AXIS (Adaptive eXplanation Improvement System) via MOOClets: Generating Explanations at Scale with Learnersourcing and Machine Learning

Right now, Go to URL:

tiny.cc/axisgdoc
GDoc to Ask & Answer Questions, make Comments

Flipped: tiny.cc/axisedx
Questions if Gdoc error: Sli.do, enter code 2626

Joseph Jay Williams (Harvard VPAL-Research)
Juho Kim (KAIST)
Anna Rafferty (Carleton)
Sam Maldonado (San Jose State)
Krzysztof Gajos (Harvard)
Walter Lasecki (Michigan)
Neil Heffernan (WPI)

Disclaimer: Speaker is originally from Trinidad & Tobago
Interpretation of "Flipped" as "Different"

You writing questions & comments into Gdoc at URL tiny.cc/axisgdoc (Alternative: sli.do with 2626 (April 26)).

Collaborative Questioners: Chairs/Neil will ask questions, chip in, choose your questions. Don't expect formal question period.

Persistent, asynchronous discussion at tiny.cc/axisgdoc and tiny.cc/axisedx

POLL: Put hand up for time spent on this Edge module

>20 mins
~10 mins
~3 mins
0 mins
Problem: Generating Explanations for Students

Please read the following sentences, and select the item that is TRUE of Tang.

- Just as Tang took in ideas and products from around the world, so too did it become a model for the world.

- Japan and Korea looked to adopt Tang models of state building, while Central Asian countries looked to adopt Tang civilization.

- Tang’s neighbors admired the dynasty’s bottom-up, grassroots approach to local governance and sought to emulate these practices themselves.

- Generally, emissaries to Tang looked to the Tang model for state-society relations in which aristocracy did not exist independent of government, but was to some extent (in Tang, to a large extent) sponsored by government. But Tang provided models in many other ways as well. East Asian countries looked to Tang civilization, where Central Asian countries and Tibet were able, as we saw, to look to Tang models for state-building and power projection while choosing another civilization. Those looking to Tang for a model of church-state relations were likely interested in a state that could patronize various traditions without becoming beholden to any one tradition. And those interested in Tang law would have found a complex code that applied universally - regardless of region or status.

EXPLANATION

Answer: Sentence 4

Tang provided a model for state-society relations in which aristocracy did not exist independent of government, but was to some extent (in Tang, to a large extent) sponsored by government. But Tang provided models in many other ways as well. East Asian countries looked to Tang civilization, where Central Asian countries and Tibet were able, as we saw, to look to Tang models for state-building and power projection while choosing another civilization. Those looking to Tang for a model of church-state relations were likely interested in a state that could patronize various traditions without becoming beholden to any one tradition. And those interested in Tang law would have found a complex code that applied universally - regardless of region or status.
Objectives/Takeaways

• How AXIS system enables creation of explanations, through learnersourcing and machine learning
• AXIS System design and results, critiques
• "MOOClet" framework and how enabled AXIS
• Future use of AXIS & MOOClets, potential collaboration
Go to URL tiny.cc/axisgdoc and add Questions/Comments
[Alternative sli.do with code 2626, 26=today's date]
Prior Work: Generating Explanations at Scale

- Learnersourcing Subgoal Labels for How-to Videos, Kim et al, CSCW 2015
- SPEDS: A Taxonomy for Crowdsourcing in Education, Mitros & Kim, CSCL 2015 Workshop
- A Framework for Automatically Generating Interactive Instructional Scaffolding, O'Rourke et al, CHI 2015
Approach: Elicit *Self-Explanations* from Students

Why is that answer right? Explain it in your own words.

Chi et al, 1994; Aleven & Koedinger, 2002; Williams & Lombrozo, 2010;
• Insert a plug-in “box” via iFrame or LTI (Learning Technology Interoperability) component to ASSISTments/EdX/Canvas/Coursera/Moodle etc
• Student View:
  – Prompts learners for explanations
  – Provides learners with explanations
• BackEnd: Algorithm for changing how frequently explanations are presented based on ratings
• 150 people recruited online to take part in a study
Mary’s music store had 5 truck loads of CDs delivered. Each truck dropped off 12 boxes. Each box has \(c\) CDs. Write an expression for how many CDs were delivered.

**Explanation**
Take the problem step by step. Every truck has 12 boxes and there are 5 trucks, so how many boxes are there? \(12 \times 5 = 60\).

**How would you rate the helpfulness of this hint?**
- 1 - Not at all helpful
- 2
- 3
- 4
- 5
- 6
- 7 - Very Helpful

**Explain in your own words what this step is saying.**
Go to URL tiny.cc/axisgdoc and add Questions/Comments

[Alternative slido with code 2626, 26=today's date]
Which explanations are good? Experiment Ethically

- Frame the problem computationally
- How do we dynamically use ratings to decide which explanations to present to new students?

