AI for Adaptive Tutoring and Transfer Student Success

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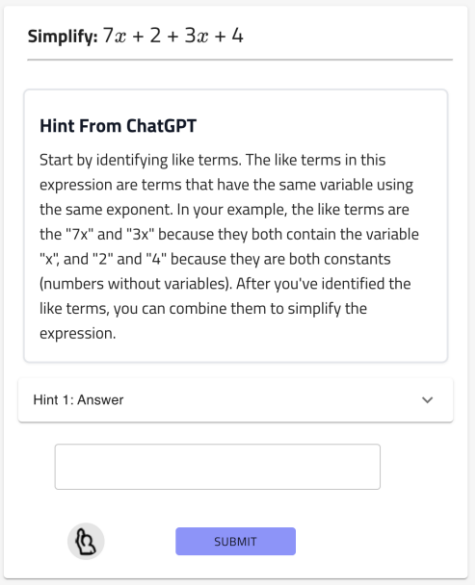
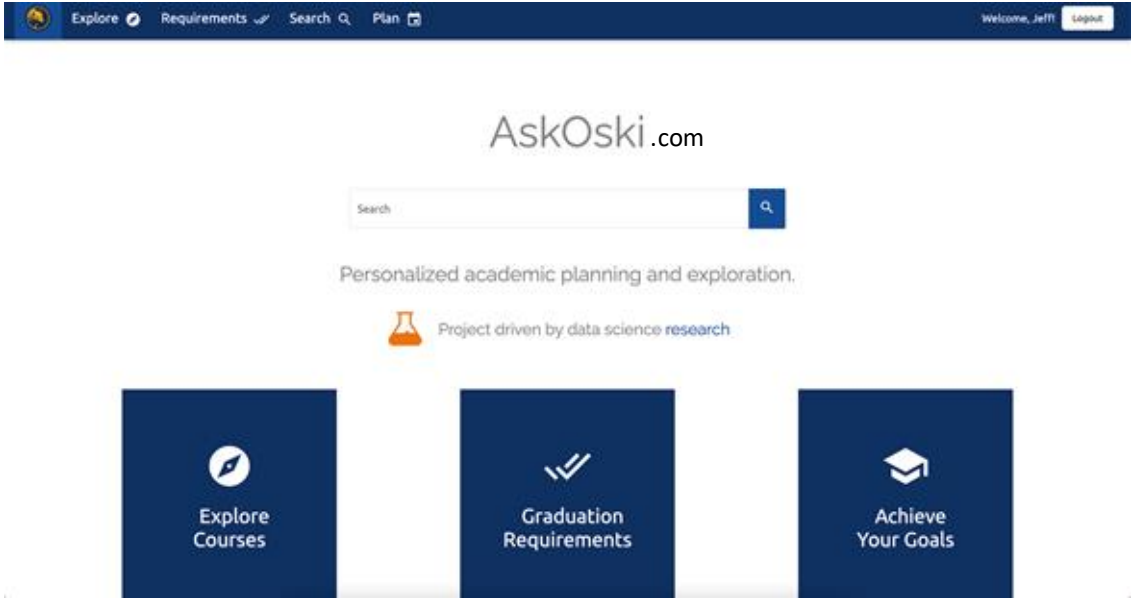
UC Berkeley School of Education

CAHL

Computational Approaches to Human Learning Lab (CAHL)





Timeline of AI for advising research from the lab:

- 2015: Two NSF grants awarded to apply AI to higher education
- 2016: First prototype of a course guidance system (AskOski.com) was released at UC Berkeley
- 2019: Development began on an ***Open Adaptive Tutoring System*** deployed at Missions College
- 2020: ***AI for transfer*** collaborations began with CUNY, SUNY, and the CA Community Colleges

What is AI?

Anything that pushes the boundary between the tasks that computers are good at and the tasks that only humans are good at

Artificial Intelligence > Machine Learning > Statistical Model > Neural Networks

Game Play

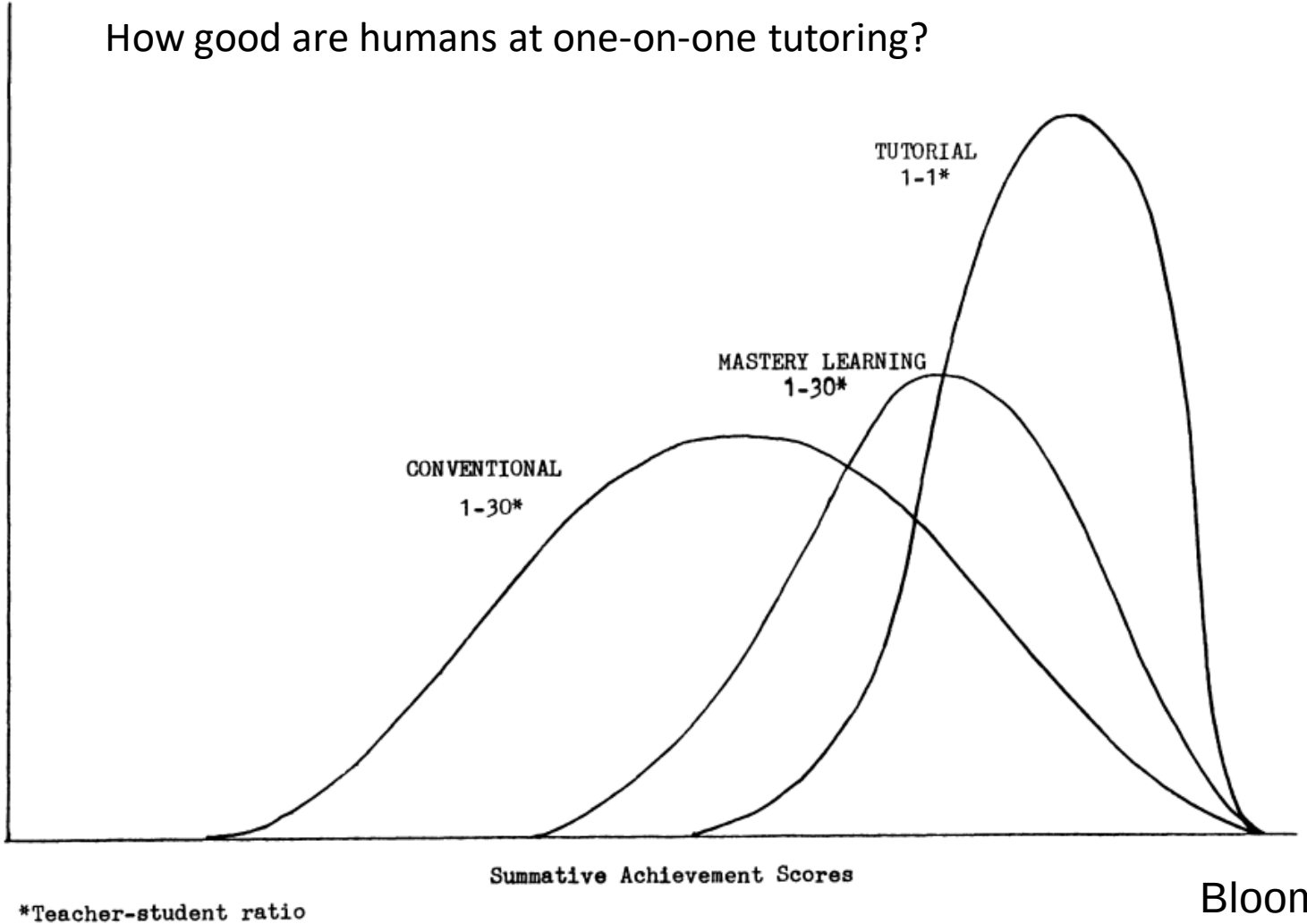
Driving

Translation

ChatGPT

Natural language

How good are humans at one-on-one tutoring?



Bloom (1984)

Where's the open source

Corbett (2001) – "Cognitive Computer Tutors: Solving the Two-Sigma Problem" (Intelligent Tutoring Systems approach)

