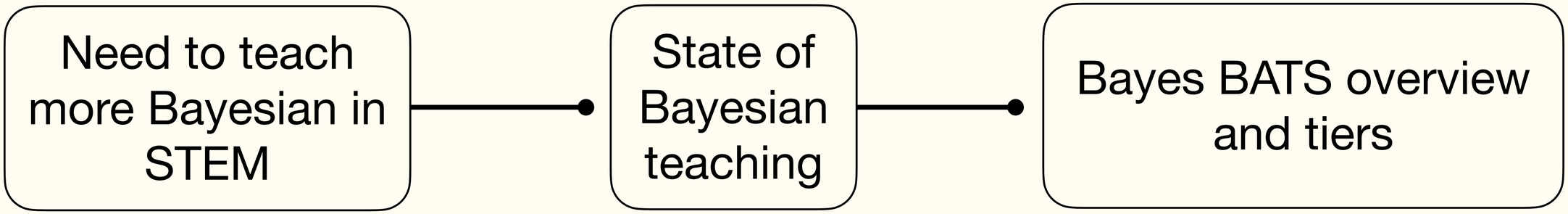
Bayes BATS

A program for advancing Bayesian thinking in STEM education

Federica Zoe Ricci
University of California, Irvine

JSM 2024

Talk Outline



More Bayes in STEM!

Bayes, because we *should*

- Bayesian methods provide a natural way to understand uncertainty

> *Bayes is natural: People use probability in loose, informal ways every day and* ***in a sense, every student is a subjective Bayesian***
>
> (Witmer 2017)

Bayes, because we *should*

- Bayesian methods provide a natural way to understand uncertainty

> *The **philosophical contrasts** between Bayesian approaches and classical statistical methods are profound and enhance learning*
>
> (Hoegh 2020)

Bayes, because we *should*

- Bayesian methods have become common in many scientific fields

> *In 1985, only about 10% of **JASA articles** involved Bayesian statistics. Between 2022 and 2023, **about 50%**!*
>
> (Witmer @ JSM 2023)

Bayes, because we *should*

- Bayesian methods have become common in many scientific fields

> *[A] review of clinical trials at one cancer center found that* ***one-third of phase I or II drug trials used Bayesian*** *designs and analyses (Biswas et al. 2009).*
>
> (Witmer 2017)

Bayes, because we ***should***

- Bayesian methods have become common in many scientific fields

> *(…) there are now **highly cited Bayesian textbooks** for "Social and Behavior Sciences" (Jackman 2009; Gill 2014), "Ecology" (McCarthy 2007; Hobbs and Hooten 2015), and "Econometrics" (Koop 2003), amongst others*
>
> (Hoegh 2020)

