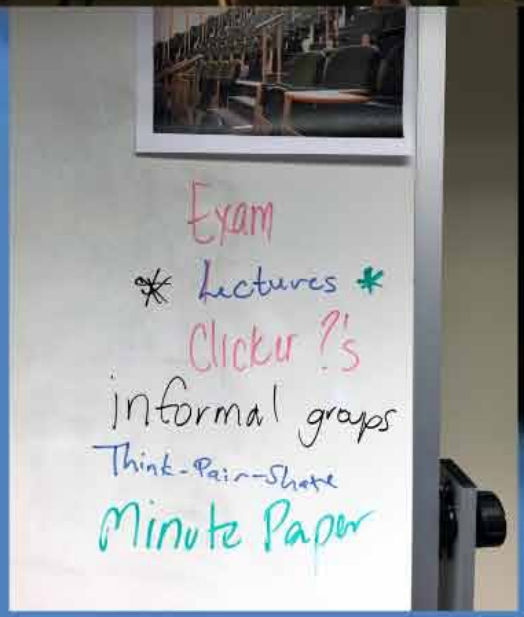

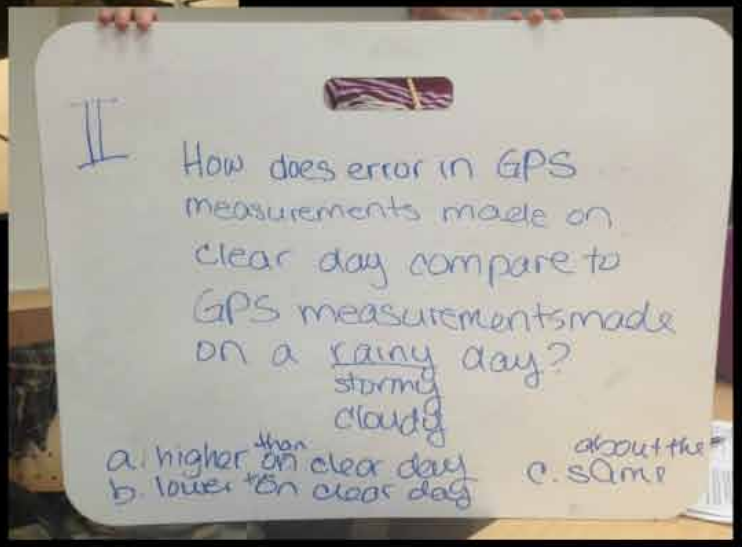

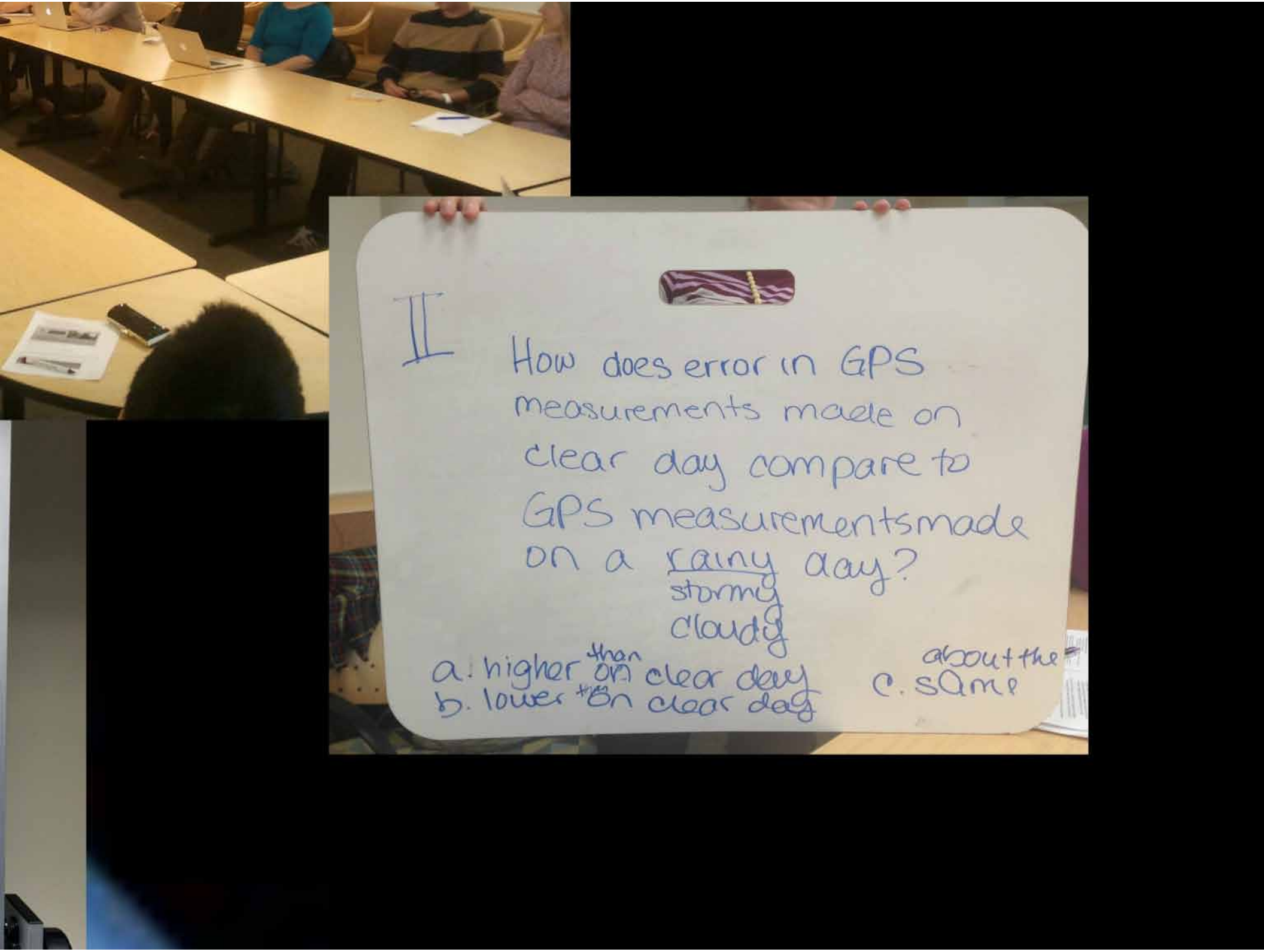
II
How does error in GPS measurements made on clear day compare to GPS measurements made on a rainy stormy cloudy day?
a. higher than on clear day
b. lower than on clear day
c. about the same

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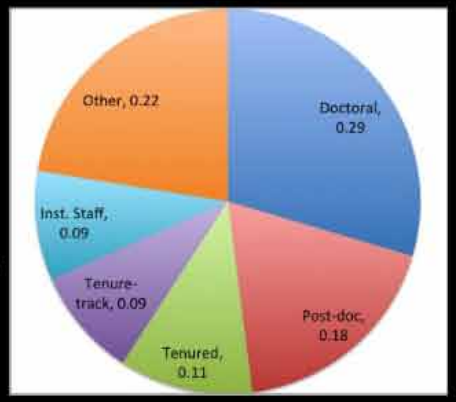
4009 Active Students

566 Statements of Accomplishment

14% Completion Rate

29% Doctoral student
18% Post-doc
20% Faculty member
9% Instructional staff