<table>
<thead>
<tr>
<th>Explanation</th>
<th>Exp. 1</th>
<th>Exp. 2</th>
<th>Exp. 3</th>
<th>… Exp. n</th>
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<tr>
<td>Ratings</td>
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<td>3, 2. Mean = 2.5</td>
<td>9, 9, 8, 9, 10 Mean = 9.0</td>
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<tr>
<td>Model parameters &amp; Update Algorithm</td>
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<tr>
<td>Probability of being presented</td>
<td>30%</td>
<td>15%</td>
<td>55%</td>
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<tr>
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<td>0%</td>
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</table>
Example of Policy/Probability of presenting explanations

<table>
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<tr>
<th>AXIS Index for Explanation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>7</th>
<th>8</th>
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<td>Policy for 76th learner (after 75 learners)</td>
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<td>Policy for learner 151 (after 150 learners)</td>
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<td>0.09</td>
<td>0.1</td>
<td>0.09</td>
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<td>0.09</td>
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<td>Explanation Rating</td>
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<td>Increase in Perceived Skill at Solving Problems (on a 1 to 10 scale)</td>
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<td>Learning Gains</td>
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</table>

Figure 5. AXIS Policy for the explanation pool for one of the four problems. The policy’s probability distribution over the ten explanations that were added to the pool during deployment is shown after 75 learners (row 2) and after 150 learners (row 3).
Prompt: Clear on algorithmic approach?

Go to URL tiny.cc/axisgdoc and add Questions/Comments

[Alternative sli.do with code 2626, 26=today's date]
• 564 people solved 4 math problems
• Completed a pre- and post- test
• Experimental Conditions
  – Practice as Usual: Problems Only
  – Discarded Explanations
  – AXIS Explanations
  – Instructor-written explanations
• Outcome Variables
  – Self-Rated Perceived Gains in Learning
  – Accuracy Increase in solving math problems
Go to URL tiny.cc/axisgdoc and add Questions/Comments
[Alternative sli.do with code 2626, 26=today's date]
Did learners report better understanding?

Increase in Perceived Skill at Solving Problems (on a 1 to 10 scale)
Did AXIS explanations *objectively* enhance learning?

**Overall Increase in Accurately Solving Problems**

- **AXIS**
  - Increase: 0.15
- **Practice-as-Usual: Problems Only**
  - Increase: 0.05
Does *any* explanation help learning? AXIS vs Discarded

Overall Increase in Accurately Solving Problems

- AXIS
- Learnersourced Explanations Filtered via Machine Learning
How much worse are explanations from AXIS vs. Instructor?

Overall Increase in Accurately Solving Problems
AXIS curates potentially useful explanations

Design Principles
"Organic" learnersourcing & improvement
Design guided by psychological research (e.g. Williams & Lombrozo, 2010)
Machine Learning for *Experimentation* that 'turns' *Practical*
Go to URL tiny.cc/axisgdoc and add Questions/Comments
[Alternative sli.do with code 2626, 26=today's date]
Future: How would you use AXIS?

• Request more information at URL tiny.cc/useaxis
• Other contexts to collect & provide explanations
• Personalization
• Crowdsourced Competition for instructors & researchers (ASSISTments w/ Neil Heffernan)
AXIS adaptive explanations enabled by "MOOClet" technology framework
“MOOClet” is a Technology to make any text adaptive

Webpage

MOOClet or AdapComp

www.josephjaywilliams.com/mooclet

Email

Mary’s music store had 5 truck loads of CDs delivered. Each truck dropped off 12 boxes. Each box has c CDs.
MOOClets extends use of A/B Experimentation for Crowdsourcing, Real-Time Data, Rapid Improvement, Personalization

- A/B testing → MOOClets
- Randomized Experimentation & Personalization have a mathematical equivalence – two sides of same coin

**Experimentation Rules in MOOClet**
30% CONDITION = A, 70% B
IF [CONDITION] = A then show V1 …

**Experimentation + Personalization Rules in MOOClet**
IF PRETEST < 50, 80% CONDITION = A, 20% B
IF PRETEST > 50, 40% CONDITION = A, 60% B,
IF [CONDITION] = A then show V1 …
Prompt: Try explaining to your neighbor what MOOClet framework is, how enabled AXIS, how it could be useful.

Go to URL tiny.cc/axisgdoc and add Questions/Comments
[Alternative sli.do with code 2626, 26=today's date]

Share your name & university, one sentence on your research area

• About MOOClets: www.josephjaywilliams.com/mooclet tiny.cc/usemooclets
How to adapt *any* text components via MOOClets?