Bayes, because we *can*

- Bayesian models are **no longer difficult** to implement

```
library(brms)
```

```
fit <- brm(formula = y ~ x1 + x2,
           prior = prior(student_t(1, 0, 1), coef = x1)
           data = dataset)
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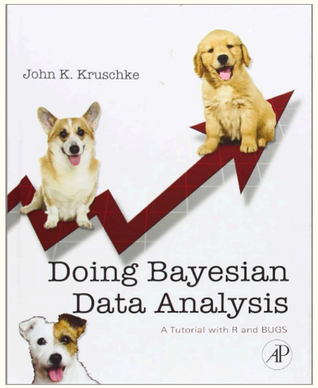
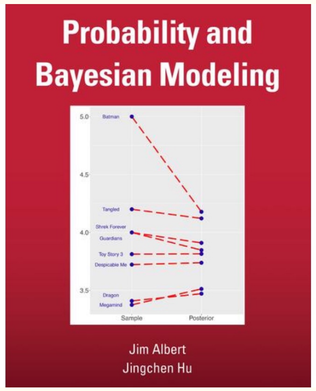
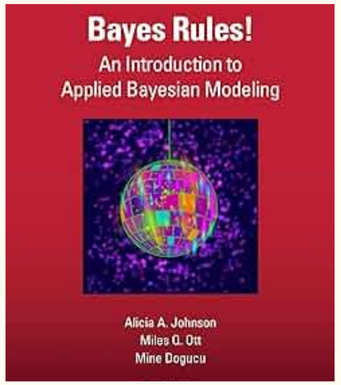
- **Easy-to-use textbooks** make Bayes accessible to undergraduates



J. Kruschke (2014)



J. Albert and J. Hu (2020)



A. Johnson, M. Ott and M. Dogucu (2022)

Some articles on the topic

- Witmer, Jeff. "Bayes and MCMC for Undergraduates." The American Statistician (2017)
- Witmer, Jeff. "To Bayes or Not to Bayes – Is There Any Question?" Talk at Joint Statistical Meetings, 2023
- Hoegh, Andrew. "Why Bayesian ideas should be introduced in the statistics curricula and how to do so." Journal of Statistics Education (2020)
- Cobb, George. "Mere renovation is too little too late: We need to rethink our undergraduate curriculum from the ground up." The American Statistician (2015)
- Hu, Jingchen, and Mine Dogucu. "Content and computing outline of two undergraduate Bayesian courses: Tools, examples, and recommendations." Stat (2022)