75% United States
3% Canada
2% India
20% Elsewhere

99% already had a college degree!

Source: Pre-Course Survey (response rate = 36%)

ons:

CIRTL MOOC

14% Spent 0-2 hrs/wk
62% Spent 3-6 hrs/wk
19% Spent 7-10 hrs/wk
5% Spent >10 hrs/wk

Source: Post-Course Survey (response rate = 12%)

61% Female
37% Male
2% Prefer not to say

29% Doctoral student
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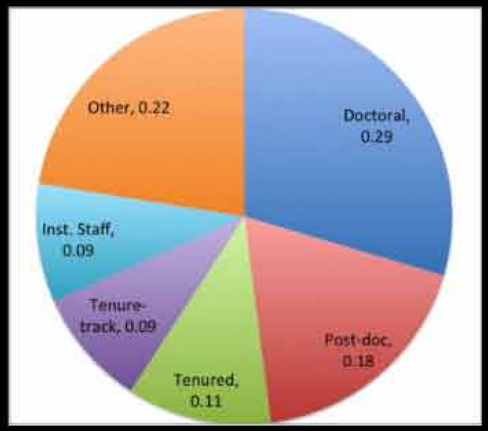

39% Biological sciences
20% Physical sciences
12% Engineering
5% Earth sciences
5% Mathematics
4% Computer science
4% Social sciences