• Explanations for (math) problems
• Learning Tips above problems (Biochem on EdX, Canvas with Harvard Extension School, Khan Academy)
• Videos
• Emails to students: e.g. motivational messages to re-engage
Objectives/Takeaways

• How AXIS system enables creation of explanations, through learnersourcing and machine learning
• AXIS System design and results, critiques
• "MOOClet" framework and how enabled AXIS
• Future use of AXIS & MOOClets, potential collaboration
  – tiny.cc/axisgdoc, email joseph_jay_williams@harvard.edu
Ongoing/Future On-Campus & MOOC Deployments: Instructor Dashboard & Interaction with MOOClet-based Systems

- See the explanations & how likely each is to be presented
- See how students are rating them
- Enter your own ratings of explanations & add new explanations

<table>
<thead>
<tr>
<th>Version</th>
<th>Explanation</th>
<th>Instructor &quot;Priors&quot;</th>
<th>Student Ratings</th>
<th>Mean Rating</th>
<th>Probability of Presentation</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Every number has one other number that will sum it to 8. After the first spin there's a 20% chance (1 out of the 5 options) that the wheel will land on the one number that sums the first number to 8</td>
<td>9 10</td>
<td>6 8 6 7</td>
<td>6.75</td>
<td>30%</td>
</tr>
<tr>
<td>2</td>
<td>There's a 1 in 5 chance because there are 5 choices and each trial is independent of the other.</td>
<td>9 10</td>
<td>3 2</td>
<td>2.5</td>
<td>15%</td>
</tr>
<tr>
<td>3</td>
<td>Ok given any first spin, there is one and only one number on the wheel which when added to it will result in 8. Since there is one number which works and 5 that do not, the chance is 1 in 5.</td>
<td>9 10</td>
<td>9 8 9 10</td>
<td>9</td>
<td>55%</td>
</tr>
</tbody>
</table>

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Thank You

• Harvard VPAL (Vice Provost for Advances in Learning) Research Team
• Lytics Lab at Stanford VPTL
• WPI ASSISTments, EDM & LST groups
Do it in tiny.cc/axisgdoc!!

Piotr, Nina, Neil?
Overview

• Goal: Help instructors easily provide good explanations by automatically using data
• AXIS System: LTI Plug-in to adapt explanations for how to solve problems (EdX, Canvas)
  – Student View
  – Backend: ML for Ethical Experimentation
  – Instructor View
• Deployment with 150 Mechanical Turk Lab Participants
• Evaluation with 564 participants
  – AXIS explanations were rated highly, improved learning, matched instructor’s explanations
• How would you use AXIS or MOOClets? (URL tiny.cc/useaxis)
  – Other contexts to collect & provide explanations
  – Personalization
  – Crowdsourced Competition for instructors & researchers
  – Other kinds of text responses, or motivational messages via email (tiny.cc/mooclets)
Learning Tips above problems

Practicing Equations with variables on both sides

To use this strategy, ask yourself these "What? Why? How?" questions while solving a problem.

What are you doing or thinking right now?
Why is what you are currently doing helpful? Why is it useful for achieving your goal?
How well is your current approach to this problem working?
As a reminder to ask yourself these questions, they will sometimes appear in purple.

What if I can't do it?

Solve for $x$:

$8x - 2 = 3x + 2$

At any time, it's helpful to reflect on "Why is what you are currently doing helpful?"

Before moving on to the next topic, check your ability to describe the behavior of a particular family of curves. Consider the family of curves given by

$f(x) = ax^6 + bx^3$

where $a$ and $b$ are unknown positive constants.

Find $f'(x)$ and $f''(x)$ and use them to answer the following questions.
Learning Tips in MOOCs (HarvardX)

- tiny.cc/ltipopen
- tiny.cc/ltiprequest

GLYCOLYSIS VIDEO 2 QUESTIONS

Click here for a Learning Tip

(1 point possible)
You know that ATP is a major energy currency of cells. What are two energetic reasons that ATP is well-suited for this role?

Click here for a Learning Tip

The more effort you put into this, the better you will be at biochemistry.

It can be help to stop and ask: "How am I trying to approach this question? Is there anything I might be missing?"
Pre-Course Survey

Problem

MOOClets

Lesson

Email

Research Testbed: tiny.cc/researchtestbededge
## MOOClets Real Time Data

### Pre-Course Survey

![Survey Image]

### Lesson

![Lesson Image]

### Problem

![Problem Image]

### Email

![Email Image]

<table>
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• Goal: Help instructors easily provide good explanations by automatically using data

• AXIS System: Plug-in for any problem (EdX, Canvas)  
  – Student View  
  – Backend: ML for Ethical Experimentation  
  – Instructor View

• Deployment

• Evaluation (Williams et al, 2016, Learning at Scale)  
  – AXIS explanations were rated highly, improved learning, matched instructor’s explanations

• Future: How would you use AXIS? (URL tiny.cc/useaxis)  
  – Other contexts to collect & provide explanations  
  – Personalization  
  – Crowdsourced Competition for instructors & researchers

• MOOClets to adapt other kinds of text responses (tiny.cc/mooclets or email joseph_jay_williams@harvard.edu)
Thank You

- Juho Kim, Anna Rafferty, Walter Lasecki, Neil Heffernan, Krzysztof Gajos, Elena Glassman
- Sam Maldonado
- Harvard VPAL (Vice Provost for Advances in Learning) Research
- Andrew Ho, Jake Whitehill
Application to Crowdsourcing Explanations

• Key insights?
• Thoughts?
Future Directions

• Where could MOOClets be useful to your work?
Pre-Course Survey

Lesson

MOOClets

Problem

Email
MOOClets Real Time Data

Pre-Course Survey

Lesson

Problem

Email

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</table>
Enable Instructor-Researcher Collaboration

