

AI for Adaptive Tutoring and Transfer Student Success

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Berkeley
UNIVERSITY OF CALIFORNIA

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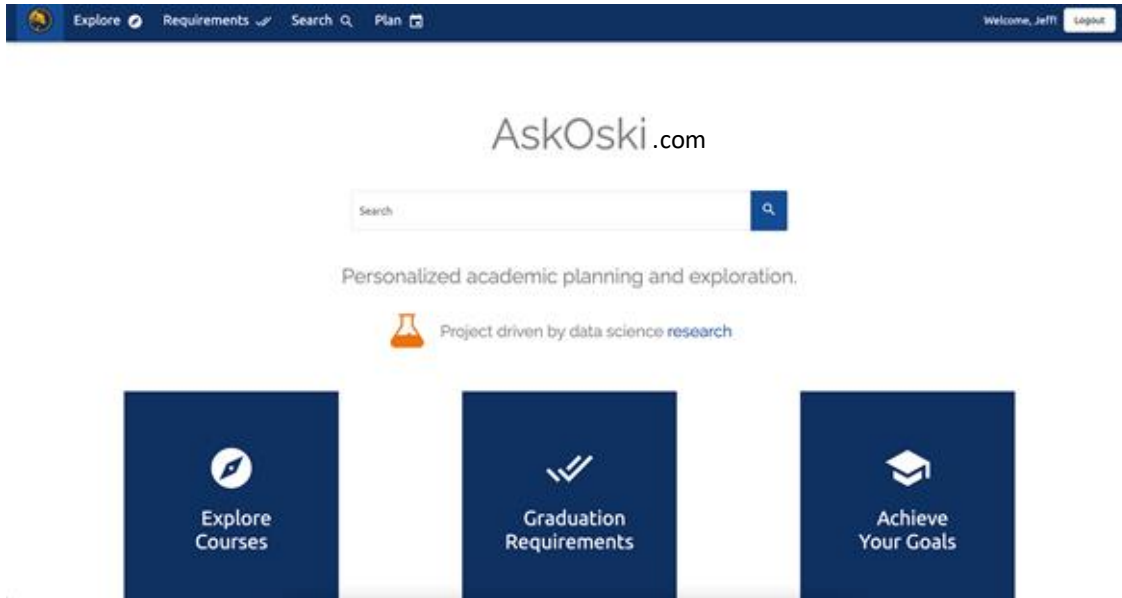
Simplify: $7x + 2 + 3x + 4$

Hint From ChatGPT

Start by identifying like terms. The like terms in this expression are terms that have the same variable using the same exponent. In your example, the like terms are the "7x" and "3x" because they both contain the variable "x", and "2" and "4" because they are both constants (numbers without variables). After you've identified the like terms, you can combine them to simplify the expression.