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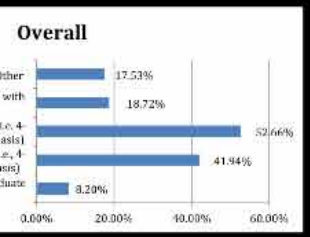
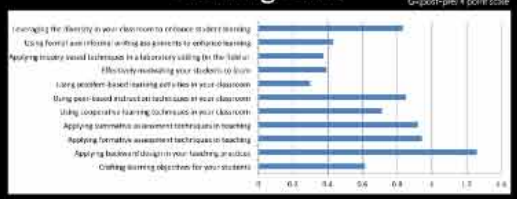


- Postdocs completed at ~50%
- Grad students completed at ~40%
- Meeting large need of future faculty!

Current Position	All Participants Overall Number	All Participants Completion Rate	MCLC participants Overall Number	MCLC participants Completion Rate	Non-MCLC participants Overall Number	Non-MCLC participants Completion Rate
Doctoral student	404	38.40%	145	46.9%	259	33.6%
Post-doctoral researcher	262	49.60%	92	55.4%	170	46.5%
Instructional Staff	134	26.90%	38	34.2%	96	24.0%
Faculty member (tenured)	156	18.60%	32	25.0%	124	16.9%
Early career faculty member (pre-tenure)	129	17.80%	28	25.0%	101	15.8%
Master Student	63	33.30%	16	31.3%	47	34.0%
Faculty professional development staff	44	20.50%	16	31.3%	28	14.3%
Other	57	24.60%	15	46.7%	42	16.7%
Researcher	33	33.30%	14	57.1%	19	15.8%
Not affiliated with a higher education institution.	96	27.10%	13	38.5%	83	25.3%
Administrator	35	17.10%	8	12.5%	27	18.5%
Information technology staff	3	33.30%	2	50.0%	1	0.0%

Table 1: Completion rate by current position overall and as a function of their intention to participate in a MOOC-centered learning community as reported on the pre-course survey. Note that graduate students and post-docs had by far the largest completion numbers and rates, with MCLC participant rates higher than individuals.

Learning Gains



Metrics and Research Que

Measurements:

- Completion rates
- Individual or Group participant
- Intention to complete
- Learning activities during course

Questions:

- Who were high completers and why
- Does being in a learning community completion?
- Does intention impact actual compl
- Correlations among learning activitie

- The number of participants who watched at least one video was 3100. If they watched one video, they watched on average 35% of the videos, based on regression.
- The number of participants who completed one quiz was 1119. If they completed one quiz, they

Metrics and Research Questions:

Measurements:

- Completion rates
- Individual or Group participant
- Intention to complete
- Learning activities during course

14% Spent
62% Spent
19% Spent
5% Spent

Source: Post-Course Sur

Questions:

- Who were high completers and why?
- Does being in a learning community affect completion?
- Does intention impact actual completion?
- Correlations among learning activities

- Postdocs completed at ~50%
- Grad students completed at ~40%
- Meeting large need of future faculty!