Effectiveness of Cognitive Tutor Algebra I at Scale

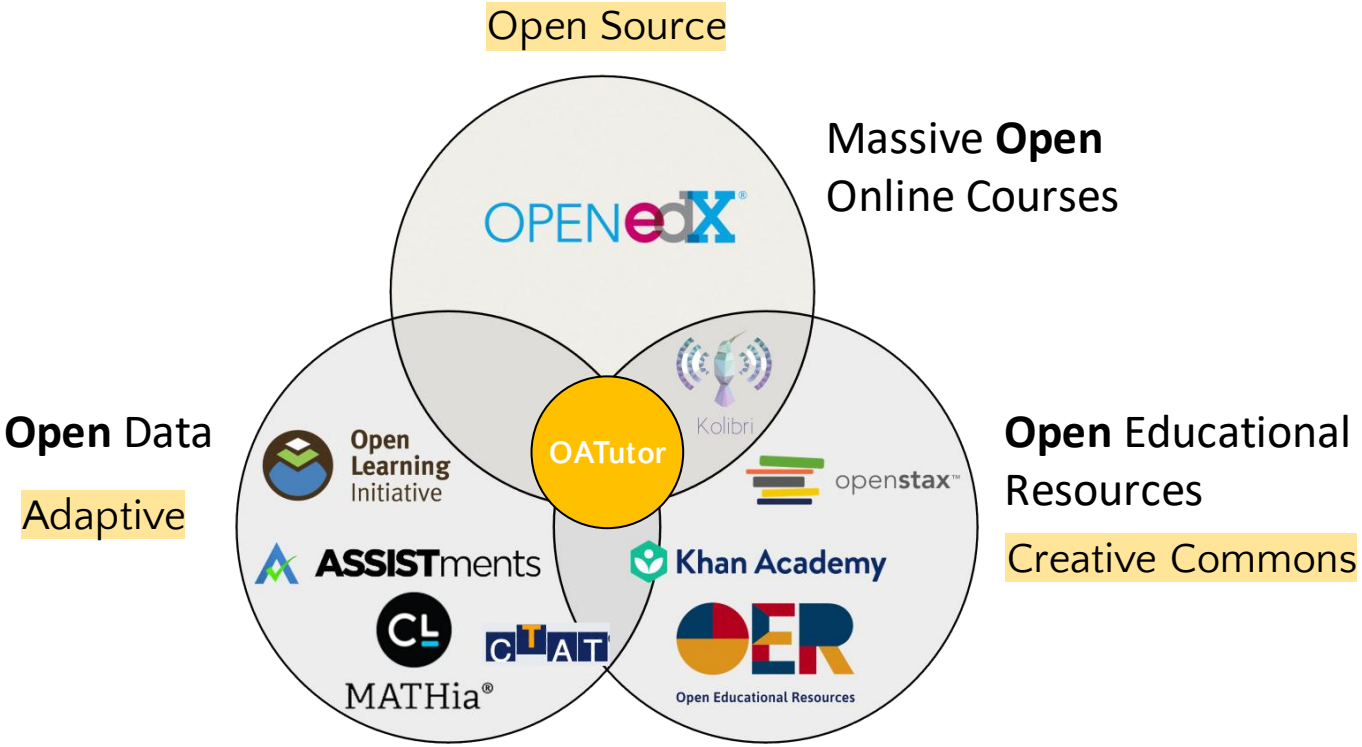
RAND External Publication

Published in: Educational Evaluation and Policy Analysis, v. 36, no. 2, June 2014, p. 127 - 144

Posted on RAND.org on June 01, 2014

by John F. Pane, Beth Ann Griffin, Daniel F. McCaffrey, Rita T. Karam

📌 *Open* movements and exemplar systems



Road image generated by DALL-E 2

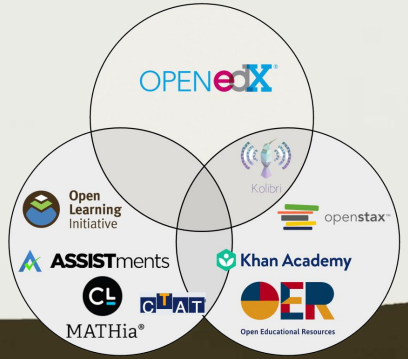
Research through Design

(Zimmerman, et al, 2007)

Open state

OATutor

Proprietary state



Three-year fielding and iterative development

- **1 community college**
- **7 math classrooms**
- **1 pilot teacher**
- **4 pilot researchers**
- **25 content authors**

Pardos et al. (2023)

Road image generated by DALL-E 2

California Policy Relevance

- AB 1705 / 705 – Effectively eliminates remedial English and Math classes
- AB 1187 – Expands access to tutoring at community colleges
- Significant UC wage increases to TAs after labor union negotiation

Can OATutor be beneficial in these scenarios?

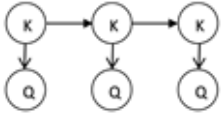
System

Features based on eight ITS Principles

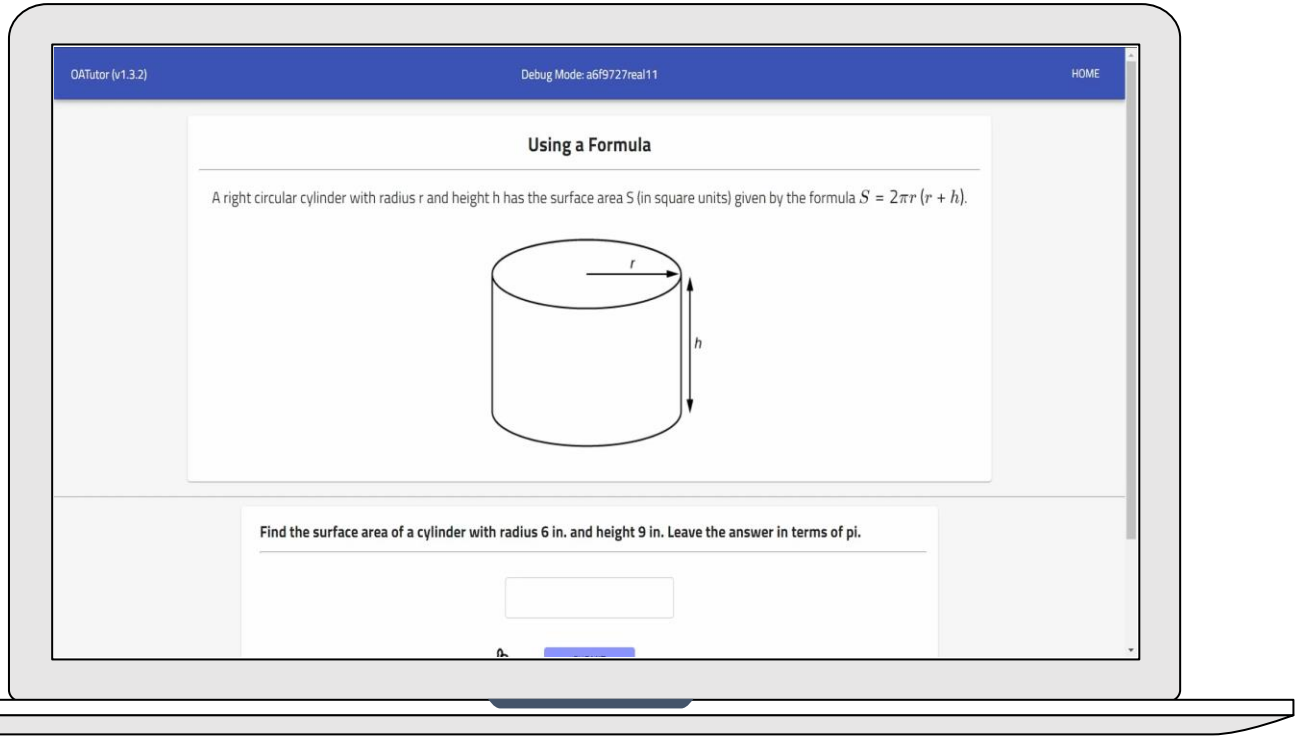
(Anderson, Corbett, Koedinger, & Pelletier, 1995)

#	ITS Principle
1	Represent student competence as a production set
2	Communicate the goal structure underlying the problem solving
3	Provide instruction in the problem-solving context
4	Promote an abstract understanding of the problem-solving knowledge
5	Minimize working memory load
6	Provide immediate feedback on errors
7	Adjust the grain size of instruction with learning
8	Facilitate successive approximations to the target skill

Knowledge tracing
(Corbett & Anderson, 1994)



Open Adaptive Tutor student interface



Open Source

```
1   MIT License
2
3   Copyright (c) 2023 Zachary A. Pardos (@zpardos) - CAHL research lab
```