The state of Bayesian education

From a study by **Mine Dogucu** and **Jingchen Hu** on *The American Statistician* (**2022**)

Sample

- **All research universities** with a ranking of 100 or higher* (i.e., better ranking);

- **All liberal arts colleges** with a ranking of 50 or higher* based on U.S. News rankings

**based on U.S. News rankings*

How many Bayesian courses?

- **46 out of 152** high-ranking institutions offered a Bayesian course
- 6 out of 50 colleges and 40 out of 102 universities
- 51 Bayesian courses were identified (5 universities offered 2 Bayesian courses)

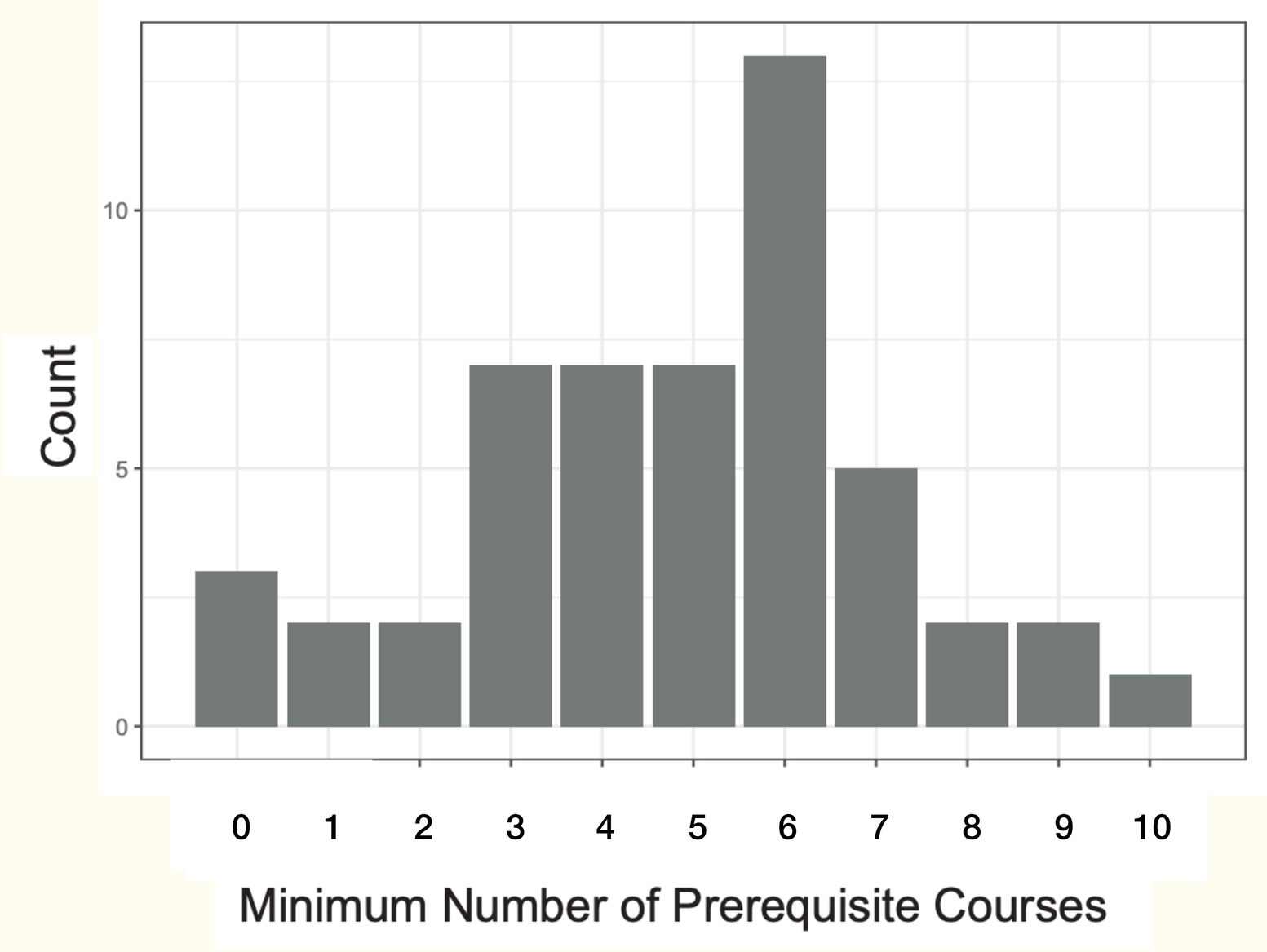
Majors including Bayesian

Table 1. Summary of major disciplines that explicitly include any of the 51 identified Bayesian courses.

Major discipline	Elective	Required	Total
Statistical Sciences	29	2	31
Mathematical Sciences	13	0	13
Combination of Statistical, Mathematical, Computer, or Data Sciences	12	0	12
Data Sciences	6	2	8
Computer Sciences	5	0	5
Biological Sciences	5	0	5
Quantitative Economics	4	0	4
Business, Economics, and Management	3	0	3
Psychology and Cognitive Sciences	3	0	3
Public Policy and Political Science	2	0	2