Current Position	All Participants Overall Number	All Participants Completion Rate	MCLC participants Overall Number	MCLC participants Completion Rate	Non-MCLC participants Overall Number	Non-MCLC participants Completion Rate
Doctoral student	404	38.40%	145	46.9%	259	33.6%
Post-doctoral researcher	262	49.60%	92	55.4%	170	46.5%
Instructional Staff	134	26.90%	38	34.2%	96	24.0%
Faculty member (tenured)	156	18.60%	32	25.0%	124	16.9%
Early career faculty member (pre-tenure)	129	17.80%	28	25.0%	101	15.8%
Master Student	63	33.30%	16	31.3%	47	34.0%
Faculty professional development staff	44	20.50%	16	31.3%	28	14.3%
Other	57	24.60%	15	46.7%	42	16.7%
Researcher	33	33.30%	14	57.1%	19	15.8%
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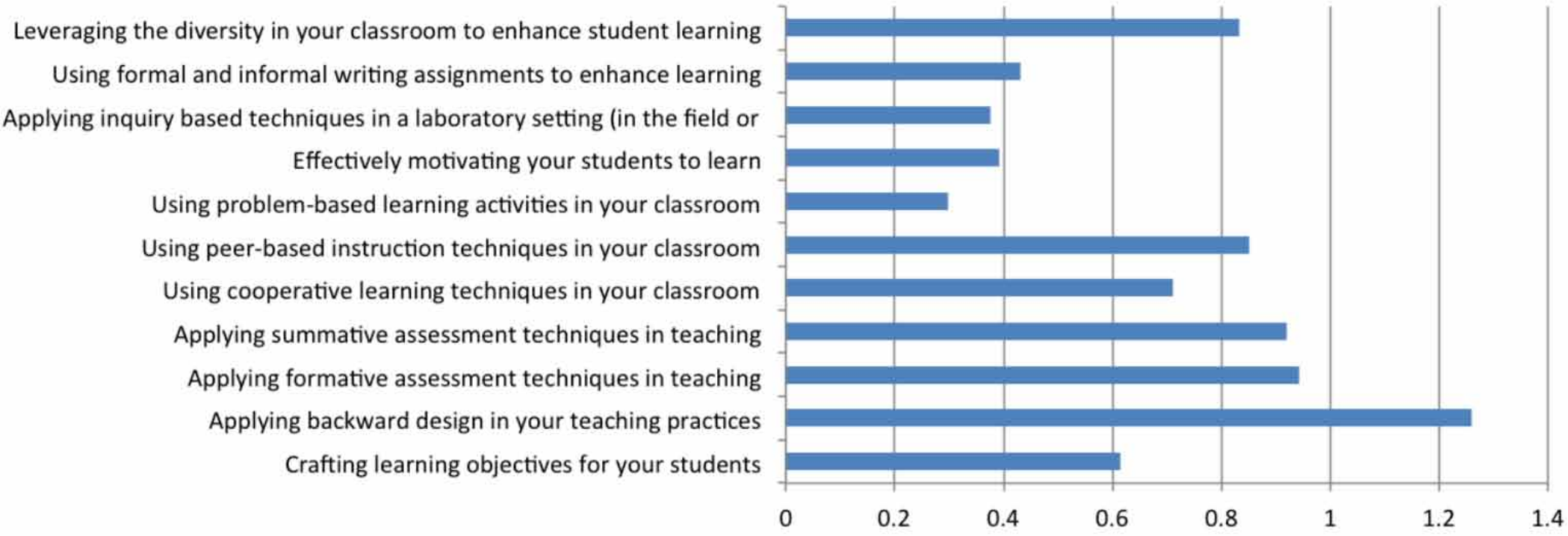
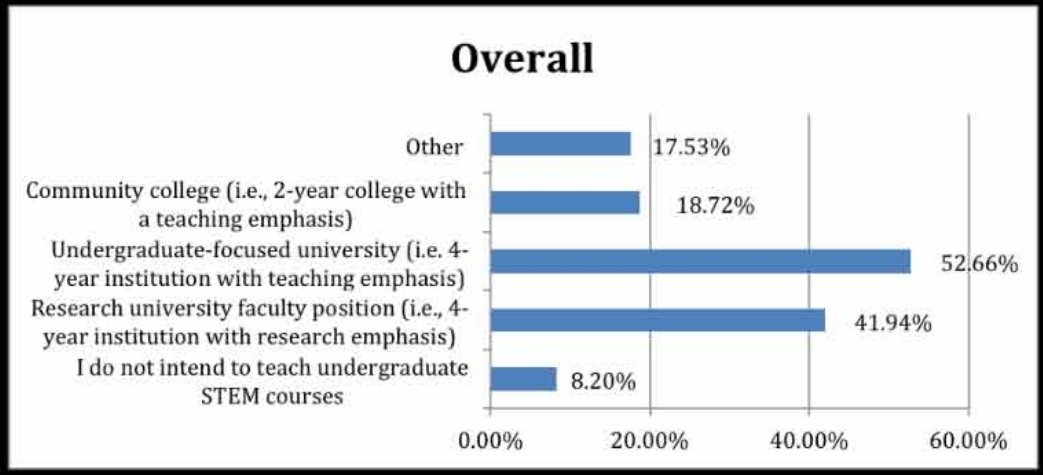
Learning Gains