Hint 1: Answer





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

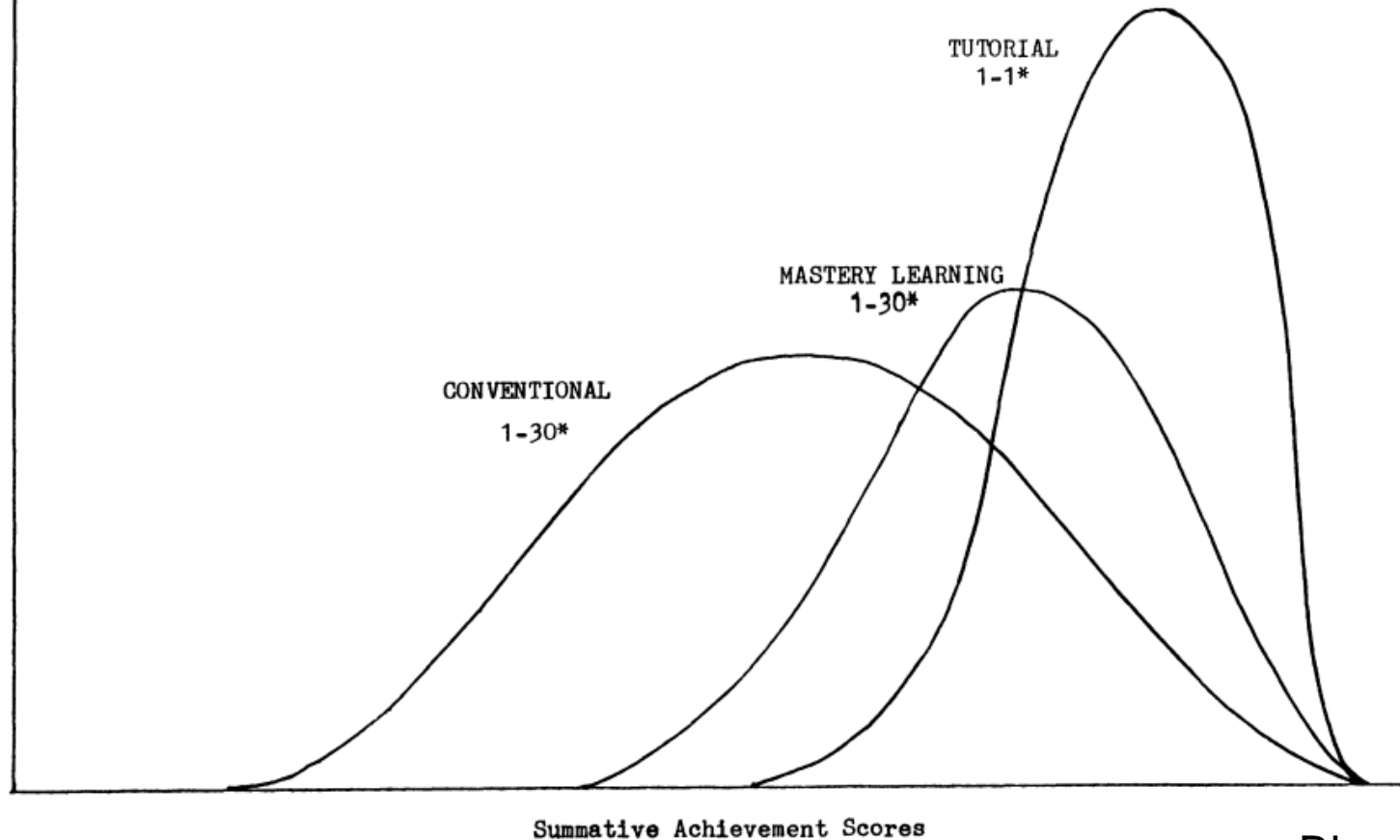


Translation



Natural language

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



*Teacher-student ratio

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

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

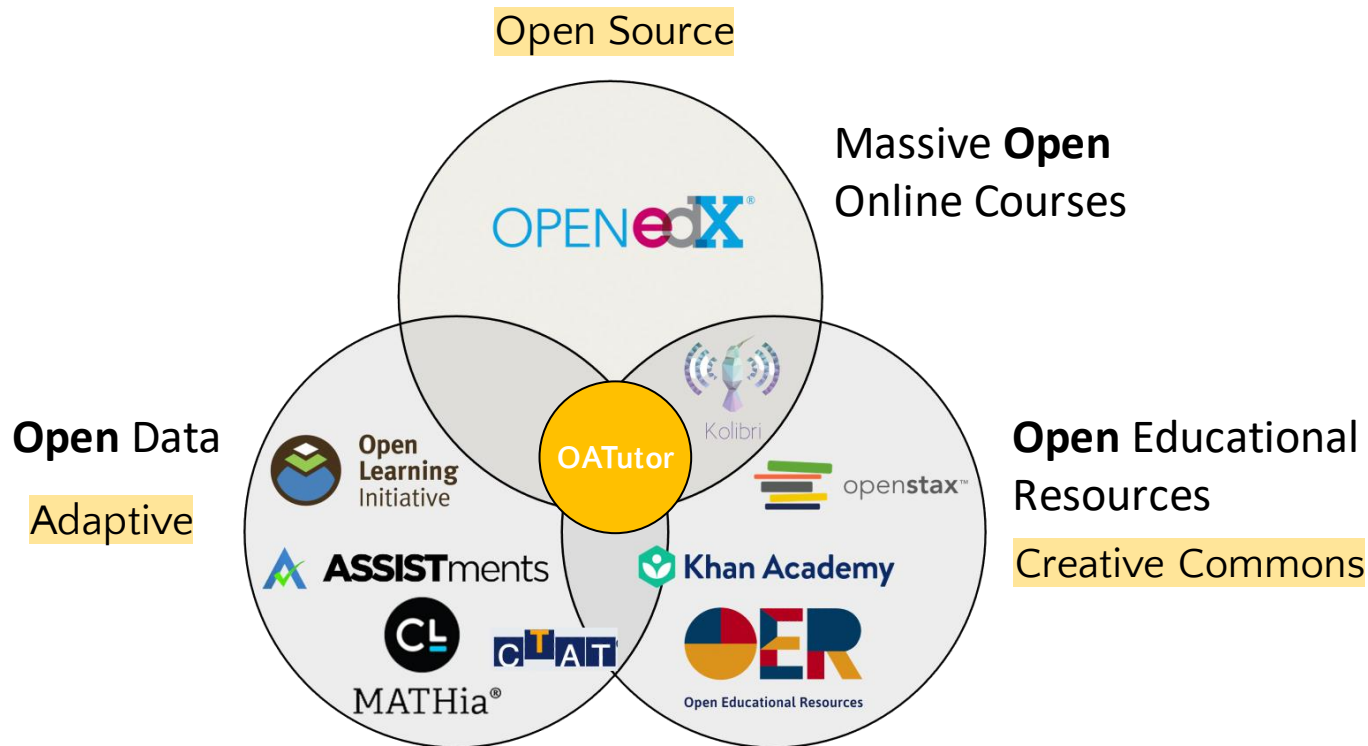
RAND
External
Publication

Christopher Field

Research Director



Open movements and exemplar systems



OPENedX

Open Learning Initiative

ASSISTments

MATHia®

Kolibri

Khan Academy

openstax

CL

QUAT

OER
Open Educational Resources



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?