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19  LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
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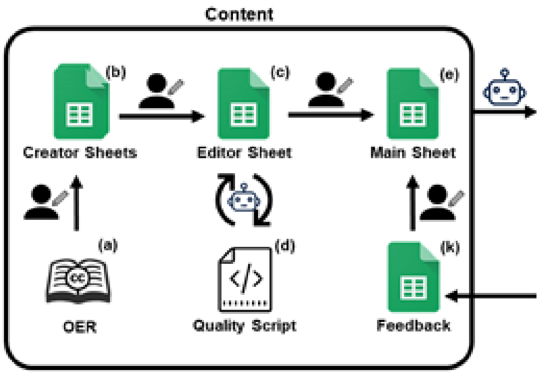
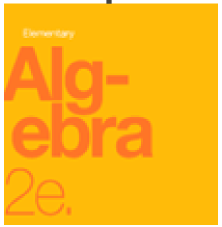
21  SOFTWARE.
```

Content curation process

Problem Name	Row Type	Title	Body Text	Answer	answerType	HintID	Dependency	kc	Images	Variabilization
real11	problem	Using a Formula	A right circular cylinder with radius r and height h has the surface area S (in square units) given by the formula S=2pir(r+h).					Evaluating Algebraic Expressions	https://openstax.org/resources/ba710f0ba5657f6dca83dc7f31ef9af7f93a25ea	
real11	step	Find the surface area of a cylinder with radius @{r} in. and height @{h} in. Leave the answer in terms of pi.		2*@{r}*(@{r} + @{h}) pi	algebra					r:1|2|3|4|5 h:6|7|8|9|10
real11	hint	Substitute	Substitute @{r}and @{h} into the equation to obtain 2pi(@{r})((@{r})+(@{h}))			h1				
real11	hint	Parentheses	Simplify the parentheses.			h2	h1			
real11	scaffold	Parentheses	What is @{r} + @{h}?	@{r} + @{h}	algebra	h3	h2			
real11	hint	Multiplication	The next step is to simplify multiplication and division.			h4	h3			
real11	scaffold	Multiplication	What is 2*@{r}*(@{r} + @{h})?	2*@{r}*(@{r} + @{h})	algebra	h5	h4			
real11	hint	Multiply by pi	Multiply by pi to obtain 2@{r}@{r}pi + 2@{r}@{h}pi.			h6	h5			

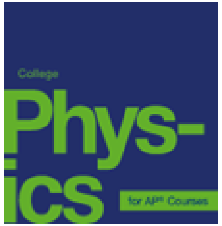


Completed:



(31 chapters, 199 lessons)

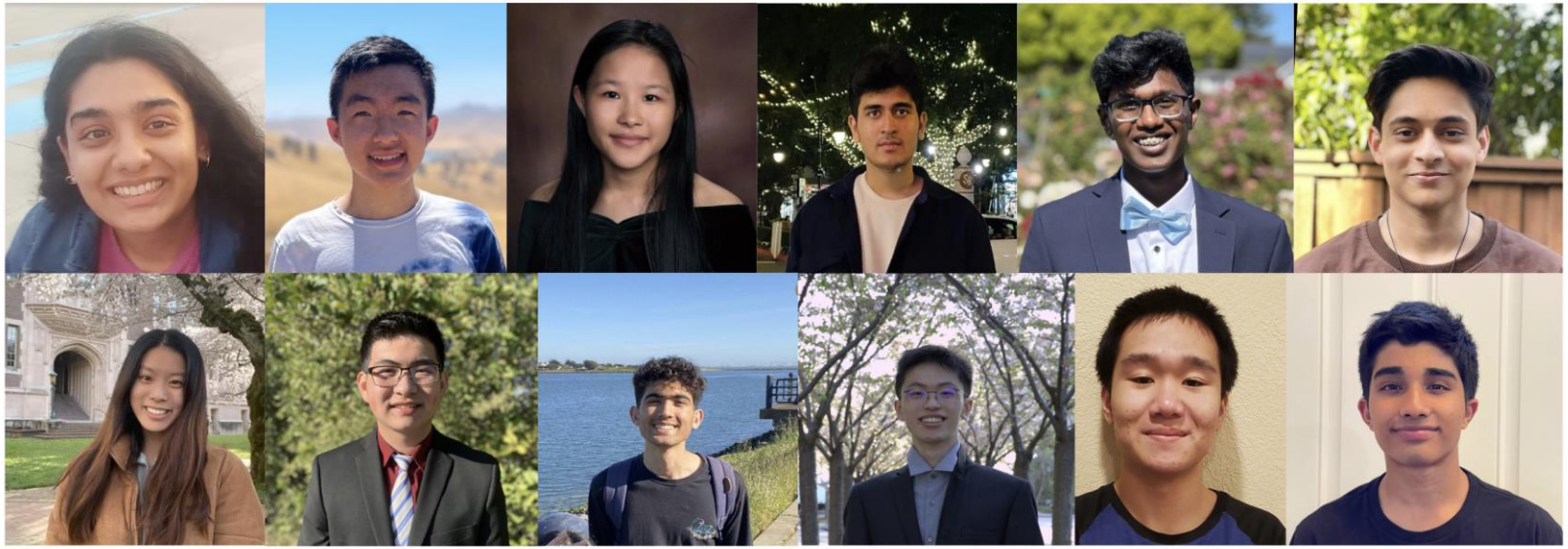
In Progress:



(23 chapters, 52 lessons)

Adapted from openstax™

OATutor Project Content Team



Methods

Research through Design Process

Content Creators

25 undergraduate students

Data Collection:

- Weekly meetings
- Survey

Teachers

4 pilots over 7 course offerings

Data Collection:

- Co-design meetings
- Interview
- Student feedback via LMS

Researchers

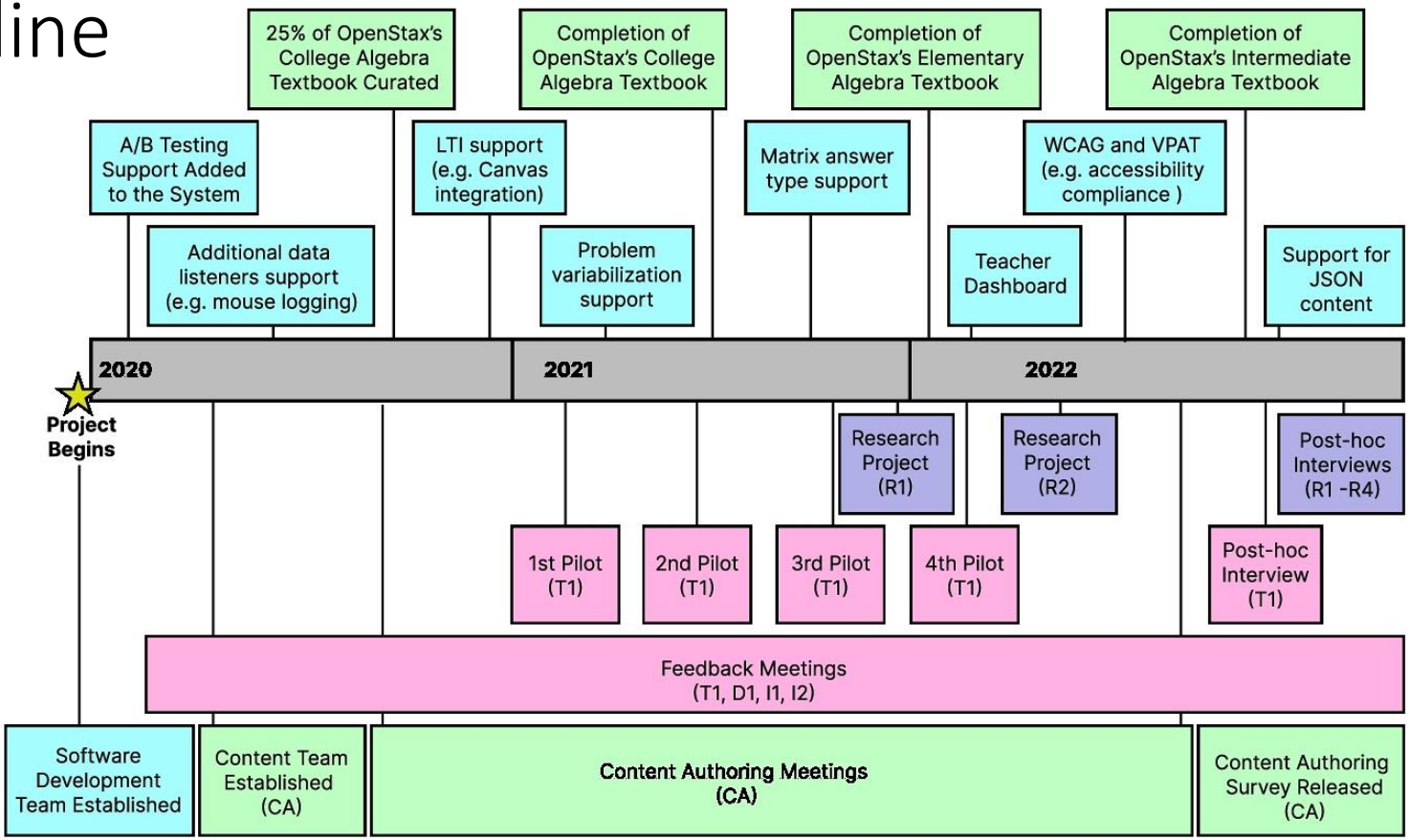
2 undergraduates and 2 PhD candidates

Data Collection:

- Advising meetings
- Interview

Data collection methods: survey, semi-structured interviews with follow-up, meeting notes

Timeline



Results

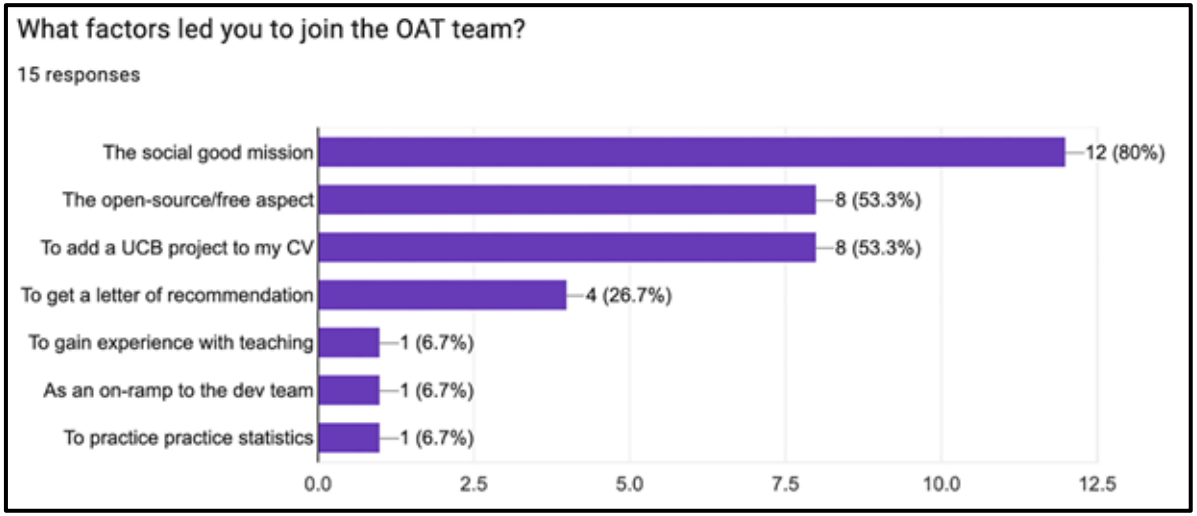
Authoring survey results (Self-report)

- Average time to complete training course
  - 2.27 hours *(SD = 1.10)*

- Average time to create problem
  - 11.03 min *(SD = 9.11)*

CA

Content Authors



Learning Gain Results

- Based on 77 crowdsourced learners

Textbook Level	Condition	N	Avg. Time	Hints Requested	Learning Gain	Avg. Pre-test	Avg. Post-test
Elementary	Control	19	08:16	132	24.63%	59.68%	84.32%