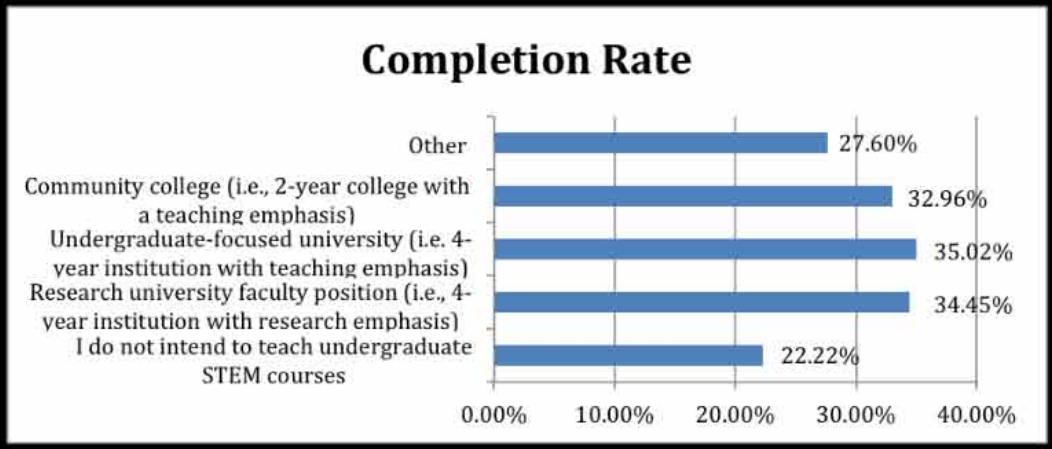
G=(post-pre) 4 point scale



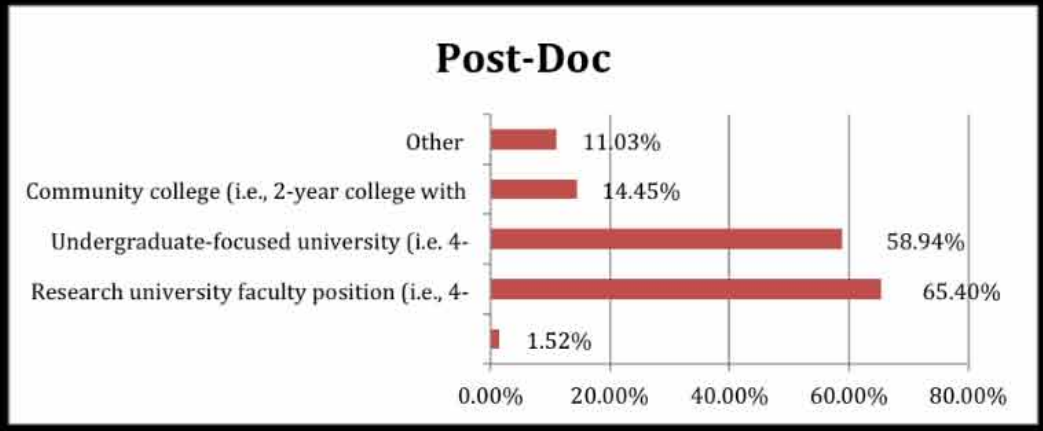
Participants' career goals are to be STEM faculty