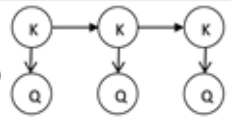
System

Features based on eight ITS Principles

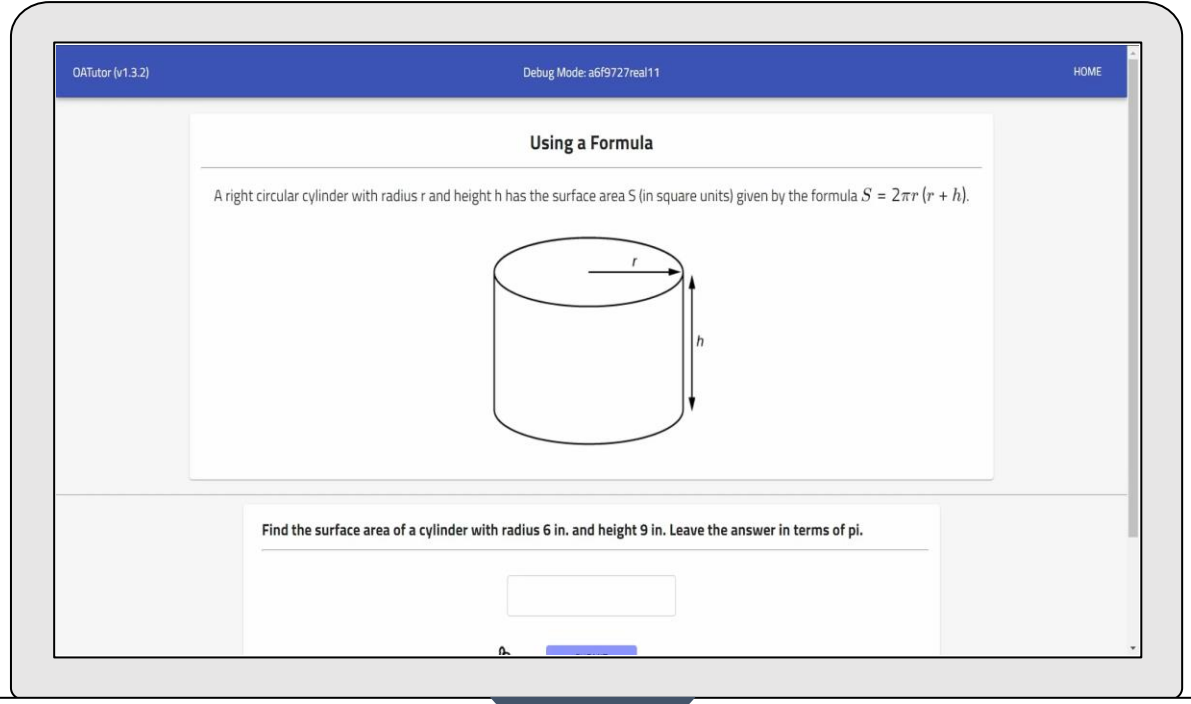
(Anderson, Corbett, Koedinger, & Pelletier, 1995)

#	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



1 MIT License

2

3 Copyright (c) 2023 Zachary A. Pardos (@zpardos) – CAHL research lab

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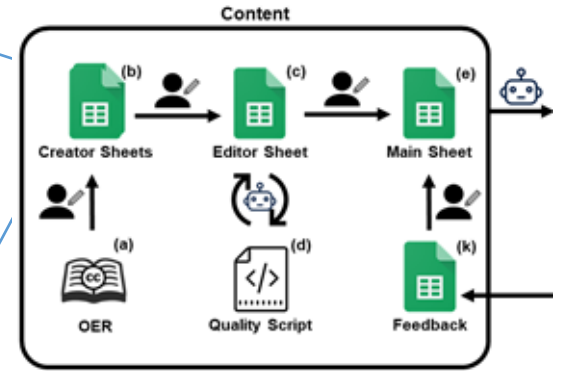
- Liability
- Warranty

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	Verbalization
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 $S=2\pi r^2+2\pi rh$.					Evaluating Algebraic Expressions	https://openstax.org/resources/Book/Book-500760ca830c731e5fa7f93a25ca	
real11	step	Find the surface area of a cylinder with radius $(@1)$ in, and height $(@2)$ in. Leave the answer in terms of π .		$2\pi(@1)^2+2\pi(@1)(@2)$	algebra					r:120345 h:6778010
real11	hint	- Substitute	Substitute $(@1)$ and $(@2)$ into the equation to obtain			h1				
real11	hint	- Parentheses	$2\pi(@1)^2+2\pi(@1)(@2)$			h2	h1			
real11	scaffold	- Parentheses	Simplify the parentheses.			h3	h2			
real11	hint	- Multiplication	What is $(@1) + (@2)$?	$(@1) + (@2)$	algebra	h3	h3			
real11	hint	- Multiplication	The next step is to simplify multiplication and division.			h4	h3			
real11	scaffold	- Multiplication	What is $2\pi(@1)^2+2\pi(@1)(@2)$?	$2\pi(@1)^2+2\pi(@1)(@2)$	algebra	h5	h4			
real11	hint	- Multiply by π	Multiply by π to obtain $2\pi(@1)^2\pi+2\pi(@1)(@2)\pi$.			h6	h5			

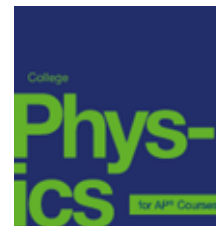


Completed:



(31 chapters, 199 lessons)