Intermediate	Control	17	12:53	150	23.65%	50.94%	74.59%

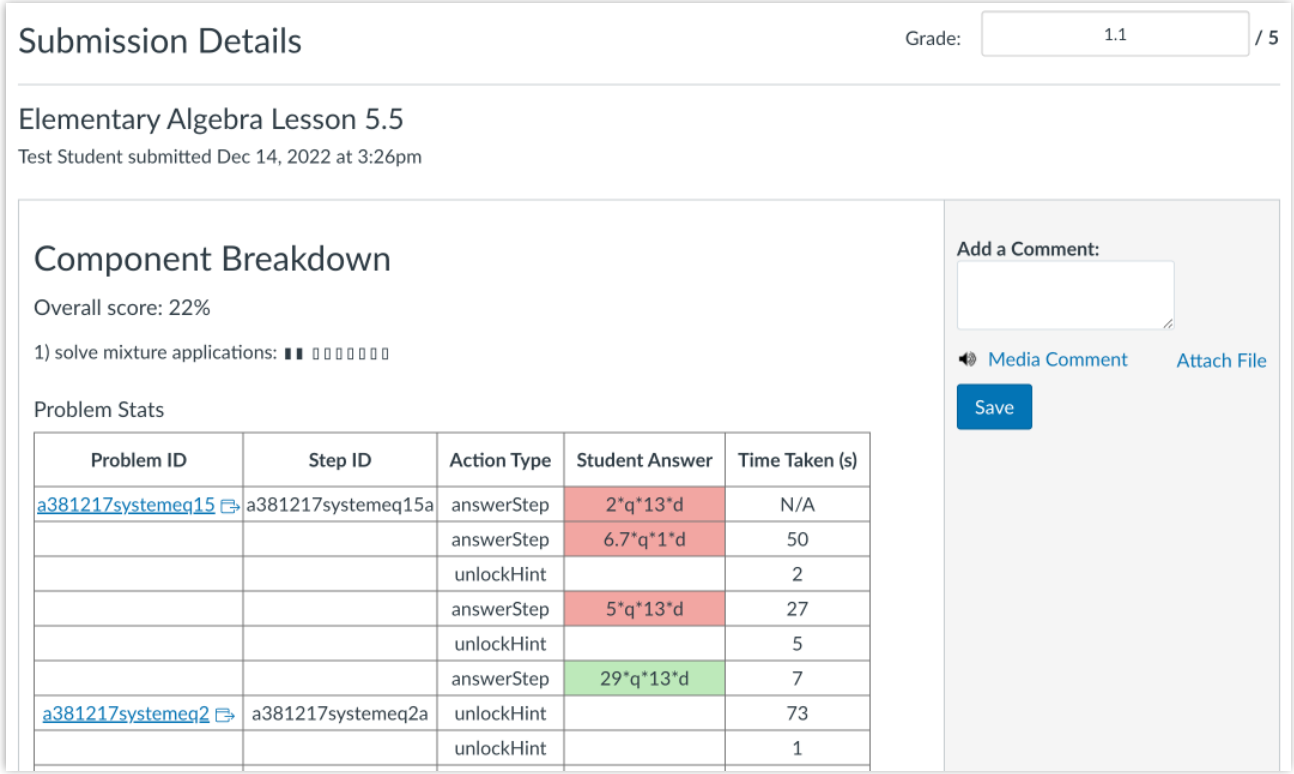
Elementary Algebra Learning Objective:
Solve Equations Using the Subtraction and Addition Properties of Equality

Intermediate Algebra Learning Objective:
Solve linear equations using a general strategy

Features lack consistency with other web-based platforms, such as a detailed dashboard

T1

Teacher



Submission Details

Grade: 1.1 / 5

Elementary Algebra Lesson 5.5

Test Student submitted Dec 14, 2022 at 3:26pm

Component Breakdown

Overall score: 22%

1) solve mixture applications: ▮▮ ▯▯▯▯▯▯▯

Problem Stats

Problem ID	Step ID	Action Type	Student Answer	Time Taken (s)
a381217systemeq15	a381217systemeq15a	answerStep	2*q*13*d	N/A
		answerStep	6.7*q*1*d	50
		unlockHint		2
		answerStep	5*q*13*d	27
		unlockHint		5
		answerStep	29*q*13*d	7
a381217systemeq2	a381217systemeq2a	unlockHint		73
		unlockHint		1

Add a Comment:

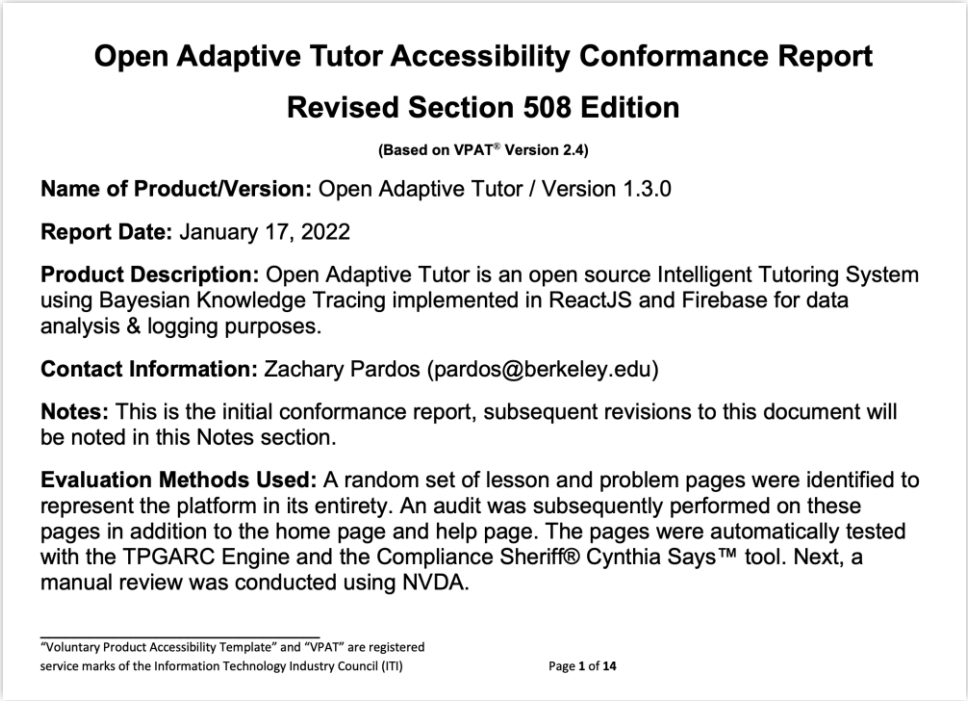
Media Comment Attach File

Save

Accessibility compliance under Section 508 is a requirement for software regularly used in classrooms

T1 Teacher

D1 Dean



Open Adaptive Tutor Accessibility Conformance Report

Revised Section 508 Edition

(Based on VPAT® Version 2.4)

Name of Product/Version: Open Adaptive Tutor / Version 1.3.0

Report Date: January 17, 2022

Product Description: Open Adaptive Tutor is an open source Intelligent Tutoring System using Bayesian Knowledge Tracing implemented in ReactJS and Firebase for data analysis & logging purposes.

Contact Information: Zachary Pardos (pardos@berkeley.edu)

Notes: This is the initial conformance report, subsequent revisions to this document will be noted in this Notes section.

Evaluation Methods Used: A random set of lesson and problem pages were identified to represent the platform in its entirety. An audit was subsequently performed on these pages in addition to the home page and help page. The pages were automatically tested with the TPGARC Engine and the Compliance Sheriff® Cynthia Says™ tool. Next, a manual review was conducted using NVDA.

"Voluntary Product Accessibility Template" and "VPAT" are registered service marks of the Information Technology Industry Council (ITI)

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https://cahlr.github.io/OATutor/static/documents/OATutor_Sec508_WCAG.pdf

Workshops / Tutorials

OATutor.io (technical tutorial)

July 7th (full day) @ Artificial Intelligence in Education

Conducting Rapid Experimentation with an Open-source Adaptive Tutoring System

July 20th (half day) @ Learning at Scale