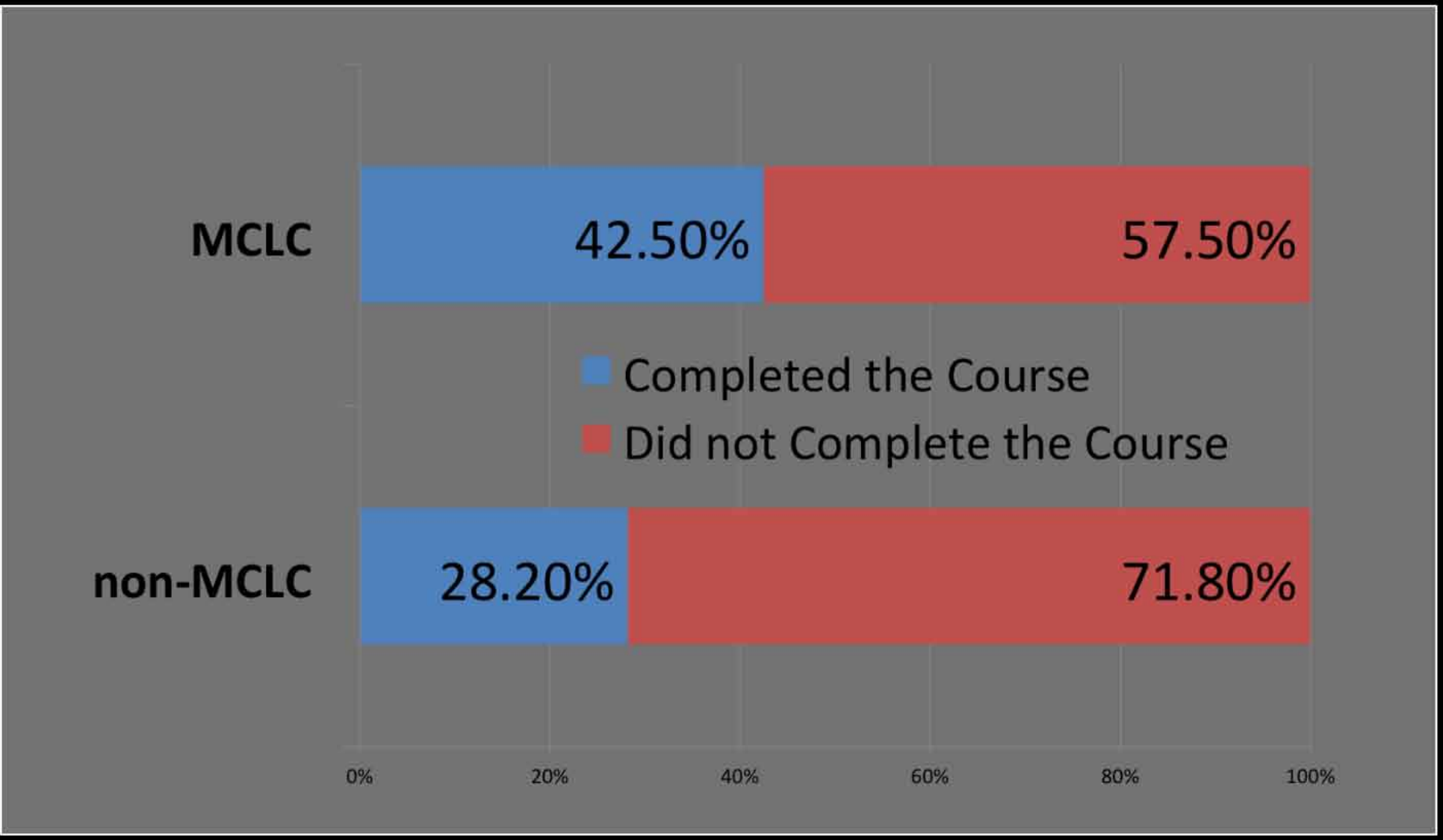
Participants complete with small preference those who want to be STEM faculty



Postdocs are focused on careers as STEM faculty



Being in an MCLC increased your completion by 1.5-2.0 times, whether you intended to complete or not



Best aspects of the MCLC experience for participants?

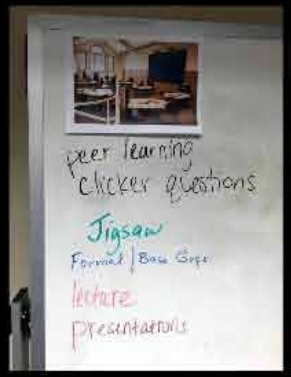
92% Interacting with peers
86% Meeting others interested in teaching
75% Discussing course material & assignments
72% Discussing teaching topics beyond the MOOC

Source: Post-Course Survey (response rate = 12%)

MCLC Facilitator Survey (n=24)

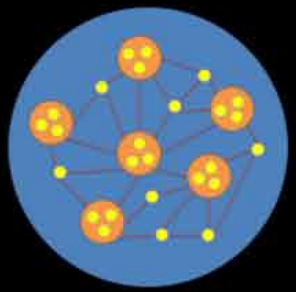
Most facilitator prep time was spent deciding what topics, videos, and discussions to prioritize.

"There was much more material then we could cover in an hour meeting so it was important for the participants to focus on what we would discuss during the meeting."



Most (68%) selected activities from the facilitator's guide. Some (29%) just used the guide for inspiration.

A common request: "Early communication, even earlier access to the videos than the students, and more complete facilitator notes would be immensely beneficial."



Facilitators were of mixed opinions on the value of the global learning community to their local ones.

"Yes. It is valuable to hear from other students and educators for a varied, diverse perspective."

"Some students engaged in the online forum earlier on in the MOOC; however, as time went on, it seemed apparent that the online discussion board was not used by our participants."

"We were all very pressed for time, and I think most of us prioritized the in-person MOOC over the online forum since it was nice to be able to discuss things in person."

Several facilitators pointed to the value of local learning communities.

"Being at a research intensive institution, it's been difficult to find and connect with other graduate students who are interested in education and teaching as a future career. This learning community allowed us to meet and connect and, hopefully, will serve as the start of an education interest group."

"Our participants reported that the primary benefit of the MCLC was accountability to actually watch the videos and stay current with the course, and secondarily growing our local STEM teaching community."

Almost all facilitators said they would use MOOC content in other contexts.

"The videos are much more accessible than, say, assigning a reading on the same content. So I would appreciate being able to use the videos to help participants prepare for a workshop or class discussion."

"Actually I [already] have. I was giving a talk about diversity a few weeks ago... I used Mark Connolly's two videos about 'talking about leaving' - they were perfect."

MEET Faculty

1 - Principles of Learning
Derek Bruff
Vanderbilt U.

2 - Learning Objectives
Stephanie Chasteen
U. Colorado - Boulder

3 - Assessment
Angela Little
U. California - Berkley

4 - Cooperative Learning
Rique Campa
Michigan State U.

5 - Peer Instruction
Bennett Goldberg
Boston University

6 - Lecturing
Derek Bruff
Vanderbilt U.

7 - Inquiry-Based Labs
Cynthia Brame
Vanderbilt U.

8 - Writing to Learn
Janet Littrell
U. Pittsburgh

9 - Problem-Based Learning
Rique Campa
Michigan State U.

10 - Inclusive Teaching
Trey Mack
Vanderbilt U.

11 - Student Motivation
Derek Bruff
Vanderbilt U.

Intros & Outros
Trina McMahon, UW-Madison
Derek Bruff, Vanderbilt U.

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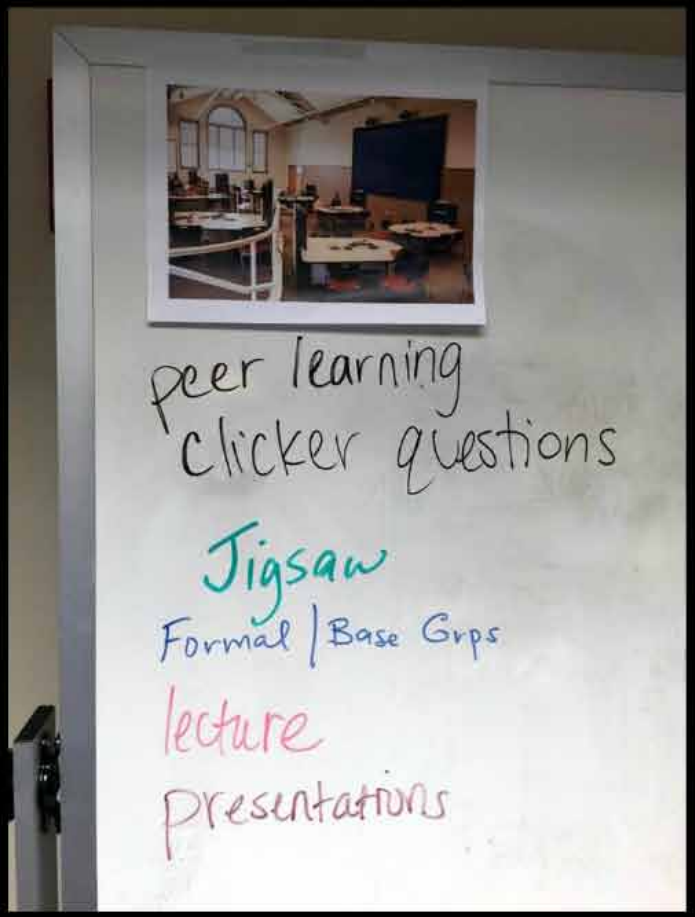

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3000 pre-registered
33 MOOC-Centd Learning Communities

http://stemteachingcourse.org

Home | About the Course | Syllabus | Learning Communities | Course Content | Data and Results | About Us

An Introduction to Evidence-Based Undergraduate STEM Teaching

Course Dates

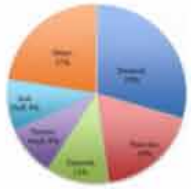
September 28th – November 20th, 2015

Enroll Here!

Local learning communities

Preview our course content

Data from the offering last fall



Learn about us and course creation

C I R T L

"An Introduction to Evidence-Based Undergraduate STEM Teaching" is an open, online course designed to provide future STEM faculty, graduate students and post-doctoral fellows with an introduction to effective teaching strategies and the research that supports them. The goal of the eight-week course is to equip the next generation of STEM faculty to be effective teachers, thus improving the learning experience for the thousands of students they will teach.

Streamlined, improved and less content

"I really loved the course and I will definitely be using the skills that I've acquired. I'm teaching my first class next semester, and I've already been putting these new tools you've provided me with to good use. I'm much more excited and less nervous about teaching now!..."
– Fall 2014 participant

The future of STEM education: Preparing the next generation of faculty

Bennett Goldberg

BOSTON UNIVERSITY

The Arguments for Active Learning

Team work

Inquiring minds

Critical thinking

Productive conflict

Social action

Challenge

The challenge in undergraduate STEM education now lies less in knowing what works and more in getting people to use proven techniques.

- Faculty reward system and time
- Disciplinary traditions
- Institutional structures

Center for the Integration of Research, Teaching and Learning

Mission – To develop a STEM faculty committed to implementing and advancing effective teaching practices, for diverse student audiences as part of their professional careers

Strategy

Undergraduate STEM Education

Liberal Arts Colleges · 4,500 · Comprehensive Universities

Two-Year Colleges

Research Universities

~80% of STEM faculty

PhDs from ~100 Research Universities

Strategy: Prepare these future STEM faculty to implement and advance evidence-based teaching practices

Network: Faculty, staff, and administrators at 22 research universities in the U.S.

CIRTL Core Ideas:

Teaching as Research is the deliberate, systematic, and reflective use of research methods to develop and implement teaching practices that advance the learning experiences and outcomes of both students and teachers.

⇒ STEM professors as change agent

Learning Communities bring together groups of people for shared learning, discovery, and generation of knowledge.

⇒ Supports institutional growth in teaching and learning

Learning through Diversity capitalizes on the rich array of experiences, backgrounds, and skills among STEM undergraduates and graduates–through–faculty to enhance the learning of all.

⇒ Excellence and diversity are necessarily intertwined

CIRTL Outcomes:

CIRTL Outcomes – Early Career Faculty

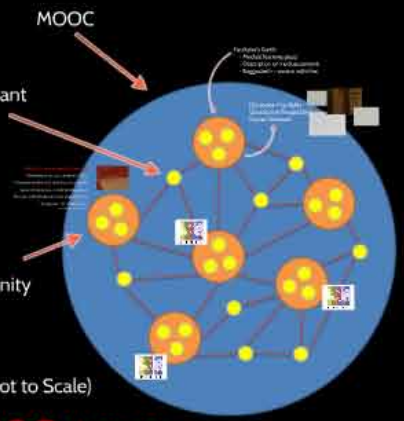
Longitudinal study of outcomes

CIRTL Goal (2018-19)

2700 CIRTL Associates
600 CIRTL Practitioners
150 CIRTL Scholars

Best aspects of the MCLC experience for participants?

MCLC Facilitator Survey (n=24)



MOOCs as Networks of Local Learning Communities

An Experiment in Preparing Future Faculty

"An Introduction to Evidence-Based Undergraduate STEM Teaching"
@CIRTLMOOC

coursera

2013 - NSF WIDER CFP

"WIDER exists to substantially increase the scale of application of highly effective methods of STEM teaching and learning in institutions of higher education, by emphasizing evidence-based materials and methods that have a convincing evidentiary basis of efficacy."

What comes to mind when you hear the word "MOOC"?

MOOC as Course Replacement

MOOC as Educational Outreach

Something else...?

CIRTL MOOC Outcomes

Given what you've heard about the MOOC and its MCLCs, what predictions would you make for this experiment?

Being in an MCLC increased your completion by 1.5-3 'U' scores, whether you intended to complete or not

- Postdocs completed at ~50%
- Grad students completed at ~40%
- Meeting segment of future faculty?

Metrics and Research Questions

Measurements:

- Completion rates
- Individual or Group participant
- Intention to complete
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Questions:

- Who were high completers and why?
- Does being in a learning community affect completion?
- Does intention impact actual completion?
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CIRTL MOOC Participation

5908 Enrolled Students

4009 Active Students

566 Statements of Accomplishment

14% Completion Rate