Others	5	0	5
Total	87	4	91

*The Others category includes Geological and Planetary Sciences, Quantitative Sciences, Physics, Philosophy, and No Specific Major, each of which has one elective course.

Bayesian course pre-requisites



Bayesian course stats and probability pre-requisites

Table 2. Summary of statistics and probability prerequisite courses of the 51 Bayesian courses.

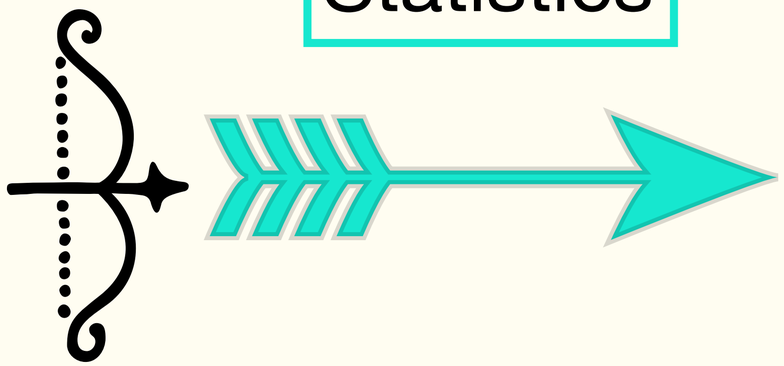
Prerequisite Course	Count
Probability	16
Linear Models	13
Probability and Statistics	13
Mathematical Statistics	11
Statistics	8
Statistical Inference	7
Statistical Methods	7
Introduction to Statistics	6
Bayesian Statistics	2
Machine Learning	2
Others	5

*The Others category includes Data Analysis and Statistical Inference, Econometrics, Foundation of Information and Inference, Introduction to Statistical Theory, and Linear Algebra, Probability, and Statistics for the Life Sciences, each of which has one occurrence.

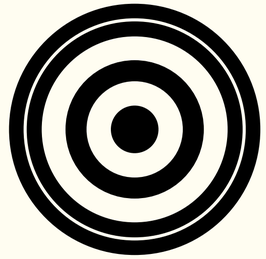
Bayes BATS in a Snapshot

Bayesian Statistics

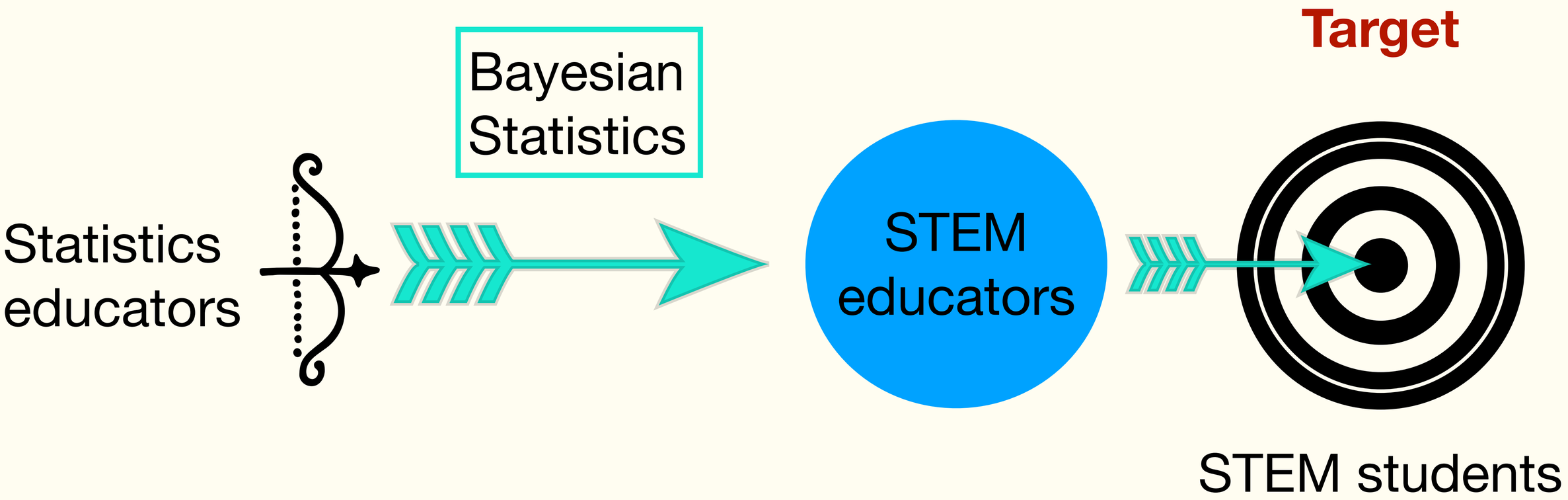
Statistics educators



Target



STEM students


Target
Bayesian
Statistics
Statistics
educators
STEM