Introducing an Open-Source Adaptive Tutoring System to Accelerate Learning Science Experimentation

September 5th (half day) @ ECTEL

Introducing an Open-Source Adaptive Tutoring System to Accelerate Learning Science Experimentation

September 19th (half day) @ KTH

Introducing an Open-source Adaptive Tutoring System to Accelerate Learning Sciences Experimentation

Discussion / Future Directions

- Increasing adaptivity to teachers
- Localization / Multi-lingual content
- **Generative AI**

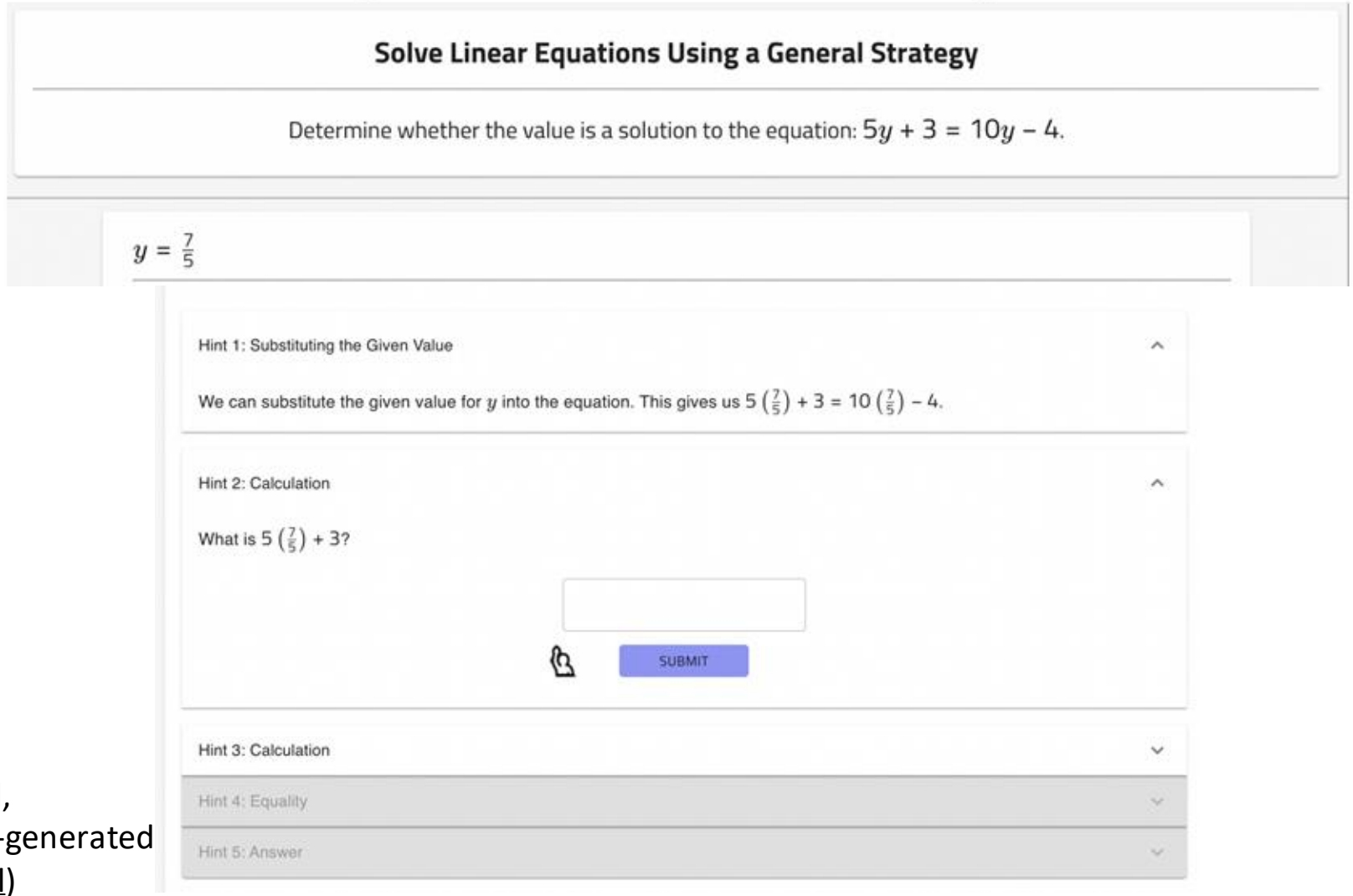
Challenge: Content production was EXPENSIVE

- Creating each adaptive textbook took the equivalent of one year of an FTE
- This is a problem for scaling and further personalizing adaptive tutoring

Experiments using Generative AI/Large Language Models to create educational content

Generative-AI for Tutoring

Pardos, Z. A., & Bhandari, S. (2023). Learning gain differences between ChatGPT and human tutor generated algebra hints. *arXiv preprint arXiv:2302.06871*.A



Manual, human-generated (control)

Solve Linear Equations Using a General Strategy

Determine whether the value is a solution to the equation: $5y + 3 = 10y - 4$.

$y = \frac{7}{5}$

Hint 1: Worked Solution

To determine whether a given value is a solution to a given equation, you can substitute the value into the equation in place of the variable and see whether the equation is satisfied.

So, if we substitute $y = \frac{7}{5}$ into the equation $5y + 3 = 10y - 4$, we get:

$5\left(\frac{7}{5}\right) + 3 = 10\left(\frac{7}{5}\right) - 4$

$\frac{35}{5} + 3 = \frac{70}{5} - 4$

$\frac{35}{5} + 3 = 14 - 4$

$\frac{35}{5} + 3 = 10$

$\frac{35+15}{5} = 10$

$\frac{50}{5} = 10$

$10 = 10$

Since the equation is satisfied when $y = \frac{7}{5}$, this value is indeed a solution to the equation.

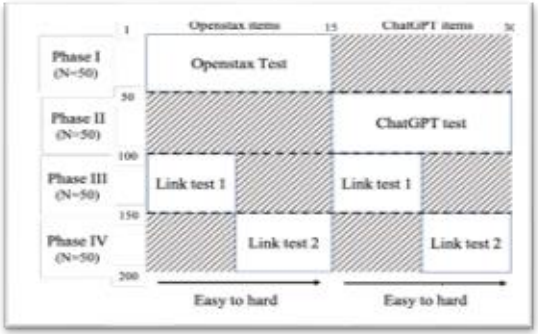
Hint 2: Answer

ChatGPT generated (experiment)

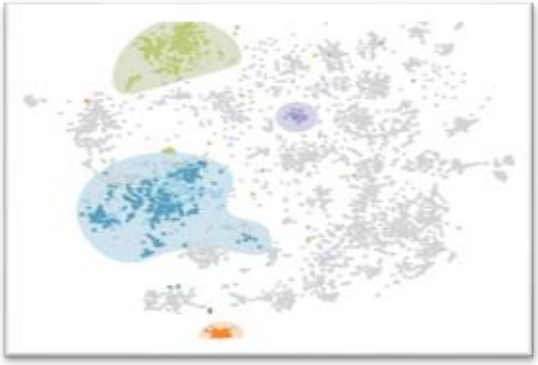
Result of Learning Gain Study

👍 Time efficient to produce - took ~30s to quality check each hint
👎 Often wrong - 30% of hints were incorrect (filtered out of study)
👉 Produced positive learning gains
👉 Human tutor hints produced higher gains

Other related work from our lab



Generative AI produces math problems with similar properties as gold standard textbook problems
Bhandari, Liu, & Pardos (NeurIPS 2023)

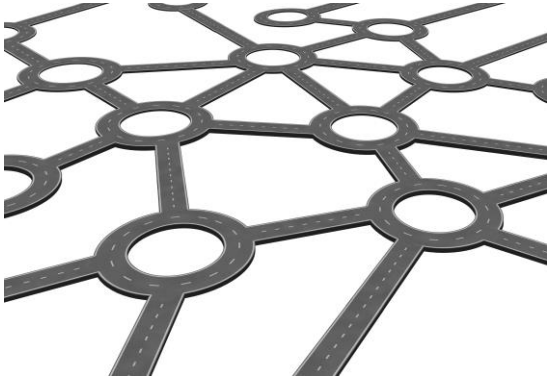


Educational pathways and AI advising
Pardos & Nam (PONE 2020),
Shao et al. (AAAI 2021),
Kizilcec et al. (Science 2023)

Reducing AI-aversion in higher ed credit approval