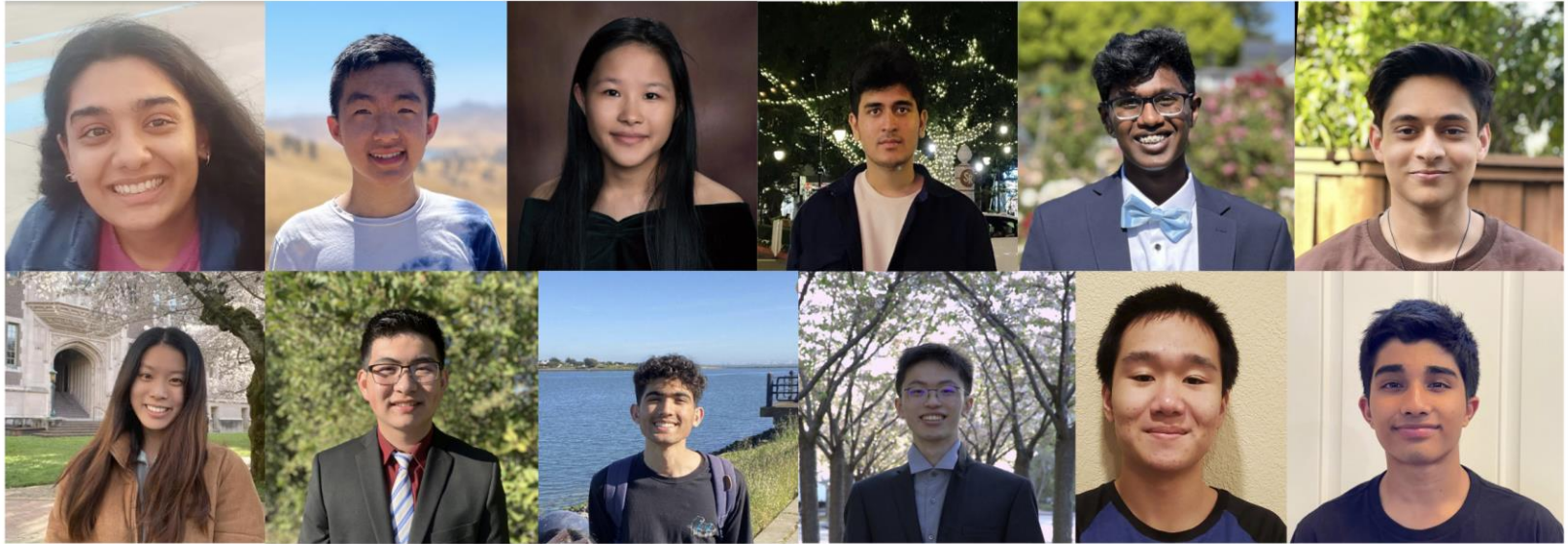
In Progress:



(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



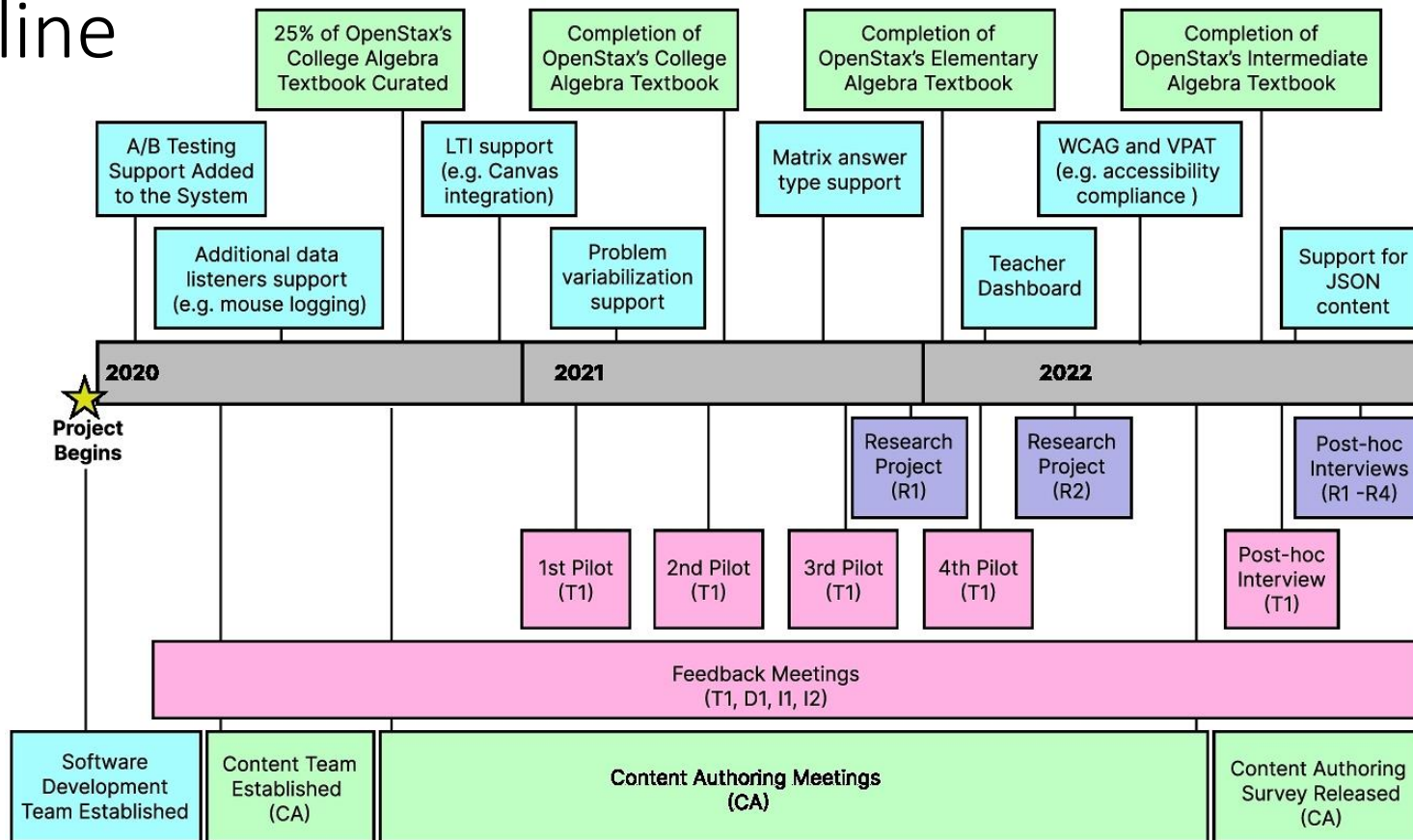
Data Collection:

- Advising meetings
- Interview

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



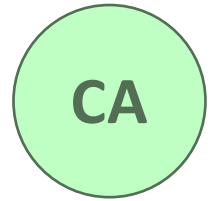
Timeline



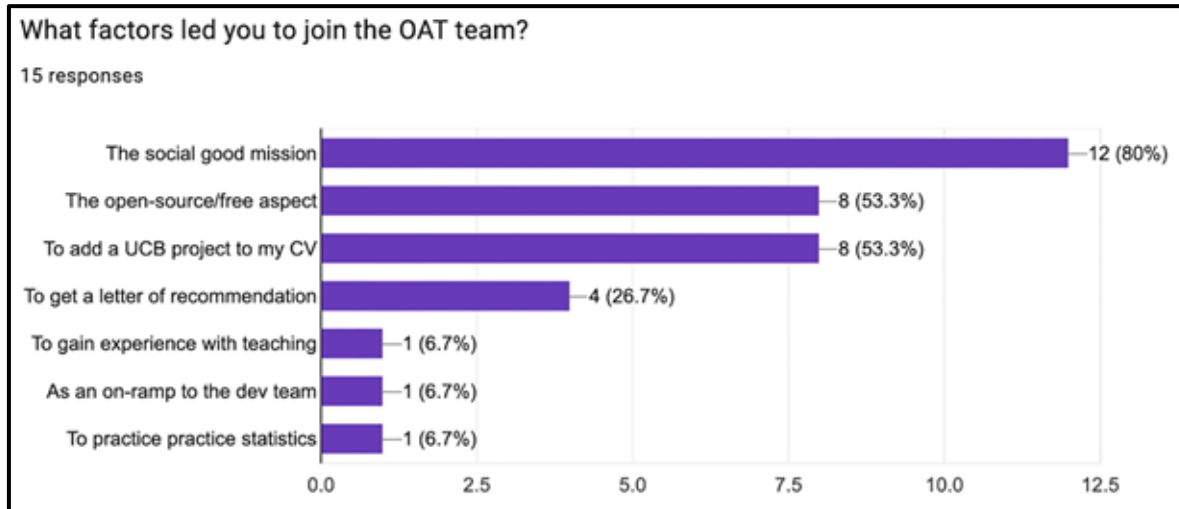
Results

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 ($SD = 9.11$)

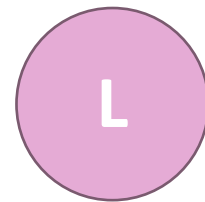


Content Authors



Learning Gain Results

- Based on 77 crowdsourced learners



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%

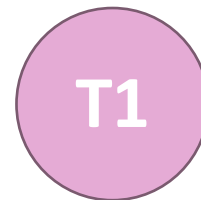
Elementary Algebra Learning Objective:

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



Teacher

Submission Details

Grade: / 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

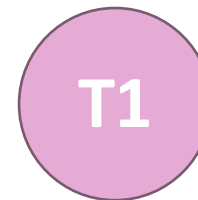
Add a Comment:

Media Comment

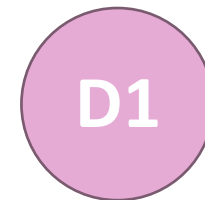
[Attach File](#)

Save

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



Teacher



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.



Workshops / Tutorials

[OATutor.io](https://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*

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: Substituting the Given Value ^

We can substitute the given value for y into the equation. This gives us $5\left(\frac{7}{5}\right) + 3 = 10\left(\frac{7}{5}\right) - 4$.

Hint 2: Calculation ^

What is $5\left(\frac{7}{5}\right) + 3$?



SUBMIT

Hint 3: Calculation v

Hint 4: Equality v

Hint 5: Answer v

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:

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

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

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

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

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

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

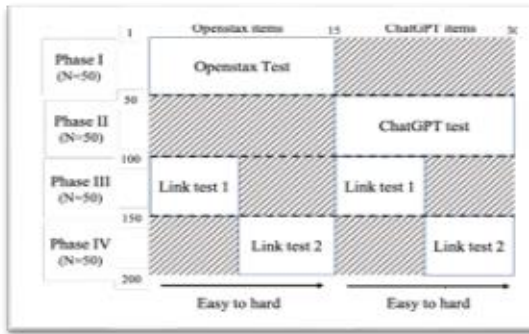
$$10 = 10$$

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

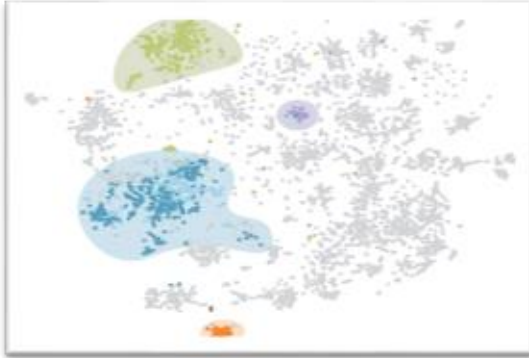
Hint 2: Answer v

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



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



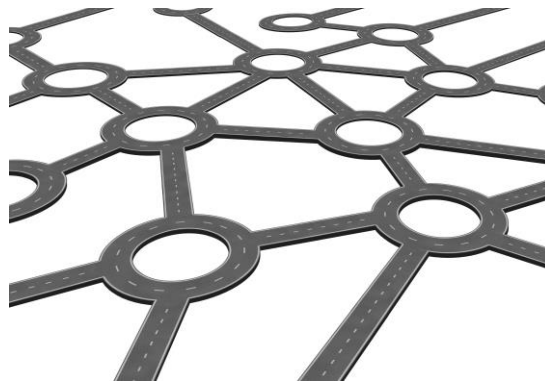
Educational pathways and AI advising
Pardos & Nam ([PONE 2020](#)),
Shao et al. ([AAAI 2021](#)),
Kizilcec et al. ([Science 2023](#))



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).



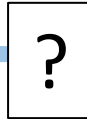
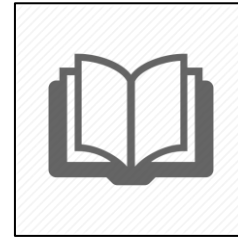
Course-to-Course Articulation

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

Courses at Institution A



Sophomore 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 ($50 * 20 * 35$)

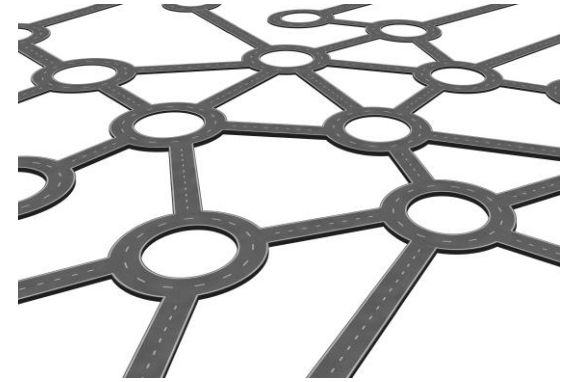
36M between all CCCs and UCs

+ the CSUs, private schools, out of state schools

+ new courses introduced every term

Comprehensive articulation cannot be established and maintained purely by hand

AI for Articulation



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



Students' course enrollment histories:

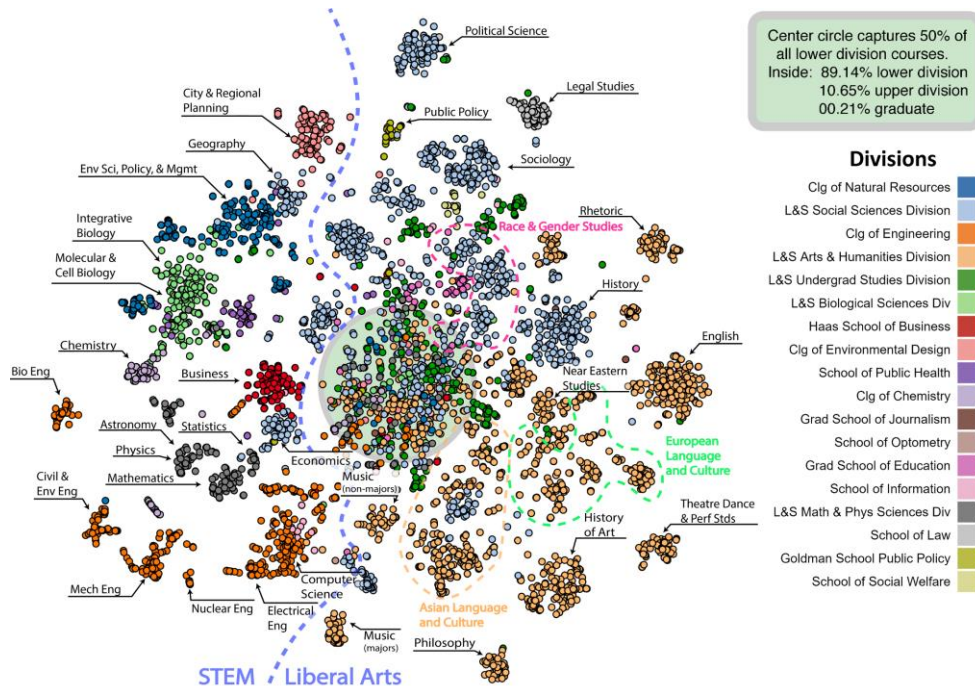
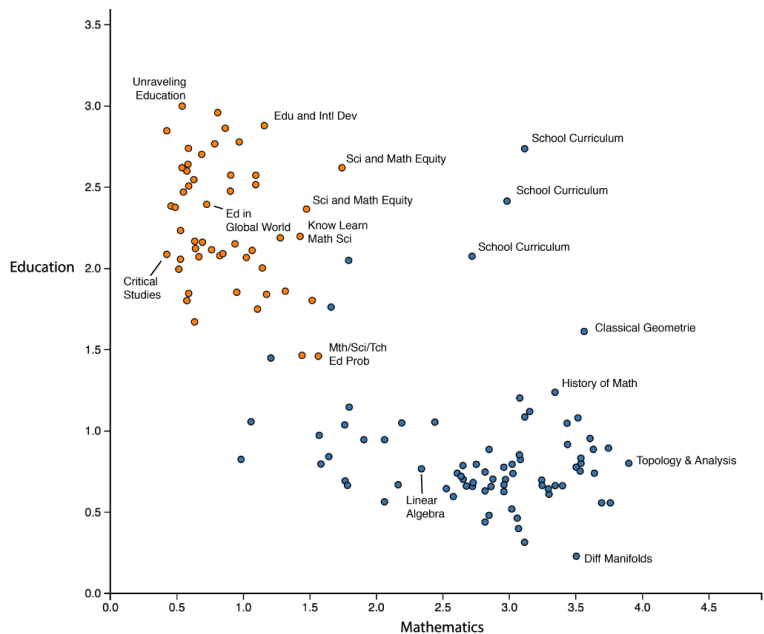
Stu1: MATH54 SPA12 STAT200B **CS61B** CUE100A DATA100 DATA144

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



Center circle captures 50% of all lower division courses.
 Inside: 89.14% lower division
 10.65% upper division
 00.21% graduate

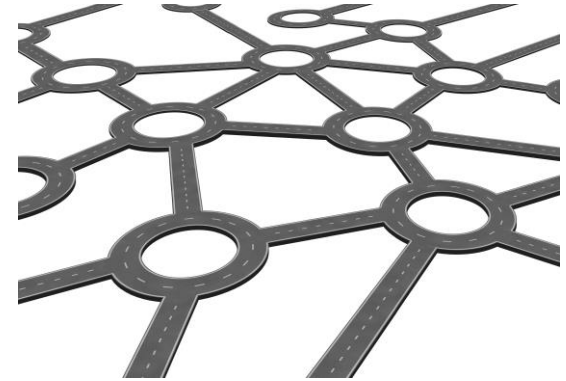
- Divisions**
- Clg of Natural Resources
 - L&S Social Sciences Division
 - Clg of Engineering
 - L&S Arts & Humanities Division
 - L&S Undergrad Studies Division
 - L&S Biological Sciences Div
 - Haas School of Business
 - Clg of Environmental Design
 - School of Public Health
 - Clg of Chemistry
 - Grad School of Journalism
 - School of Optometry
 - Grad School of Education
 - School of Information
 - L&S Math & Phys Sciences Div
 - School of Law
 - Goldman School Public Policy
 - School of Social Welfare

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

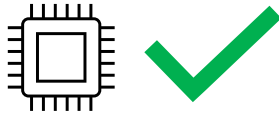
Pardos Z. A., Nam A. J. H. (2020) A university map of course knowledge. *PLoS ONE* 15(9): e0233207.

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

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 staff in adjudicating articulations (Xu, Pardos, Pai, [2023](#))
- Software workflow integration
- Still being developed through real-world deployments



Computational Approaches to
Human Learning Lab (CAHL)

Deployments (to learn to solve the policy challenges)

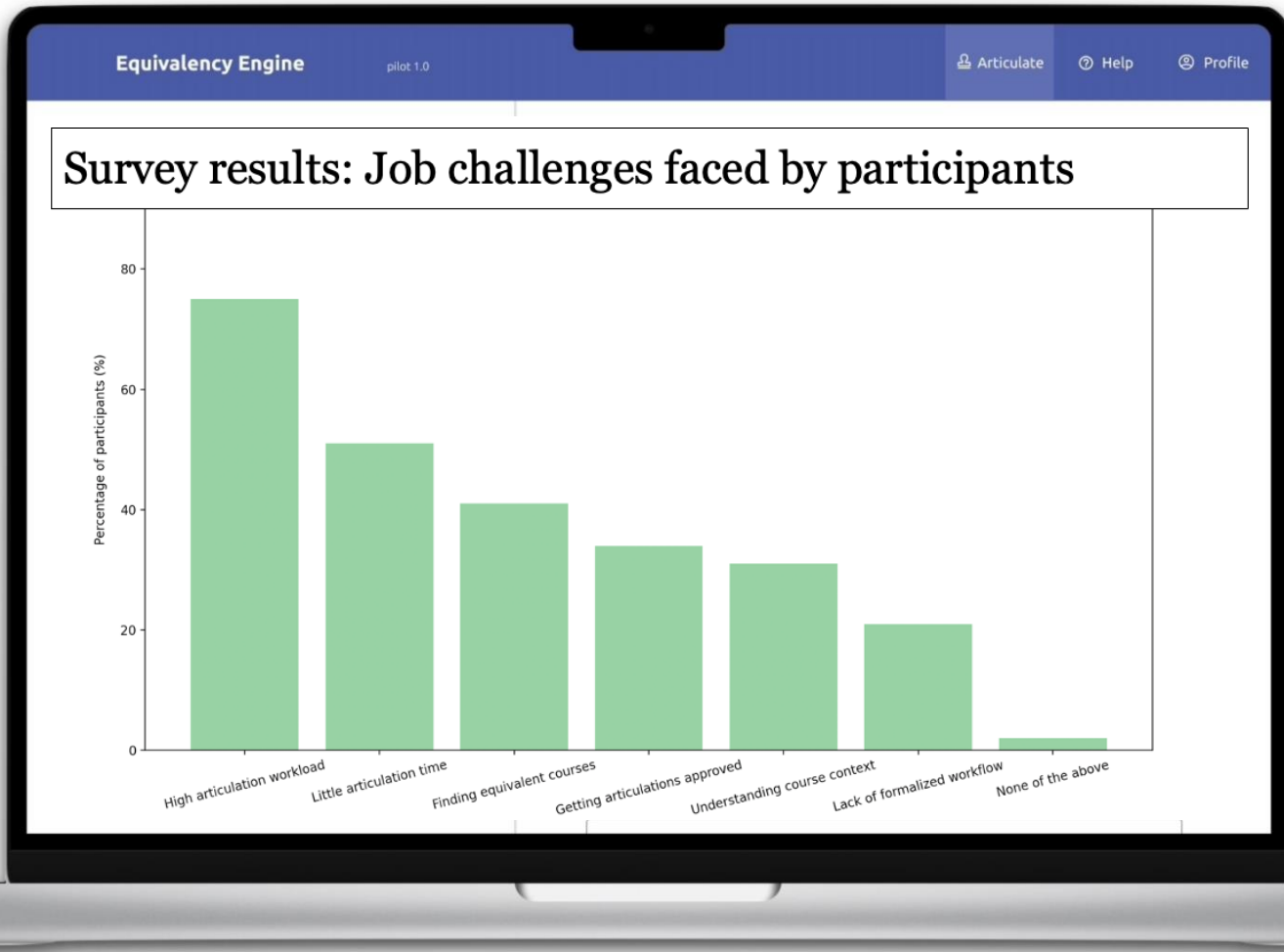
- 2018: AI articulation pilot between UCB and Laney Community College
- 2020: AI articulation pilot with City University of New York
- 2021: AI articulation + transfer pilot with State University of New York (BMGF)
- 2023: Scaled up AI articulation + transfer deployment at SUNY (BMGF/Ascendium)

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

Equivalency Engine

pilot 1.0

Articulate

Help

Profile

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

```
Requirement('Social Control Elective', 'AllLessKCourses($CRM_333, $CRM_363, $CRM_392,
CRM_464, $ORM_477, $CRM_485, $PHI_205) Z?')

Requirement('Sociology Elective', 'AllLessKUnits($SOC_230, $SOC_235, $SOC_315,
SOC_322, $SOC_335, $SOC_340, $SOC_390, $SOC_391, $SOC_392, $SOC_395, $SOC_396,
SOC_398, $SOC_370, $SOC_371, $SOC_385, $SOC_401, $SOC_430, $SOC_451, $SOC_465,
SOC_470, $SOC_475, $SOC_480, $SOC_499) Z?')
```

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](https://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

Background

- The **choice of an undergraduate major** is one of the most consequential decisions a student will make in their academic career
- UC Berkeley has nearly **150 majors/minors**
- The **viability of LLMs** for impactful tasks like **assisting with major selection** is unexplored
- Our work aims to test if LLMs can **provide helpful recommendations tailored to individual students' backgrounds and interests**:
 - **RQ1**: How closely do the AI's major recommendations, explanations, and question responses match a gold standard advisor response?
 - **RQ2**: Does incorporating the student's demographic information affect the AI's performance?
 - **RQ3**: Does showing the AI's response influence an advisor's subsequent major recommendation?

Prompting Strategy

System role statement:
You are an excellent major advisor at <university name>. The following are the majors, along with their descriptions, that you can recommend to students: ...

Prompt for major recommendation and reasoning*:
<At least one/Neither> of the student's parents worked in STEM jobs. The student's favorite courses include: ... The student's least favorite courses include: ... The student's personal and academic interests include: ... Potential career paths the student is considering include: ... Based on the student details above, recommend one major. Provide detailed reasoning for why the major is the best fit for the student.

* Developed based on our manual evaluation on 3 samples

Experimental Design

Survey Phase 1

Survey Phase 2

Survey Phase 3

- **Surveyed undeclared first and second-year undergraduate students** at the university (n=18) eliciting student details helpful to advisors.
- Student survey responses were used to **generate personalized AI recommendations for majors and answers to student questions** using GPT-4 (June 13th, 2023 version 0613).
- Students' responses and AI recommendations were provided to **university advisors (n=18) in 2x1 between-subjects design**. Group A saw the AI responses after providing their recommendation, while Group B saw the AI response beforehand.

- We gathered **expert advisor evaluations (Eval 1)** on the effectiveness of the GPT-4-0613 responses.
- We perform offline evaluations of the success of model outputs relative to the advisors based on:
 - **(Eval 2) the accuracy of the recommended major.**
 - **(Eval 3) the semantic similarity of the answers to student questions.**
 - **(Eval 4) the semantic similarity of the recommendation reasoning** in cases where AI and advisor recommendations match.

Preliminary Results

- **RQ1: Advisors favorably viewed the AI's major recommendations, explanations, and question responses.**
 - Mean rating major rec.: 3.9
 - Mean rating QA: 4.1
- **RQ2: marginal differences in agreement** in demographic-aware and blind models (0.33 and 0.39)
 - However, **half of the students were classified differently** between the two scenarios
- **RQ3: Substantially more agreement in the AI-1st condition** (0.56) than the AI-2nd condition (0.22) – not stat sig.

Model	Agreement Cond. A (AI-2nd)	Agreement Cond. B (AI-1st)	Agreement Overall	Major Rec. Reasoning Similarity	Question Response Similarity
GPT-4 demographic-blind	0.22	0.56	0.39	0.68	0.53
GPT-4 demographic-aware	0.33	0.33	0.33	0.67	0.53
GPT-3.5 demographic-blind matching 8k context	0.11	0.22	0.17	0.77	0.54
GPT-3.5 demographic-blind	0.22	0.33	0.28	0.69	0.52
GPT-3.5 demographic-aware	0.33	0.33	0.33	0.67	0.51

Table 1: Model performance. Agreement is the percentage of instances where the model's recommendation matched the advisor's. Similarity is the average cosine similarity between explanations.

Condition A Major Recommendations (AI-2nd)		Condition B Major Recommendations (AI-1st)	
Advisor Rec.	GPT-4 Rec.	Advisor Rec.	GPT-4 Rec.
Interdisciplinary Studies	Cognitive Science	Comp. Sci.	Comp. Sci.
Applied Mathematics	Comp. Sci.	Astrophysics	Astrophysics
Cognitive Science	Comp. Sci.	Data Science	Data Science
Mathematics	Applied Mathematics	EECS and Business Admin.	Comp. Sci.
Data Science	Cognitive Science	Environ. Econ. Policy	Environ. Econ. Policy
Interdisciplinary Studies	English	Legal Studies	Legal Studies
Comp. Sci.	Comp. Sci.	Eng. Math Statistics	Aerospace Eng.
Molecular Cell Biology	BioEng	Integrative Biology	BioEng
Data Science	Data Science	Industrial Eng. and Ops.	Comp. Sci.

Lekan, K., Pardos, Z.A. (2023). **AI-Augmented Advising: A Comparative Study of ChatGPT-4 and Advisor-based Major Recommendations.** Presented at the Generative AI for Education Workshop (GAIED) at the Thirty-seventh Conference on Neural Information Processing Systems (NeurIPS). New Orleans, LA.

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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