educators
STEM students

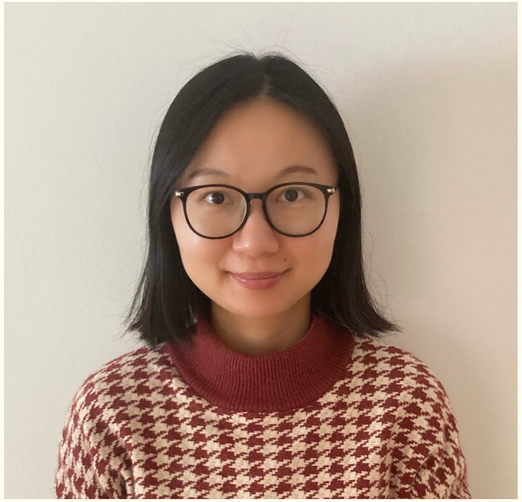
PI Team

Mine Dogucu

University of California, Irvine

Amy Herring

Duke University



Jingchen (Monika) Hu

Vassar College

TA Team

2023

Federica Zoe Ricci

University of California, Irvine

2024

Szofia Lewis

Vassar College

Funding

Bayes BATS program is **supported by National Science Foundation** IUSE: EHR program with award numbers 2215879, 2215920, and 2215709.

Grant proposal is available at [osf.io/34xk7](osf.io/34xk7)

Bayes BATS

Bayes BATS

Broader Impact

Accessible Bayesian Education in STEM

Rigorous conclusions from data in scientific practice

Bayes BATS

Goals

Exposure of undergraduate **students** to Bayesian Methods

STEM **teacher-scholars'** proficiency in Bayesian methods and pedagogy

Community of Bayesian STEM educators

Open-access Bayesian **teaching materials** with real scientific applications

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Bayes BATS

Inputs

Tier 1: Bootcamp for STEM instructors

Tier 2: Developing Teaching Materials

Tier 3: Dissemination

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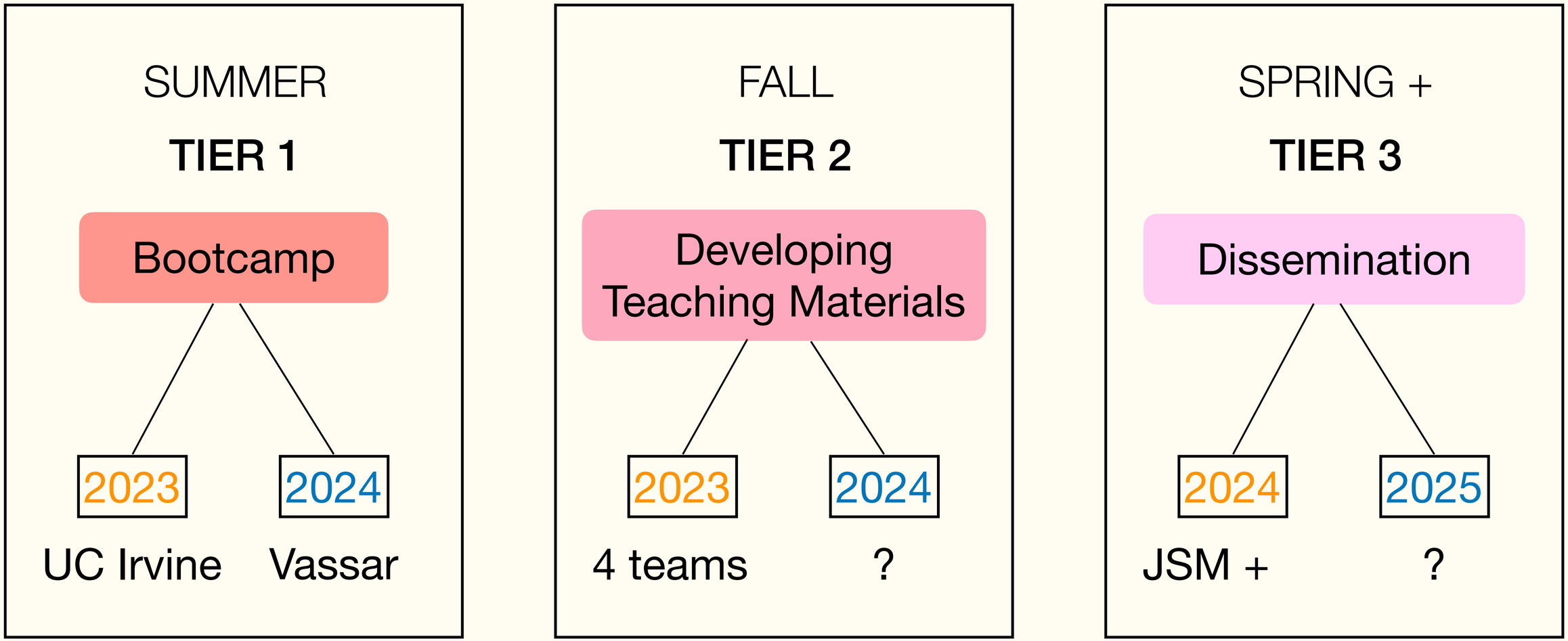
Three program tiers



SUMMER