Xu, L., Pardos, Z. A., & Pai, A. (L@S 2023)

AI for Articulation

Pardos, Z. A., Chau, H., Zhao, H. (2019) **Data-Assistive Course-to-Course Articulation Using Machine Translation**. In J. C. Mitchell & K. Porayska-Pomsta (Eds.) *Proceedings of the 6th ACM Conference on Learning @ Scale* (L@S). Chicago, IL. ACM. **Best paper award**

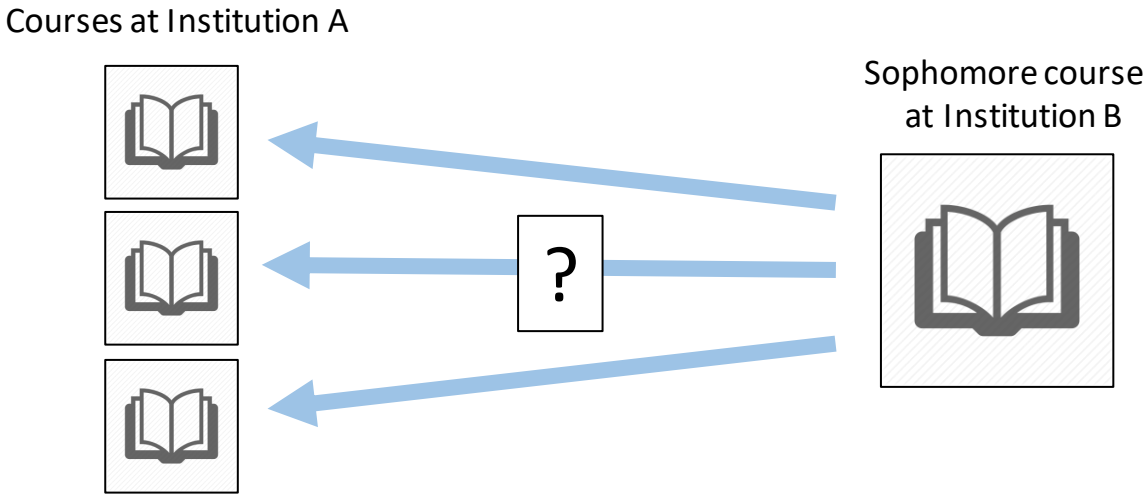


AI for Transfer Wayfinding

Shao, E., Guo, S., & Pardos, Z. A. (2021) **Degree Planning with PLAN-BERT: Multi-Semester Recommendation Using Future Courses of Interest**. In *Proceedings of the AAAI Conference on Artificial Intelligence* (Vol. 35, No. 17, pp. 14920-14929).

Course-to-Course Articulation

Which course (if any) at Institution A is academically equivalent to a course at Institution B?



Taking these courses at Institution A is often required to qualify for transfer to Institution B

California Policy Relevance

- AB 1111 – Requires the creation of a common course numbering system across the 116 community colleges
- AB 928 – Requires the CSU and UC segments to agree on a set of shared general education requirements for smoother transfer from CCCs

Can AI articulation and wayfinding be beneficial in these scenarios?

The Challenge of Articulation

The California post-secondary system alone has:

- 116 2-year California Community Colleges (CCC)
- 23 California State Universities (CSU)
- 9 University of California campuses (UC)
- An "Upward-Mobility Machine" (NYT 2015)

The number of articulations to consider between 1 CCC and 1 UC:

35,000 (50*20*35)

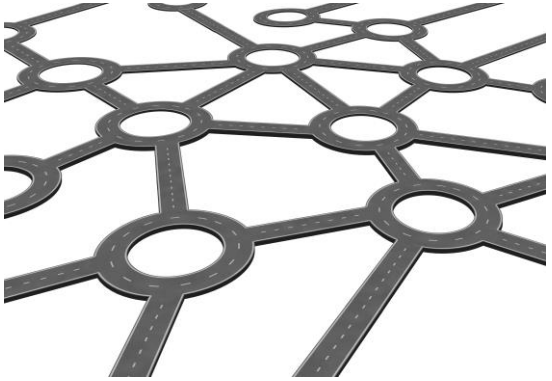
36M between all CCCs and UCs

+ the CSUs, private schools, out of state schools

+ new courses introduced every term

<u>Comprehensive articulation cannot be established and maintained purely by hand</u>

AI for Articulation



Is this Berkeley course equivalent
enough to any course at Laney College?

Berkeley | EECS
Electrical Engineering and Computer Sciences

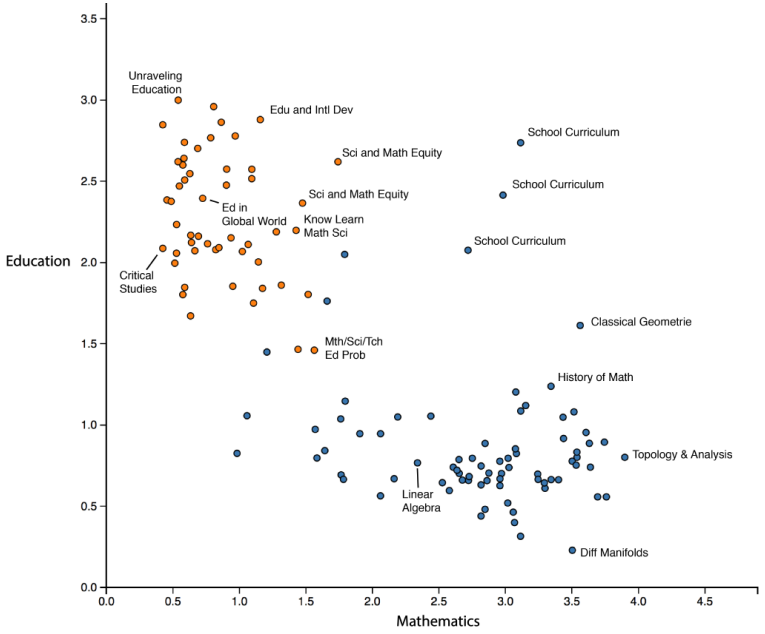
LANEY COLLEGE

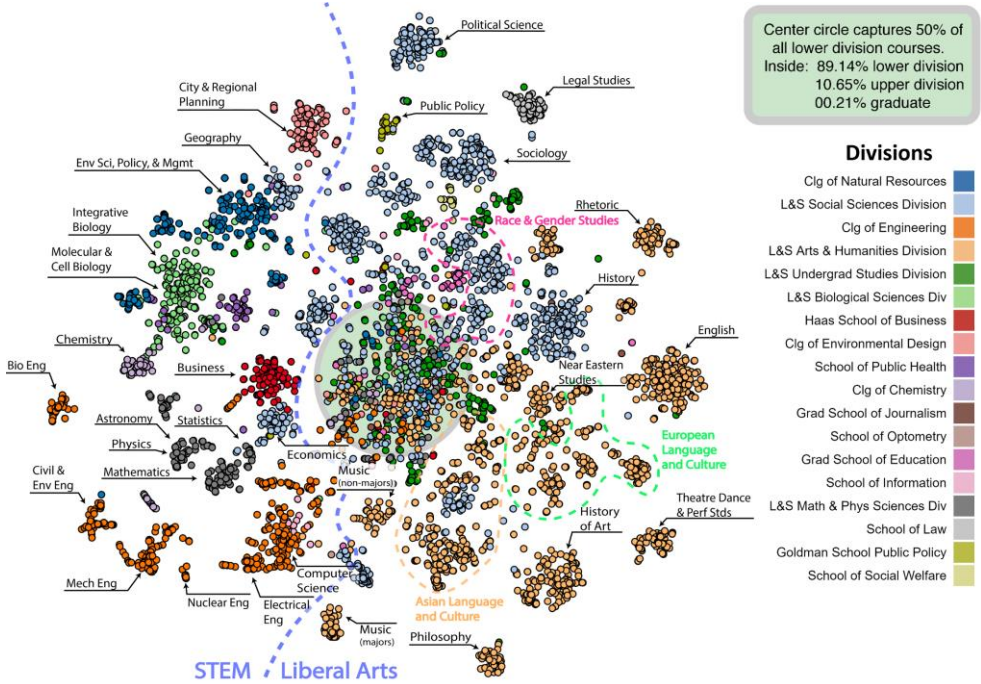
Students' course enrollment histories:
Stu1: MATH54 SPA12 STAT200B **CS61B** CUE100A DATA100 DATA144
Stu2: EDUW161 GEOG37 ESPM15 **CS61B** GEOG35 ECONC3 HIST7A

← **Sequential data**

Corroborating course information also extracted from enrollment histories

Inferring information about courses from enrollment patterns



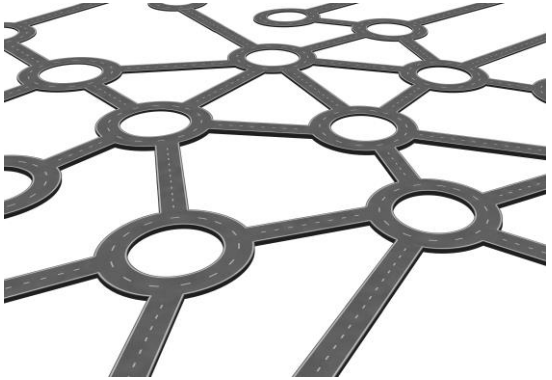


- Course relationships predicted with 51% accuracy (Jiang & Pardos, 2020)
- Comparable to the 61% obtained by Mikolov in word analogies (w/1B words)