User Variable Store

TARGET Variables: [Instructor chosen]
Grade on weekly quiz

OUTCOME Variables:
Time spent on lesson (and next 2 lessons)
Responses to in-page exercises [& next 2]

USER CHARACTERISTICS:
Accuracy on Pre-Test [0 to 100]
Goal for course [Get certificate | Audit some content]
Time spent & exercises solved in previous lesson

EXPERIMENTAL Variables:
Question Type = [A (Q1), B (Q2), C (Q3)]

ANY A/B Experimentation can be easily implemented using MOOClet

- [www.josephjaywilliams.com/mooclet](http://www.josephjaywilliams.com/mooclet)
- A/B testing widespread, but unnecessarily limited (Williams et al, 2015, L@Scale, Designing Platforms for In Vivo Experimentation)
- Conceptual Barriers in Software Engineers implementing Software for A/B Experimentation

**Experimentation Rules in MOOClet**
- 30% CONDITION = A, 70% B
- IF [CONDITION] = A then show V1 ...

**Experimentation + Personalization Rules in MOOClet**
- IF PRETEST < 50, 80% CONDITION = A, 20% B
- IF PRETEST > 50, 40% CONDITION = A, 60% B,
- IF [CONDITION] = A then show V1 ...
Thank You

• Harvard VPAL (Vice Provost for Advances in Learning) Research Team
• Lytics Lab at Stanford VPTL
• WPI ASSISTments, EDM & LST groups
MOOClet Concept

User Variable Store

EXPERIMENTAL Variables:
e.g. Question Type = [A, B, .. N]

USER Characteristics & Behaviors
e.g. Goal for course
e.g. Accuracy on problem 3 week 2

[ADDITION of VARIABLES possible]

Policy

IF [Question Type ] = A then show V1
IF [QType] = B then V2
IF [QType ] = N then VN

Dynamic API
Access & Rewrite

What is the key principle?
Thompson Sampling, Chappelle & Li, 2011
Choose action in proportion to probability that it is the best.
Mary's music store had 5 truck loads of CDs delivered. Each truck dropped off 12 boxes. Each box has $c$ CDs.
Pre-Course Survey

Problem

Lesson

MOOClets

Email

Research Testbed: tiny.cc/researchtestbededge
## MOOClets Real Time Data

### Pre-Course Survey

![Survey Image]

### Lesson

![Lesson Image]

### Problem

![Problem Image]

### Email

![Email Image]

---

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
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<td><strong>COURSE DATA</strong></td>
<td><strong>Problem Correctness</strong></td>
<td><strong>Email Version</strong></td>
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<td>education</td>
<td>age</td>
<td>Time on Lesson</td>
<td>Lesson Version</td>
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<td>26</td>
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<td>2</td>
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<td>certificate</td>
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<td>5</td>
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<td>1</td>
<td>38</td>
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<td>audit</td>
<td>2</td>
<td>5</td>
<td>23</td>
<td>36</td>
<td>Version A</td>
<td>1</td>
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<tr>
<td>10</td>
<td>audit</td>
<td>1</td>
<td>5</td>
<td>42</td>
<td>41</td>
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<td>1</td>
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<td>11</td>
<td>audit</td>
<td>5</td>
<td>4</td>
<td>34</td>
<td>85</td>
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<td>0</td>
</tr>
<tr>
<td>12</td>
<td>audit</td>
<td>5</td>
<td>2</td>
<td>56</td>
<td>130</td>
<td>Version C</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>audit</td>
<td>6</td>
<td>3</td>
<td>52</td>
<td>90</td>
<td>Version B</td>
<td>0</td>
</tr>
</tbody>
</table>
Enable Instructor-Researcher Collaboration

**User Variable Store**

**TARGET Variables:** [Instructor chosen]
Grade on weekly quiz

**OUTCOME Variables:**
Time spent on lesson (and next 2 lessons)
Responses to in-page exercises [& next 2]

**USER CHARACTERISTICS:**
Accuracy on Pre-Test [0 to 100]
Goal for course [Get certificate | Audit some content]
Time spent & exercises solved in previous lesson

**EXPERIMENTAL Variables:**
Question Type = [A (Q1), B (Q2), C (Q3)]

---

**MOOClet**

**[Q1]** What is the key principle?

**[Q2]** How would you explain this to another student?

**[Q3]** How does this relate to the last lesson?

---

**Instructor**

**Researcher(s)**

ANY A/B Experimentation can be easily implemented using MOOClet

- www.josephjaywilliams.com/mooclet
- A/B testing widespread, but unnecessarily limited
  (Williams et al, 2015, L@Scale, Designing Platforms for In Vivo Experimentation)
- Conceptual Barriers in Software Engineers implementing Software for A/B Experimentation

**Experimentation Rules in MOOClet**
- 30% CONDITION = A, 70% B
- IF [CONDITION] = A then show V1 …

**Experimentation + Personalization Rules in MOOClet**
- IF PRETEST < 50, 80% CONDITION = A, 20% B
- IF PRETEST > 50, 40% CONDITION = A, 60% B
- IF [CONDITION] = A then show V1 …
Where can you use MOOClets?

• Anything in EdX
• Any LTI Component
• Canvas
  – adapt TLT’s open source A/B testing tool
  – Use Qualtrics via LTI
• Moodle
• NovoEd
• ASSISTments
ASSISTments work to Crowdsourcsource Scientists

• NSF Cyberinfrastructure grant to enable randomized experiments in K12 classrooms
• ALI: Provides real-time analytics to researchers
• Embed external MOOClets into ASSISTments
• Embed ASSISTments into EdX via LTI
• www.assistmentsetestbed.org to propose studies
  – View at www.assistments.org, login with exploreonlineresources@gmail.com, explore321
  – Postdoc/Visiting Researcher positions: tiny.cc/assistmentspostdoc
  – nth@wpi.edu
Mary's music store had 5 truck loads of CDs delivered. Each truck dropped off 12 boxes. Each box has $c$ CDs.

HINT 1: Write an expression using $c$.

HINT 2: There are 60 boxes of CDs.

MOTIVATIONAL MSG: The harder you try, the smarter you get.

SELF-EXPLANATION PROMPT: What is your final goal?

Human Computation/Crowdsourcing Function Call: RequestDesignAlternative(Current MOOClet)

Human Computation/Crowdsourcing Function Call: RequestNumericalEfficacyRating (MOOClet version X, Reward Function, User Characteristic)

Elicit Priors & Incorporate Diverse Knowledge into Initial Probability of getting Conditions or MOOClet Versions

Bayesian & Interpretable ML: Update priors using empirical data
Lesson

Thank you for trying the STATS4STEM 2013 AP REVIEW!

Before you get started on your statistical questions, a brief overview of some suggestions/recommendations is in order before you get started.

First, when entering in probabilities, it is required that you always answer as a decimal rounded to the nearest hundredth.

For example:

If you calculate a probability of 68.2%. Your answer should be: 0.68 (or simply .68)

Problem

Problem ID: PRAJ5ZN

Calculate the slope of the least squares regression line that has the statistics found below. Round answer to the nearest hundredth.

<table>
<thead>
<tr>
<th>r</th>
<th>Sx</th>
<th>Sy</th>
<th>x-bar</th>
<th>y-bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>1.1</td>
<td>1.4</td>
<td>3.2</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

For help, click here for the AP Statistics formula sheet.

© STATS4STEM.ORG

Outcome/Target

10 question test of understanding standard deviation
Performance on problems
Time needed to learn effectively
• Any Online Education resource → adaptive via MOOClets
• Examples of MOOClets
• Experimentation & Adaptive Personalization
• Automated through Machine Learning
• Application to learning via crowdsourced explanations
• ASSISTments: Crowdsourcing Teachers & Scientists
• Future Directions
Thank You

• Krzysztof Gajos, Juho Kim, Elena Glassman
• Harvard VPAL (Vice Provost for Advances in Learning) Research
• Andrew Ho, Jake Whitehill, Na Li
• Tania Lombrozo & Tom Griffiths
• Candace Thille & John Mitchell
• Jascha Sohl-Dickstein, PERTS, Khan Academy
• Sam Maldonado
• Lytics Lab
Review

• Related Work
• MOOClet Formalism
• Scenario 1: Adapting Emails
• Scenario 2: Adapting Explanations
• Future Directions: Crowdsourcing Scientists
We hope you have enjoyed the opportunity to explore Statistics and R for the Life Sciences. It has been a pleasure to see how you have approached the course.

Each of the links below connects to a short survey. Please click on the link that best describes your experience with the course.

- I plan on continuing with the course
- I am not continuing the course because it was not what I expected when I signed up.
- I am not continuing the course because the course takes too much time.
- I am not continuing the course because I am not happy with the quality of the course.
- I am not continuing the course because I have learned all that I wanted to learn.
- I am not continuing the course now, but I may at a future time.

Your feedback is very important to us. Thank you for registering for Statistics and R for the Life Sciences.

Follow the link to opt out of future emails:
[Click here to unsubscribe]
Dear Sam,

We hope you have enjoyed the opportunity to explore Statistics and R for the Life Sciences. We can improve the course for future students?

Click here to take the survey.

If you plan on continuing with the course, please take this survey.

If you plan on not continuing with the course, please take this version of the survey.

Dear Sam,

We hope you have enjoyed the opportunity to explore Statistics and R for the Life Sciences. It has been a we can improve the course for future students?

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Click here to unsubscribe
Conceptualize the Probability that any person gets Experimental Condition A/B/C as the “Prior Probability” of Condition A/B/C being best for that person. Do Real-Time updating of the Prior to a “Posterior Probability” as data is collected.

For Emails sent to 4000 people: 33% probability of random assignment to Subject Line A, B or C

<table>
<thead>
<tr>
<th>Age</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>23-26</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>

Percentage of people responding to emails with Subject Line A, B, or C

<table>
<thead>
<tr>
<th>Age</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22</td>
<td>3.8%</td>
<td>1.6%</td>
<td>2.3%</td>
</tr>
<tr>
<td>23-26</td>
<td>5.0%</td>
<td>1.0%</td>
<td>2.3%</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>

Prior → Posterior 0.33 → 0.48 b/c

\[
\text{3.8\%} + 1.6\% + 2.3\% = 0.48
\]

For Emails to NEXT batch of people: Probability of random assignment to Subject Line A, B, or C

<table>
<thead>
<tr>
<th>Age</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22</td>
<td>0.48</td>
<td>0.22</td>
<td>0.30</td>
</tr>
<tr>
<td>23-26</td>
<td>0.60</td>
<td>0.12</td>
<td>0.28</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>
• 593 people received traditional assignment – 33% chance of condition, no weighting, no personalization
• 1177 people received Weighted Personalization

<table>
<thead>
<tr>
<th>Difference</th>
<th>Percentage Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5%</td>
<td>60%</td>
</tr>
<tr>
<td>7.2%</td>
<td>72%</td>
</tr>
<tr>
<td>2.7%</td>
<td></td>
</tr>
</tbody>
</table>
Experimentation → Adaptive Personalization

Experimentation Policy
50% [QType] = A
50% [QType] = B

Adaptive Personalization Policy
IF GoalForCourse = “Get Certificate”
80% [QType] = A
20% [QType] = B

IF GoalForCourse = “Audit content”
40% [QType] = A
60% [QType] = B

<table>
<thead>
<tr>
<th>Quiz Score</th>
<th>On Average</th>
<th>Get Certificate</th>
<th>Audit Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question Type A</td>
<td>60%</td>
<td>80%</td>
<td>40%</td>
</tr>
<tr>
<td>Question Type B</td>
<td>40%</td>
<td>20%</td>
<td>60%</td>
</tr>
</tbody>
</table>
How to (re)implement components as MOOClets

• tiny.cc/moocletimplemmentation
• joseph_jay_williams@harvard.edu
Overview

• Experiments in Digital Educational Resources
• Quick Tour of Past Work
• MOOClet Framework
• Personalized Instructional Principles
  – Email Study
• Enable Instructor-Researcher Collaboration
• Potential Online Contexts & Experimental Paradigms
• Collaboration?
Enable Instructor-Researcher Collaboration

**Instructor**

- MOOClet
  - [Q1] What is the key principle?
  - [Q2] How would you explain this to another student?
  - [Q3] How does this relate to the last lesson?

**User Variable Store**

**TARGET Variables:** [Instructor chosen]
Grade on weekly quiz

**OUTCOME Variables:**
Time spent on lesson (and next 2 lessons)
Responses to in-page exercises (& next 2)

**USER CHARACTERISTICS:**
- Accuracy on Pre-Test [0 to 100]
- Goal for course [Get certificate | Audit some content]
- Time spent & exercises solved in previous lesson

**EXPERIMENTAL Variables:**
- Question Type = [A (Q1), B (Q2), C (Q3)]

Interface: Instructors <---> Researchers

• Instructor **Provides:**
  – Candidate MOOClets: e.g. Reflective Questions
  – User Variable Store
    • Target Variable
      – Score on Week 2 Quiz
    • Covariates/Personalization Variable
      – Prior Knowledge
      – Growth/Fixed Mindset

• Receives from Researcher:
  – Novel designs or experimental conditions
  – Design-guided suggestions of extra data to collect to measure learning
• “Crowdsource” designs & experiments from Instructors/Researchers
  – NSF Cyberinfrastructure grant for ASSISTments

**MOOClet**

- [Q1] What is the key principle?
- [Q2] How would you explain this to another student?
- [Q3] How does this relate to the last lesson?
Overview

• Experiments in Digital Educational Resources
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  – Email Study
• Enable Instructor-Researcher Collaboration
• Potential Online Contexts & Experimental Paradigms
• Collaboration?
Potential Online Contexts & Experimental Paradigms
MOOCs (HarvardX)

- tiny.cc/ltipopen
- tiny.cc/ltiprequest

GLYCOLYSIS VIDEO 2 QUESTIONS

Click here for a Learning Tip

(1 point possible)
You know that ATP is a major energy currency of cells. What are two energetic reasons that ATP is well-suited for this role?

The more effort you put into this, the better you will be at biochemistry.

It can be helpful to stop and ask: "How am I trying to approach this question? Is there anything I might be missing?"
• Collection of Mathematics Exercises & Worked Examples (hundreds of teachers, thousands of students)
The mean score on Mr. Simoneau’s test was 78, with an IQR of 20. If he adds 12 points to everyone’s score, what’s the new mean?

**STATS4STEM.ORG**

\[ E(aX-b) = aE(X) - b, \text{ where } E(X) = \mu \]

Type your answer below (mathematical expression):

90

Correct!

Submit Answer  
Next Problem  
Show hint 2 of 4
ASSISTments Worked Example with Experiments

ASSISTments

Problem: 1 / 1

Below is a problem similar to your problem, already worked-out for you, and your original problem for comparison. Now explain to yourself: How is this problem and your original problem solved in general? Why is each step of the worked-out solution true? Write your explanation as the answer to this problem.

Worked-out problem:
If a new jacket is labeled $55, what would the new price be if the sign above it says "22% off"?

22% = 0.22
55 x 0.22 = 12.10
55 - 12.10 = $42.90

Your original problem:
If a new tennis raquet is labeled $54, what would the new price be if the sign above it says "16% off"?

This is how to solve a problem similar to your problem.

if a new jacket is labeled $55, what would the new price be if the sign above it says "22% off"?

22% = 0.22
55 x 0.22 = 12.10
55 - 12.10 = $42.90

Comment on this problem
Try out [www.assistments.org](http://www.assistments.org) or propose a study

- [www.assistmentstestbed.org](http://www.assistmentstestbed.org) to propose studies
- View at [www.assistments.org](http://www.assistments.org), login with [exploreonlineresources@gmail.com](mailto:exploreonlineresources@gmail.com), explore321
- Postdoc/Visiting Researcher positions: tiny. cc/assistmentspostdoc
- [joseph_jay_williams@harvard.edu](mailto:joseph_jay_williams@harvard.edu), [nth@wpi.edu](mailto:nth@wpi.edu)
Recruit Convenience Samples: Mechanical Turk

• www.josephjaywilliams.com/mturk

Recruiting Research Participants via Mechanical Turk

Contents

1 Video overview of the benefits of Mechanical Turk to run experiments
2 Scientific publications on Mechanical Turk
3 Online resources on Mechanical Turk
4 How to set up Mechanical Turk in 5-10 minutes?
5 What to do if you need help right now?
6 Getting started using Mturk
Dear Sam,

We hope you have enjoyed the opportunity to explore Statistics and R for the Life Sciences. It has been a great experience for us! We are constantly looking for ways to improve our courses for future students.

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Follow the link to opt out of future emails:
[Click here to opt out of future emails]

Best regards,
[Signature]
Embedded Learning Strategy Tips

GLYCOLYSIS VIDEO 2 QUESTIONS

Click here for a Learning Tip

(1 point possible)
You know that ATP is a major energy currency of cells. What are two energetic reasons that ATP is well-suited for this role?
Motivational Videos

Growth Mindset Video
“On-Request” Strategy for Reflective Questioning

Clickable link – transform text into cognitively sophisticated interaction

[Click here to learn about the “What? Why? How?” strategy]

To use this strategy, ask yourself these “What? Why? How?” questions after each hint in a problem:

- What does this step mean to you?
- Why is it helpful to take this step?
- How do you know this step is right?

As a reminder to ask yourself these questions, they will sometimes appear in purple.

What if I can’t do it?

The grades on a geometry midterm at Covington are normally distributed with $\mu = 70$ and $\sigma = 4.5$.
Stephanie earned a 60 on the exam.

Find the z-score for Stephanie’s exam grade. Round to two decimal places.

Accuracy = \frac{\text{Number Problems Correct}}{\text{Number Problems Attempted}}

Increase of 0.8 % \ (p < 0.05)

Health Behavior Change: Harvey, Lee, Williams et al (2014), Perspectives in Psychological Science
Learning Strategy Modules

- Tiny.cc/mmdemolesson
- Tiny.cc/mmdemotooal
• Experiments in Digital Educational Resources
• Quick Tour of Past Work
• MOOClet Framework
• Personalized Instructional Principles
  – Email Study
• Enable Instructor-Researcher Collaboration
• Potential Online Contexts & Experimental Paradigms
• Collaboration?
Collaboration?

- JJW interested in/open to:
- Grant Application? [tiny.cc/ies2013](http://tiny.cc/ies2013)
Using Experiments in Competitions for Education/Psychology

Lesson

Thank you for trying the STATS4STEM 2013 AP REVIEW!

Before you get started on your statistical questions, a brief overview of some suggestions/recommendations is in order before you get started.

First, when entering in probabilities, it is required that you always answer as a decimal rounded to the nearest hundredth.

For example:

If you calculate a probability of 68.2%. Your answer should be: 0.68 (or simply .68)

Problem

Problem ID: PRAJ5ZN

Calculate the slope of the least squares regression line that has the statistics found below. Round answer to the nearest hundredth.

<table>
<thead>
<tr>
<th>r</th>
<th>Sx</th>
<th>Sy</th>
<th>x-bar</th>
<th>y-bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>1.1</td>
<td>1.4</td>
<td>3.2</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

For help, click here for the AP Statistics formula sheet.

Hint

Use the AP formula sheet. Specifically, refer to the formula for $b_1$ - the slope.

Outcome/Target

10 question test of understanding standard deviation
Performance on problems
Time needed to learn effectively
User Variable Store

EXPERIMENTAL Variables:
e.g. Question Type = [A, B, .. N]

USER Characteristics & Behaviors
e.g. Goal for course
e.g. Accuracy on problem 3 week 2

[ADDITION of VARIABLES possible]

What is the key principle?

MOOClet Concept

Policy
IF [Question Type ] = A  then show V1
IF [QType] = B then V2
IF [QType ] = N then VN

MOOClet
V1    V2    VN
Enhancing Education by Advancing Research

- Concrete Modular Components
- Benefits & Value Adds to *all parties*
- Alternative Versions/Designs to compare in Experiments
- Instrumented to have “appropriate” data about users and measures of learning/engagement
- Real time data, tight loop between data & modifications
What is the key principle?

Define the concept of a z-score.

A z-score is...
- a statistical measurement of a score's relationship to the mean in a group of scores
- a statistical measure of the mean of a group of scores
- I don't know.
MOOClet Concept

User Variable Store

EXPERIMENTAL Variables:
e.g. Question Type = [A, B, .. N]

USER Characteristics & Behaviors
e.g. Goal for course
e.g. Accuracy on problem 3 week 2

[ADDITION of VARIABLES possible]

What is the key principle?

Dynamic API
Access & Rewrite

Policy
IF [Question Type ] = A then show V1
IF [QType] = B then V2
IF [QType] = N then VN

MOOClet

V1  V2  VN
Adaptive Personalization Policy

**Experimentation Policy**
- 50% [QType] = A
- 50% [QType] = B

**Adaptive Personalization Policy**
- IF GoalForCourse = “Get Certificate”
  - 80% [QType] = A
  - 20% [QType] = B
- IF GoalForCourse = “Audit content”
  - 40% [QType] = A
  - 60% [QType] = B

<table>
<thead>
<tr>
<th>Quiz Score</th>
<th>On Average</th>
<th>Get Certificate</th>
<th>Audit Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question Type A</td>
<td>60%</td>
<td>80%</td>
<td>40%</td>
</tr>
<tr>
<td>Question Type B</td>
<td>40%</td>
<td>20%</td>
<td>60%</td>
</tr>
</tbody>
</table>
Instructor-Researcher Coordination

**What is the key principle?**

**TARGET Variables:** [Instructor chosen]
Grade on weekly quiz

**OUTCOME Variables:**
Time spent on lesson (and next 2 lessons)
Responses to in-page exercises [& next 2 ]

**USER CHARACTERISTICS:**
Accuracy on Pre-Test [0 to 100]
Goal for course [Get certificate | Audit some content]
Time spent & exercises solved in previous lesson

**EXPERIMENTAL Variables:**
Question Type = [A (Q1), B (Q2), C (Q3)]

**MOOClet**

- [Q1] What is the key principle?
- [Q2] How would you explain this to another student?
- [Q3] How does this relate to the last lesson?
Crowdsourcing & Collaborative Design

• “Crowdsource” Instructors/Researchers
  – NSF Cyberinfrastructure grant for ASSISTments

• Contributions as novel or modified experimental/MOOClet Versions

• Evaluated using experimental comparisons on quantitative measures of behavior

Instructor

MOOClet

[Q1] What is the key principle?

[Q2] How would you explain this to another student?

[Q3] How does this relate to the last lesson?
Automated Personalization using Machine Learning

• Any MOOClet is **Formally Equivalent** to a Reinforcement Learning Agent
• Abstraction & API to apply Machine Learning & AI algorithms
  – Multi-armed & Contextual Bandits, (PO)MDPs
• User: “Machine Learning Researcher”
Kaggle for Education?

Lesson

Thank you for trying the STATS4STEM 2013 AP REVIEW!

Before you get started on your statistical questions, a brief overview of some suggestions/recommendations is in order before you get started.

First, when entering in probabilities, it is required that you always answer as a decimal rounded to the nearest hundredth.

For example:

If you calculate a probability of 68.2%. Your answer should be: 0.68 (or simply .68)

Problem

Problem ID: PRAJ5ZN

Calculate the slope of the least squares regression line that has the statistics found below. Round answer to the nearest hundredth.

<table>
<thead>
<tr>
<th>r</th>
<th>Sx</th>
<th>Sy</th>
<th>x-bar</th>
<th>y-bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>1.1</td>
<td>1.4</td>
<td>3.2</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

For help, click here for the AP Statistics formula sheet.

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Outcome/Target

10 question test of understanding standard deviation
Performance on problems
Time needed to learn effectively

Hint

Use the AP formula sheet. Specifically, refer to the formula for b1 - the slope.
Review

- Static vs Dynamic Improvement & Personalization through Collaboration
- MOOClet Concept
- Instructor & Researcher Coordination
- Collaborative Design & Communitysourcing
- Automated Personalization & Machine Learning
Mary’s music store had 5 truck loads of CDs delivered. Each truck dropped off 12 boxes. Each box has \( c \) CDs. Write an expression for how many CDs were delivered.

**Explanation/Hint**

Take the problem step by step. Every truck has 12 boxes and there are 5 trucks, so how many boxes are there? \( 12 \times 5 = 60 \).