TIER 1

Bootcamp

2023

FALL

TIER 2

Developing Teaching Materials

2023

SPRING +

TIER 3

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2024


UCI Donald Bren School of
Information & Computer Sci

Topics


DAY
1
2
3
4
5
Bayesian Inference
Simulating the Posterior
Posterior Analysis
Regression Models
Hierarchical Models

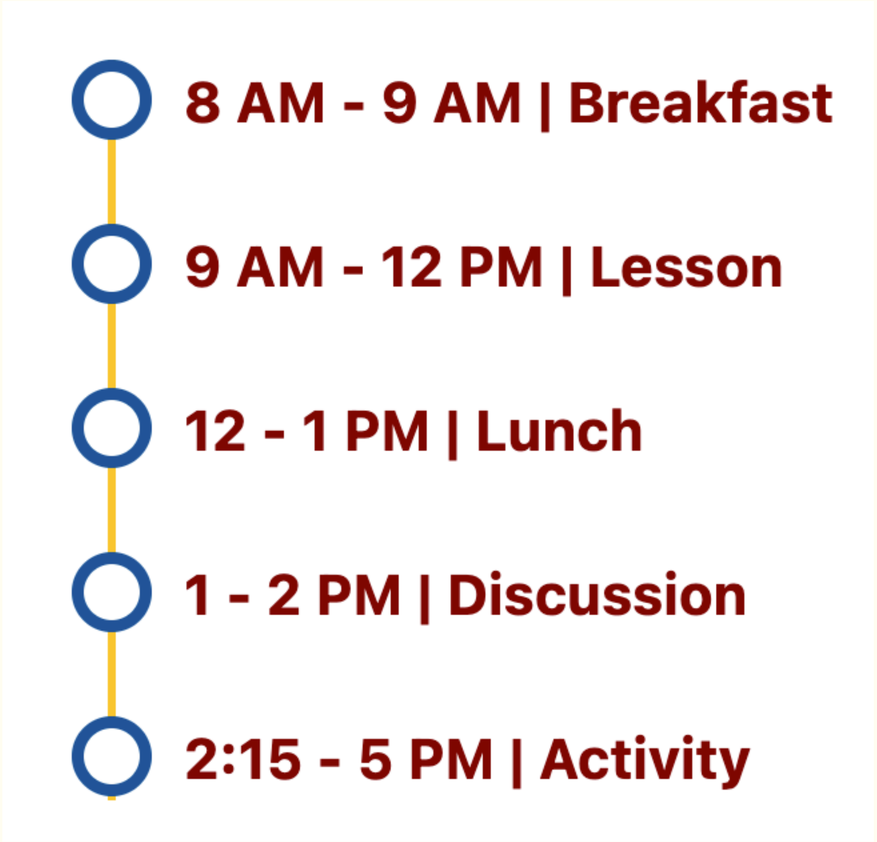
Daily schedule

Bootcamp goals

Community building

Enhance teachers' Bayes proficiency

Support creation of teaching material



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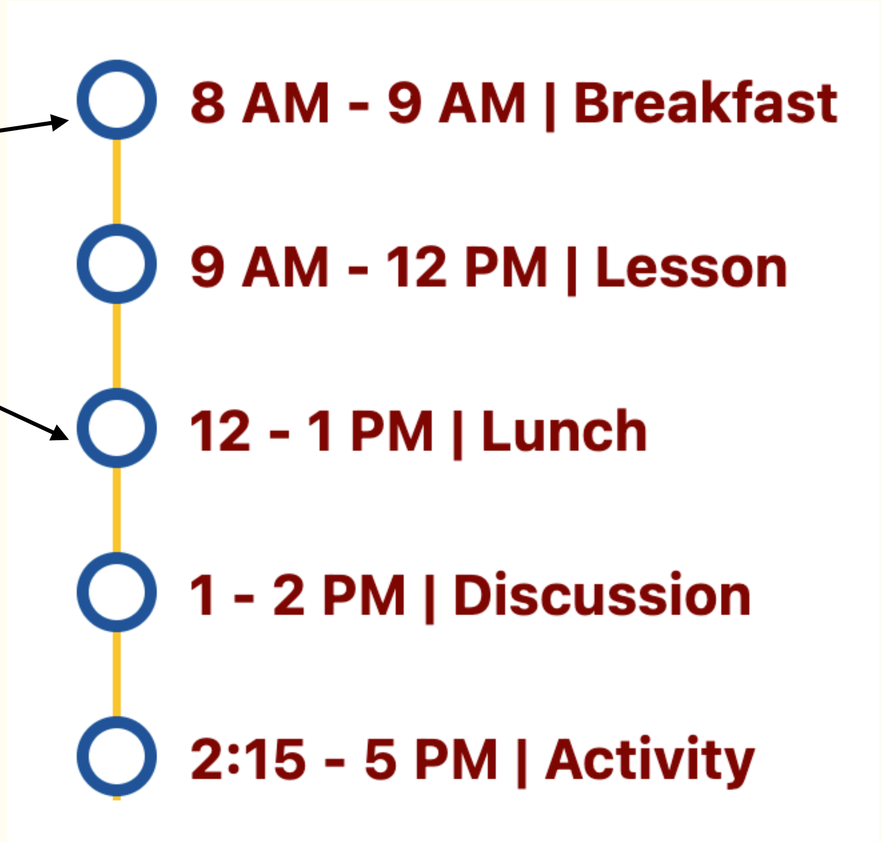

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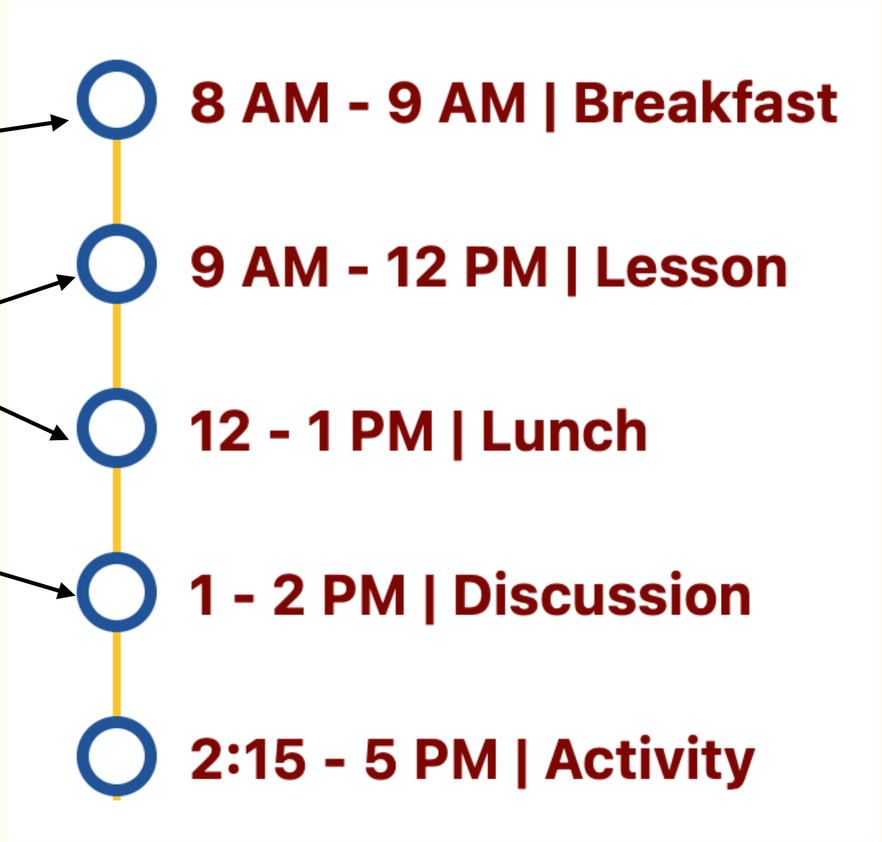

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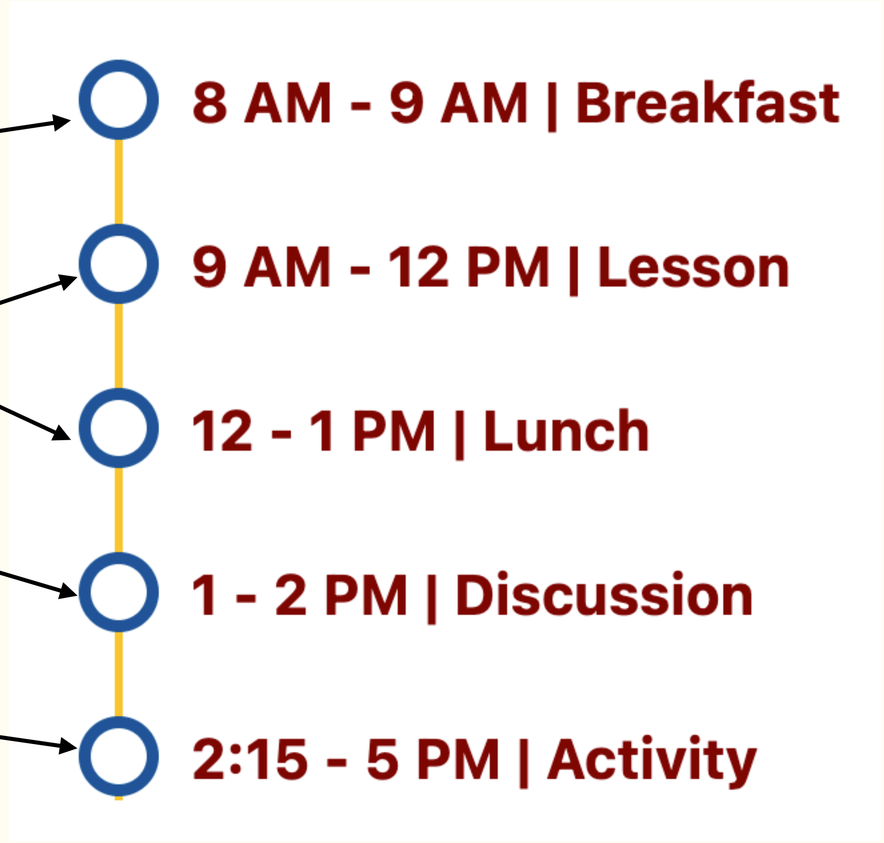

Example daily schedule

Schedule of Day 4

Time	Type	Activity
8:00 – 9:00	Community Building	Breakfast on Site
9:00 – 10:15	Lecture	Fitting Regression Models
10:30 - 12:00	Lecture	Evaluating Regression Models
12:00 – 13:00	Community Building	Lunch on Site
13:00 – 14:00	Discussion	Bayes Course vs. Module
14:15 – 17:00	Activity	Designing a regression model lab

Participants's job and experience

Academic Position	Number of Participants
Professor	3
Associate Professor	4
Assistant Professor	8
Lecturer	2

Years of Teaching Experience	Number of Participants
0-7 years	6
8-15 years	4
16-23 years	4
23+ years	3

Disciplines represented

Mathematics
Statistics
Data Science
Computer Science

Biological Sciences
Political Science
Business
Economy
Engineering

Motivating factors

Why are you interested in participating in this workshop? (Select all that apply)	Number of Participants
To enhance my understanding of Bayesian methods	13
To improve my ability to teaching Bayesian methods to students	14
To incorporate Bayesian statistics in my course curriculum	15
Other (please specify) - To use Bayesian software	1

Attitudes towards teaching Bayes

PRE - BOOTCAMP

Have you used Bayesian methods?	n = 17
Yes, extensively	6%
Yes, moderately	6%
Yes, but only a little	47%
No, not at all	41%

Evaluation report by Postsecondary Education Research & Implementation Institute

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POST - BOOTCAMP

How likely are you to incorporate Bayesian statistics in your course curriculum after attending this workshop?	n = 17
Very Likely	47%
Likely	53%
Neutral	0%
Unlikely	0%
Very Unlikely	0%

Evaluation report by Postsecondary Education Research & Implementation Institute

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TIER 3

Dissemination

2024

Four teams

Project Title	Project Participants
Surprise!—They're Different	**Zachary del Rosario** Stefani Langehennig
POGIL-style activities: Introduction to Bayesian Statistics	Olga Glebova **Kaitlyn Fitzgerald** Angela Ebeling
Bayesian Thinking: Course Materials for Bayesian Topics	Abraham Ayebo **Samantha Seals** Toni Sorrell
Introducing Frequentist and Bayesian Methods in Parallel in an Undergraduate Economics Statistics Course	**Patricia Toledo**

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Dissemination Venues

Joint Statistical Meetings

Virginia Association of **Mathematics** Teacher Educators (VA-AMTE)

Midwest **Political Science** Association Conference

International Society for **Bayesian** Analysis World Meeting

Conference on **Policy** Process Research

Conference on Teaching and Research in **Economic** Education (CTREE)

THANK YOU

Slides:

bit.ly/bats-jsm-24

Email:

fzricci@uci.edu

Bayes BATS website:

stat.uci.edu/bayes-bats

Mine, Patricia, Amy and Federica at ISBA 2024