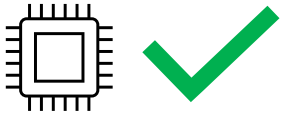
Relationship	**Results** (examples)
Honors	*Mathematics* H1B - *Mathematics* 1B + *Physics* 7B → *Physics* H7B
Online	*African American Studies* W111 - *African American Studies* 111 + *Engineering* 7 → *Engineering* W7
Sequence	*Mathematics* 1B - *Mathematics* 1A + *Physics* 7A → *Physics* 7B
Mathematical Rigor	*Mathematics* H1B - *Mathematics* 1B + *Economics* 140 → *Economics* 141
Topical (with 2 subjects)	*Economics* C110 (game theory) - *Statistics* 155 (game theory) + *Statistics* 151A (linear modeling) → *Economics* 141 (linear modeling)
	Psychology 102 (computing) - *Psychology* 1 (introductory) + *Statistics* 134 (introductory) → *Statistics* H194A (honors seminar) [intended course was *Statistics* 133 (computing), rank 8]
	Computer Science 189 (machine learning) - *Statistics* 154 (machine learning) + *Statistics* 150 (random processes)

Pardos Z. A., Nam A. J. H. (2020) A university map of course knowledge. *PLoS ONE* 15(9): e0233207.

AI for Articulation



Algorithmic State of the Art



- 70% Accurate using methods from 2013
- Substantial increase in accuracy using contemporary techniques
- Ready for prime time

Policy State of the Art

- Addressing the role of faculty and stuff in adjudicating articulations (Xu, Pardos, Pai, 2023)
- Software workflow integration
- Still being developed through real-world deployments

CAHL Computational Approaches to Human Learning Lab (CAHL)

Deployments (to learn to solve the policy challenges)

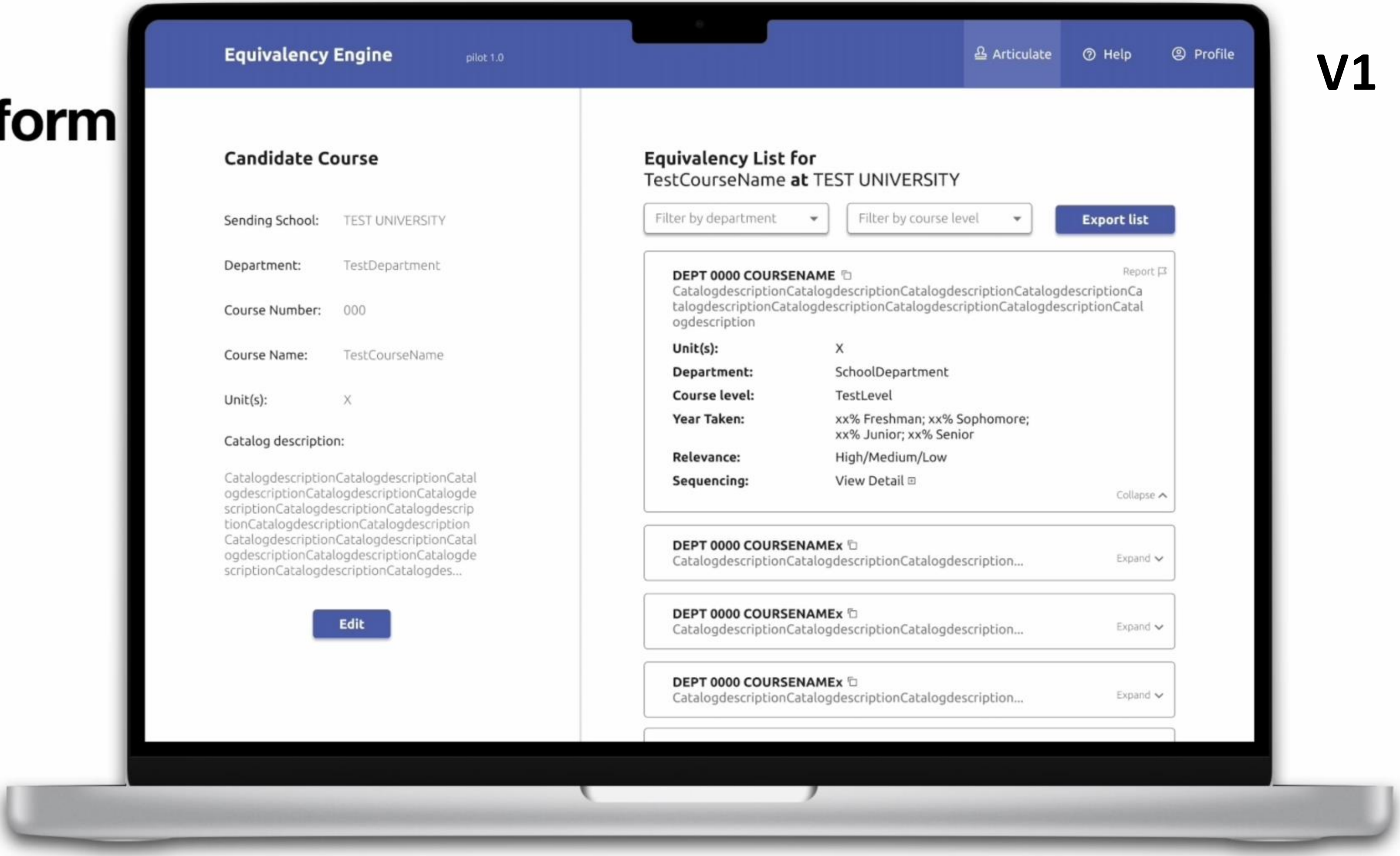
- 2018: AI articulation pilot between UCB and Laney Community College
- 2020: AI articulation pilot with City University of New York
- 2021: AI articulation + transfer pilot with State University of New York (BMGF)
- 2023: Scaled up AI articulation + transfer deployment at SUNY (BMGF/Ascendium)

Upcoming

- 2024: Common Course Numbering for 116 California Community Colleges
- 2024: Common Course Numbering for 12 Connecticut Community Colleges
- 2024: Substantial improvement in articulation algorithm to be released
- 2024: V2 of articulation platform based on large faculty pilot survey

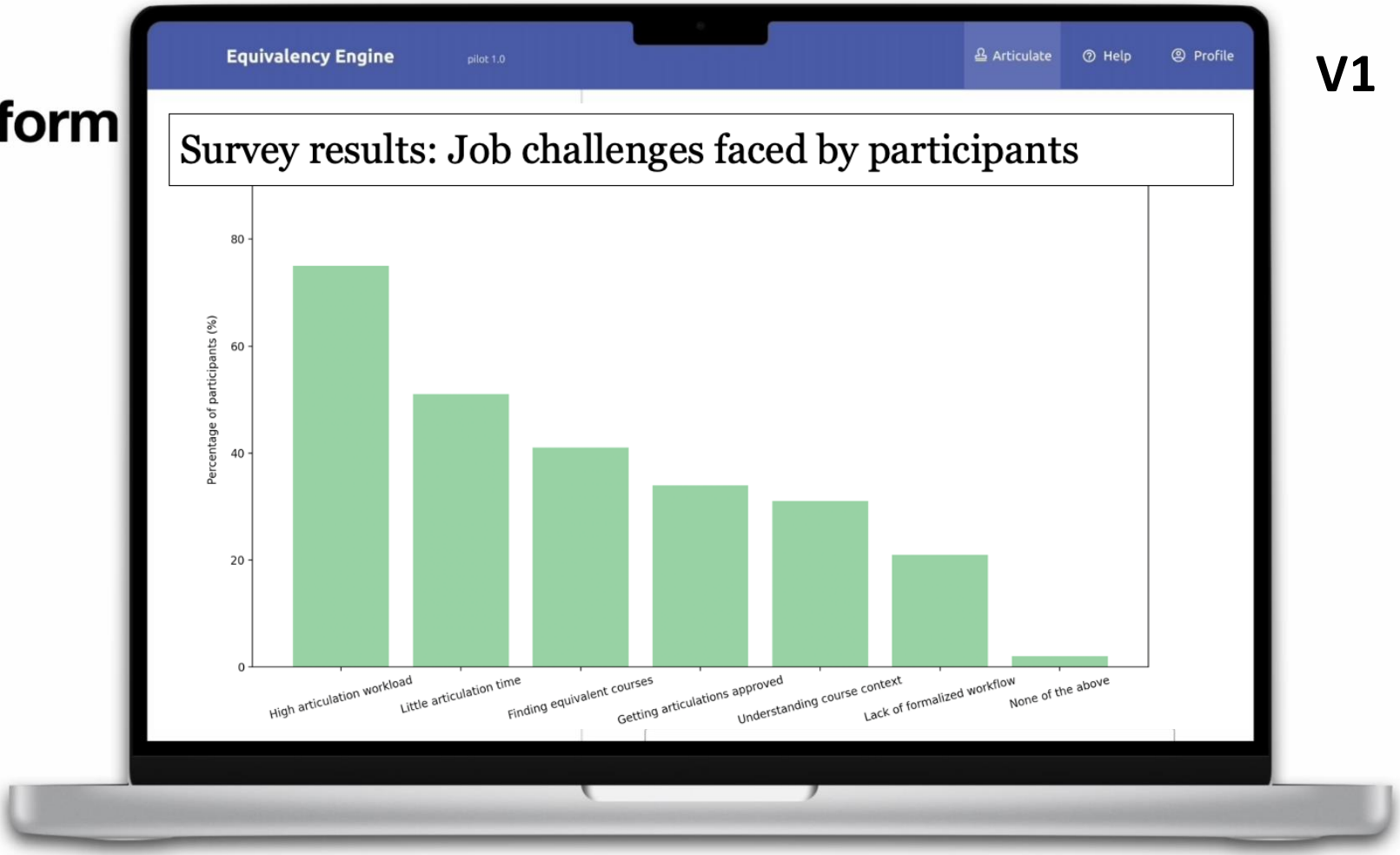
The Platform

V1



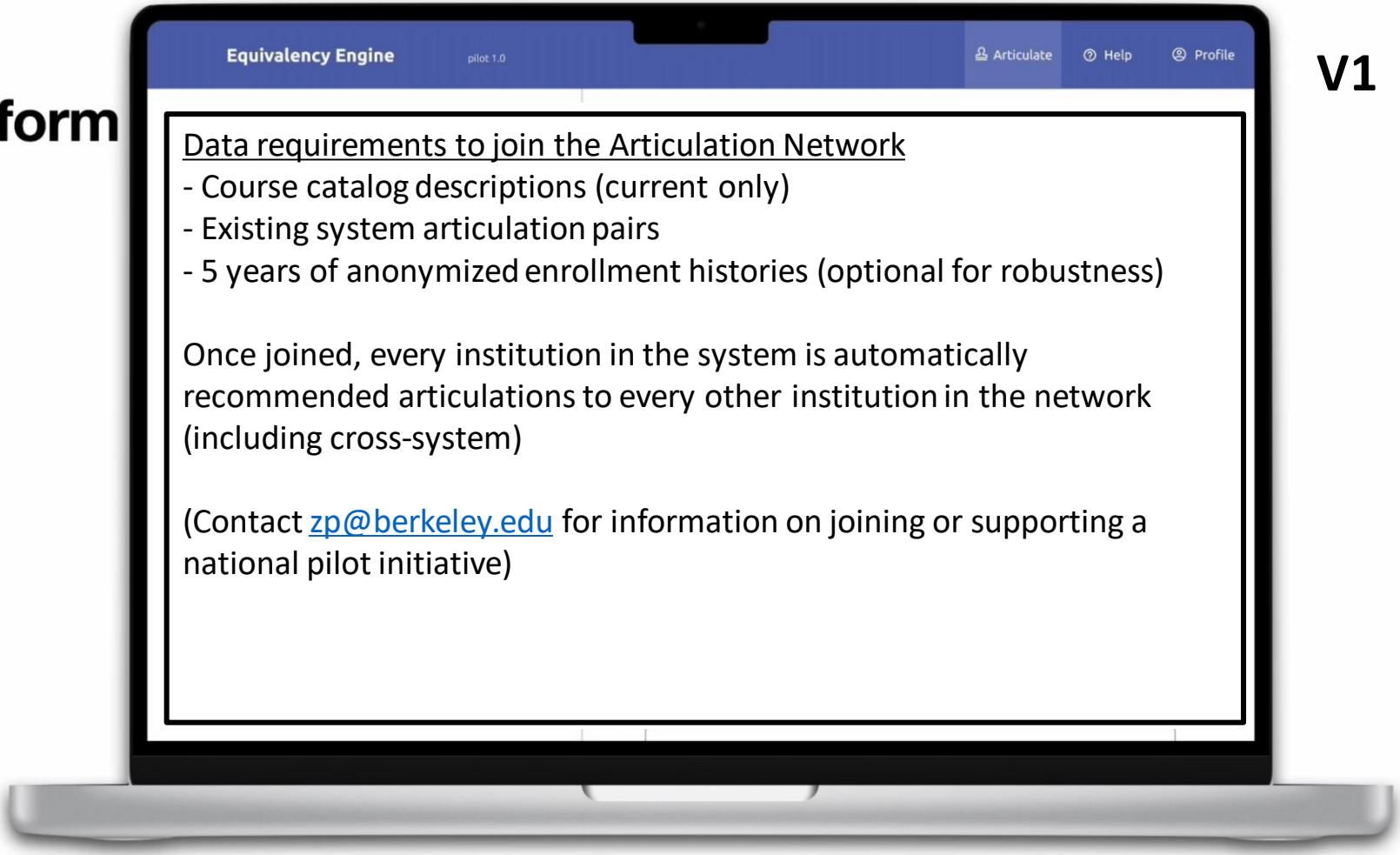
The Platform

V1



The Platform

V1



Data requirements to join the Articulation Network

- Course catalog descriptions (current only)
- Existing system articulation pairs
- 5 years of anonymized enrollment histories (optional for robustness)

Once joined, every institution in the system is automatically recommended articulations to every other institution in the network (including cross-system)

(Contact zp@berkeley.edu for information on joining or supporting a national pilot initiative)

The Problem – Algorithm aversion

- Human decision makers tend to discount algorithmic recommendations more heavily than similar recommendations made by humans, which is most acutely exhibited by **domain experts.**

(Commerford et al., 2021; Filiz et al., 2021; Logg et al., 2019)

(Xu, Pardos, Pai, 2023)

AI for Transfer Plan Generation

1) Express major (e.g., Criminology) and general education requirements

2) Procedurally generate a 4-year plan to a BA degree, personalized to the courses already taken by a student at the community college

Pre-matriculation Credit Courses	Year 1 (TC3)	Year 2 (TC3)	Year 3 (Cortland)	Year 4 (Cortland)
MATH120	ENGL100	CRJU104	CRM 222	ANT 234
MATH138	ENVS101	CRJU105	SOC 301	SOC 302
ACAD150	HSTY101	ENGL204	SOC 329	SOC 350
	PSYC103	POSC103	SPA 101	SOC 392
	ENGL101	SOCI101	ATH 121	SPA 201
	HSTY201	ANTH202	CRM 373	SPA 201
	MATH200	ENGL102	CRM 463	CRM 348
	MATH201	ENVS105	SOC 300	CRM 363
		SOCI206	SPA 102	CRM 380
				SPA 202

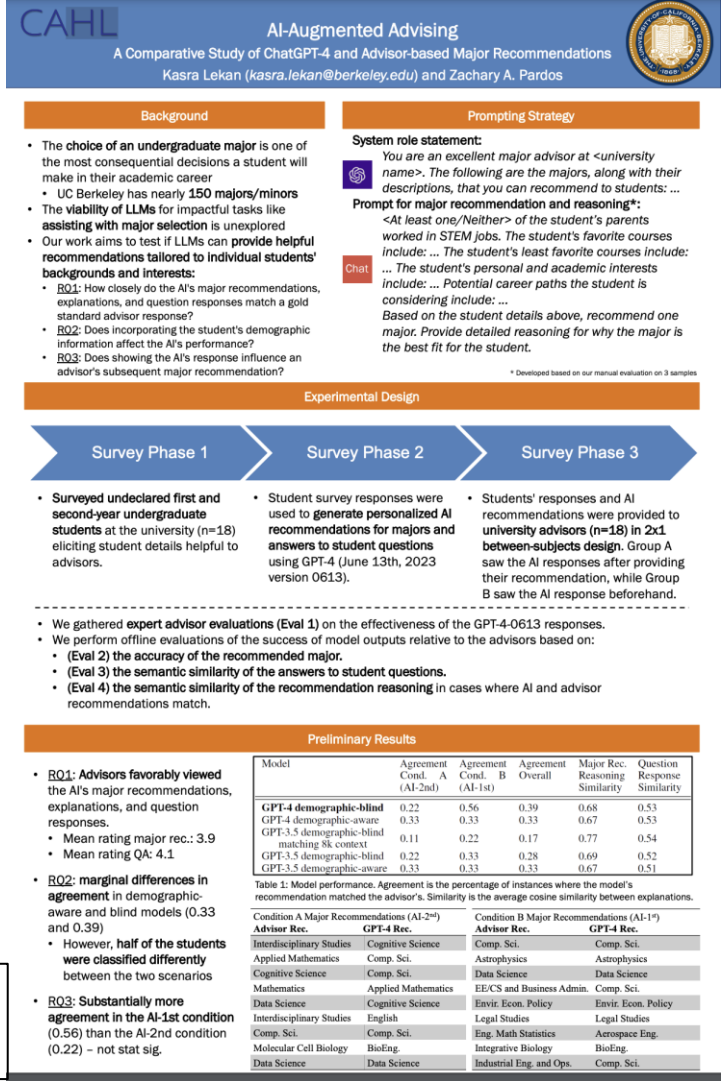
Deployments

- 2018: Generate Personalized Plans at UC Berkeley
- 2020: Offline testing on CUNY data
- 2023: Pilot Generating Transfer Plans at SUNY for advisers

Work in progress. Utilizes personalization research from Shao, E., Guo, S., & Pardos, Z. A. (2021)
See AskOski.com for the most recent publications

AI for Major Recommendation

- Campus advisors at UC Berkeley (n=18) rated personalized AI major recommendations and explanations favorably (4.1 out of 5)
- AI recommendations matched advisor recommendations for ~40% of students



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Big picture

- AI is primed to create efficiencies in educational content production and personalization
- AI is also primed to be used for student and administrator decision-making support
- In both cases, there is a human desire for and empirical justification for the necessity of Human-AI collaboration instead of full automation

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Further reading

OATutor (links at the bottom of the article):

https://bse.berkeley.edu/leveraging-ai-improve-adaptive-tutoring-systems

AI for articulation and degree planning (academic papers):

https://askoski.berkeley.edu/about

The Future of Ed Tech in CA (policy brief):

https://california100.org/report-the-future-of-education-2

Thank you! Questions?

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Funding Acknowledgements: