

Human-AI Interaction for Personalized Online Learning

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April 10, 2024



TEXAS A&M UNIVERSITY

Department of Computer
Science & Engineering

Online Learning has become widespread



A Coding Exercises Platform



A MOOCs platform
(massive open online courses)



A videotelephony software



An online discussion forum



Virtual teacher
(Chatbot)

Learning at scale, flexible locations and times

Scale



Machine Learning Specialization
#BreakIntoAI with Machine Learning Specialization. Master fundamental AI concepts and develop practical machine learning skills in the beginner-friendly, 3-course program by AI visionary Andrew Ng
★★★★★ 4.9 7,331 ratings
Andrew Ng +3 more instructors **TOP INSTRUCTORS**
120,420 already enrolled

Space



Time

CLASS TIMETABLE

	9.00-9.30	9.30-10.30	11.00-1.00	1.30-2.30
MON	SPORT	MATHS	LITERATURE	ART
TUE	SPORT	LITERATURE	ENGLISH	HISTORY
WED	SPORT	SCIENCE	COMPUTING	MUSIC
THU	SPORT	ENGLISH	HISTORY	ART
FRI	SPORT	SCIENCE	COMPUTING	GEOGRAPHY



Learning at scale, flexible locations and times

Scale



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				GEOGRAPHY

Make learning tailored to individual students a grand challenge!

Machine Learning

#BreakIntoAI with Machine Learning and develop practical machine learning program by AI visionary Andrew Ng

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120,420 already enrolled



Why personalized learning?



Non-cognitive

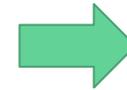
motivation
(D'Mello, Lehman, Pekrun, & Graesser, 2014)

self-regulation
skills
(Alevan & Koedinger, 2002)

Cognitive

knowledge
(Koedinger, Stamer, McLaughlin, & Nixon, 2013;)

problem-solving
strategies, errors
(Adams et al., 2014)



Learning at scale, flexible locations and times

Scale



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How could we achieve personalized online learning?

Machine Learning

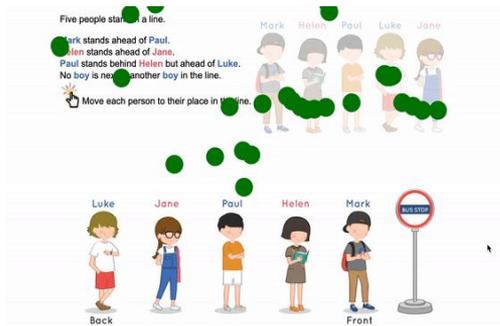
#BreakIntoAI with Machine Learning
and develop practical machine learning
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120,420 already enrolled



Learning Data is a Communication Channel



e.g. Mouse movement data



Online Learning Platforms and Data



coursera



#	Title
✓ 1249	Minimum Remove to Make Valid Parentheses
✓ 1762	Buildings With an Ocean View
✓ 1570	Dot Product of Two Sparse Vectors
✓ 1650	Lowest Common Ancestor of a Binary Tree III
✓ 426	Convert Binary Search Tree to Sorted Doubly Linked List

Problem-solving data



Click-stream data



Video and audio communication data



Online discussion data

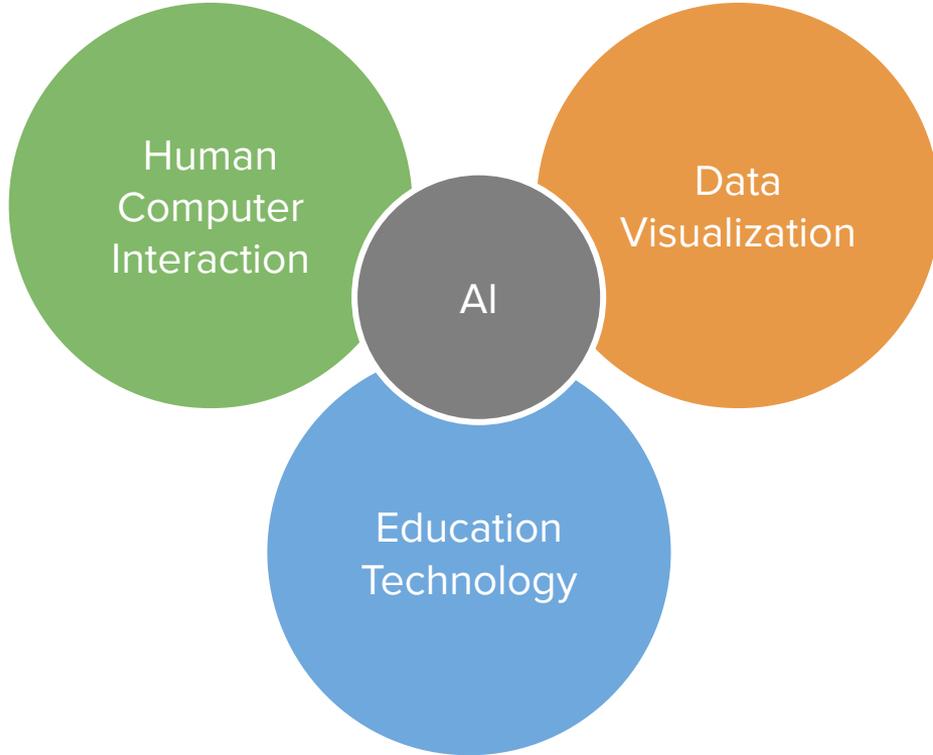
Research Goal

*Help **learners and educators** to **find insights** from learning data and use the insights to **make decisions** for achieving **personalized online learning**.*

Related Work on Learning Analytics

- Focus more on cognitive skills instead of non-cognitive variables (e.g., motivations, self-regulation skills)
Learning factor analysis (Cen et al., 2006) Performance factor analysis (Pavlik et al., 2009)
- Algorithms' outputs are not easy to interpret
Deep knowledge tracing (Piech et al., 2015) Explanatory models for educational data (Liu et al., 2017)

My Approach



*Design and build
human-centered
data-driven systems for
achieving **personalized**
online learning.*

Why *human-centered* data-driven systems?

Learners' needs

Educators' domain knowledge



data-driven interfaces
(e.g., data visualization)

Challenges

- **Learners have different aspects** that change over time
- **Learners and educators are not data analysts**
- Different learning scenarios:
 - Learning data is **voluminous and heterogeneous**
 - Learners and educators have **different tasks**



Learners (learning loop)

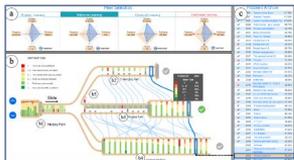
Planning

Performing
Data

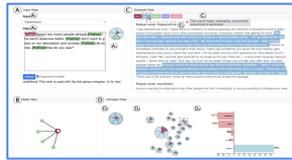
Reflecting

Understanding
and Analyzing

Redesigning



Peerlens (CHI 2019)



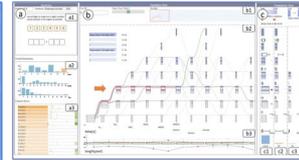
Persua (CSCW 2022)



RLens (L@S 2022)



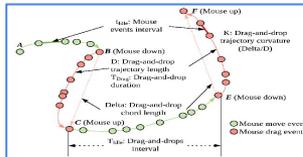
StuGPTVis (TVCG 2024)



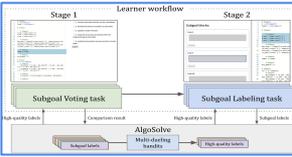
QLens (TVCG 2021)



SolutionVis (AIED 2023)



Predication (LAK 2020)



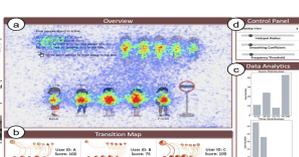
AlgoSolve (CHI 2022)



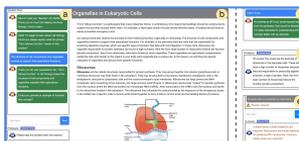
"Gaming the system" (L@S 2020)



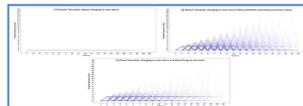
Mobile MOOCs (CHI 2022, **Best Paper Award**)



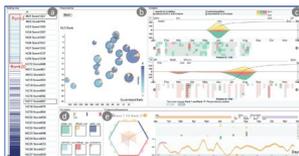
Visual Analytics K-12 (VIS 2019, **Best Poster Award**)



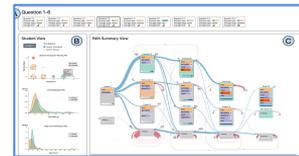
Ruffle&Riley (AIED 2024)



Distributed Tutorship (LAK 2022)



SeqDynamics (EuroVIS 2020)



BlockLens (L@S 2022)



Learners (learning loop)

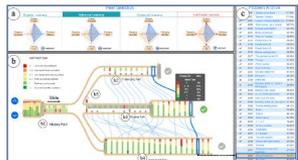
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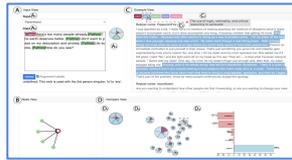
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Understanding
and Analyzing

Redesigning



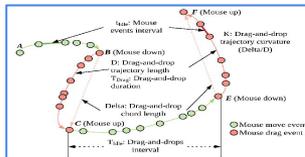
Peerlens (CHI 2019)



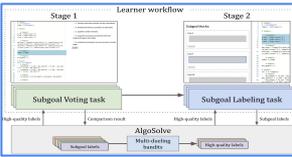
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RLens (L@S 2022)



Predication (LAK 2020)



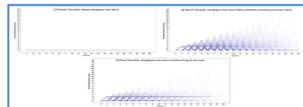
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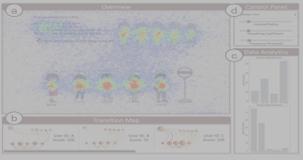
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Visual Analytics K-12 (VIS 2019, **Best Poster Award**)



SeqDynamics (EuroVIS 2020)



BlockLens (L@S 2022)



Educators (design loop)



Learners (learning loop)

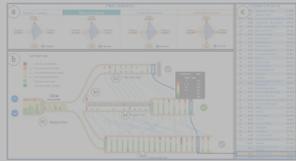
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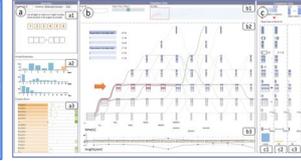
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StuGPTVis StuGPTVis (TVCG 2024)



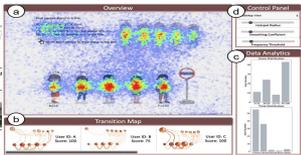
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SolutionVis (AIED 2023)



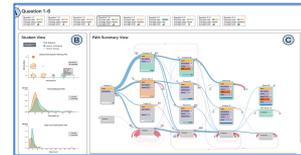
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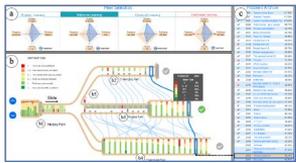
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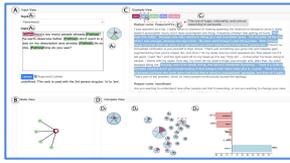
SeqDynamics (EuroVIS 2020)



BlockLens (L@S 2022)

Planning
**Performing
Data**
Reflecting
**Understanding
and Analyzing**
Redesigning


Peerlens (CHI 2019)



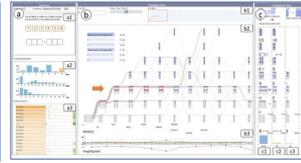
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RLens (L@S 2022)



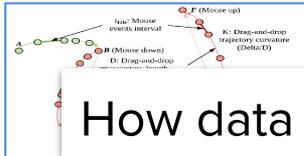
StuGPTVis (VIS 2024, under review)



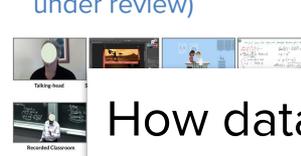
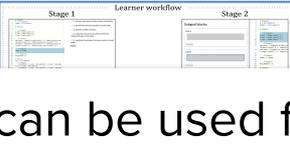
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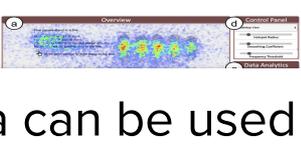
SolutionVis (AIED 2023)



Pre



Mobile 2022,



SeqDynamics (EuroVIS 2020)



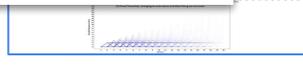
BlockLens (L@S 2022)

How data can be used for learners to plan, perform, and reflect on their learning?

How data can be used for educators to improve the design of learning materials?



Ruffle&Riley (AIED 2024)



Distributed Tutorship (LAK 2022)

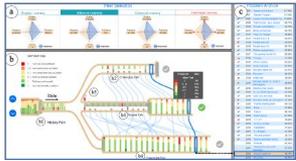
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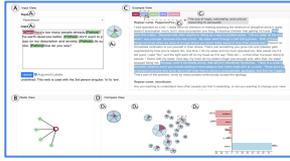
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Understanding
and Analyzing

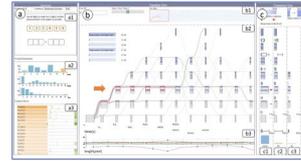
Redesigning



Peerlens (CHI 2019)



Persua (CSCW 2022)



QLens (TVCG 2021)



StuGPTVis (TVCG 2024)

How data can be used for learners to plan, perform, and reflect on their learning?

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 Learners (learning loop)

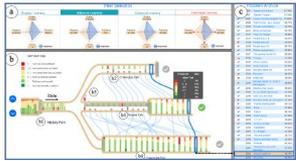
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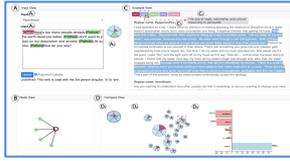
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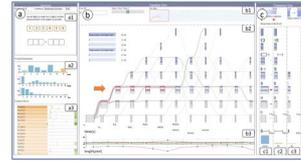
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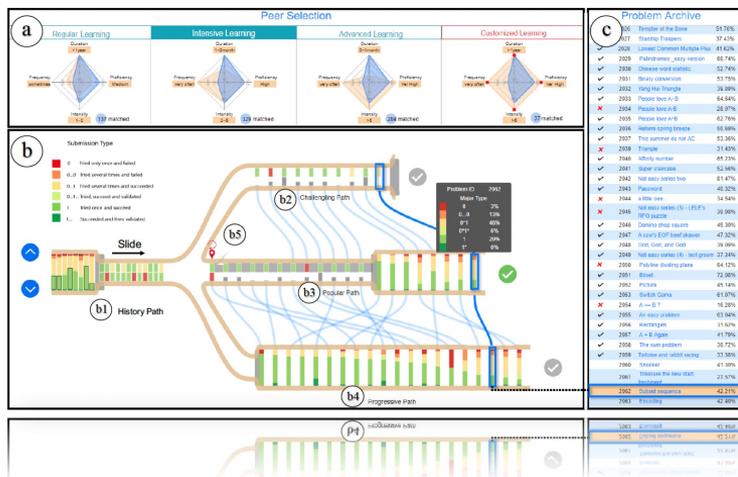


QLens (TVCG 2021)



StuGPTVis (TVCG 2024)

How data can be used for learners to **plan**, perform, and reflect on their learning?



PeerLens: Peer-inspired Interactive Learning Path Planning in Online Question Pool

Meng Xia, Mingfei Sun, Huan Wei, Qing Chen, Yong Wang, Lei Shi, Huamin Qu, Xiaojuan Ma

CHI 2019

What is an online question pool?

- A collection of questions for learners to practice their knowledge online



Math



Programming



Driving license

Motivation

Pro. ID	
1000	A + B Problem
1001	Sum Problem
1002	A + B Problem II
1003	Max Sum
1004	Let the Balloon Rise
1005	Number Sequence
1006	Tick and Tick
1007	Quoit Design
1008	Elevator
1009	FatMouse' Trade
1010	Tempter of the Bone
1011	Starship Troopers

Questions Pools:

- No pre-determined syllabus
- A lengthy list indexed by their problem IDs
- Hidden intents

Learners:

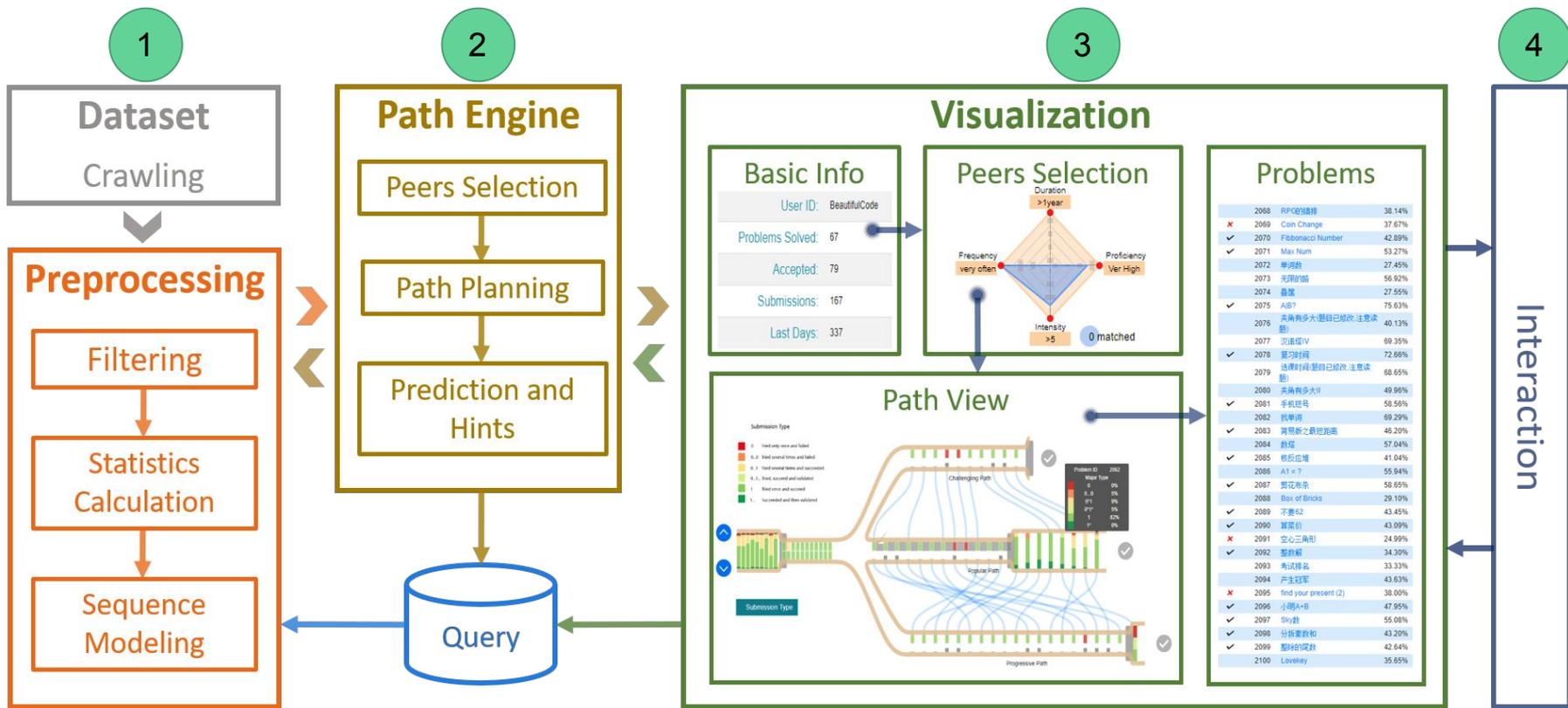
- Different learning scenarios
- One learner's learning scenario may be changing

What to do next? What sequence to follow?

A user-centered design process

- Participants: question pool designers and question pool users
- Requirements gathering iteratively for three months
 - R1: **Find peers** for a target learning scenario.
 - R2: **Compare with peers'** performance to understand the gap.
 - R3: Offer flexible learning **path suggestions with explanations.**
 - R4: Provide **convenient interaction and intuitive visual designs.**

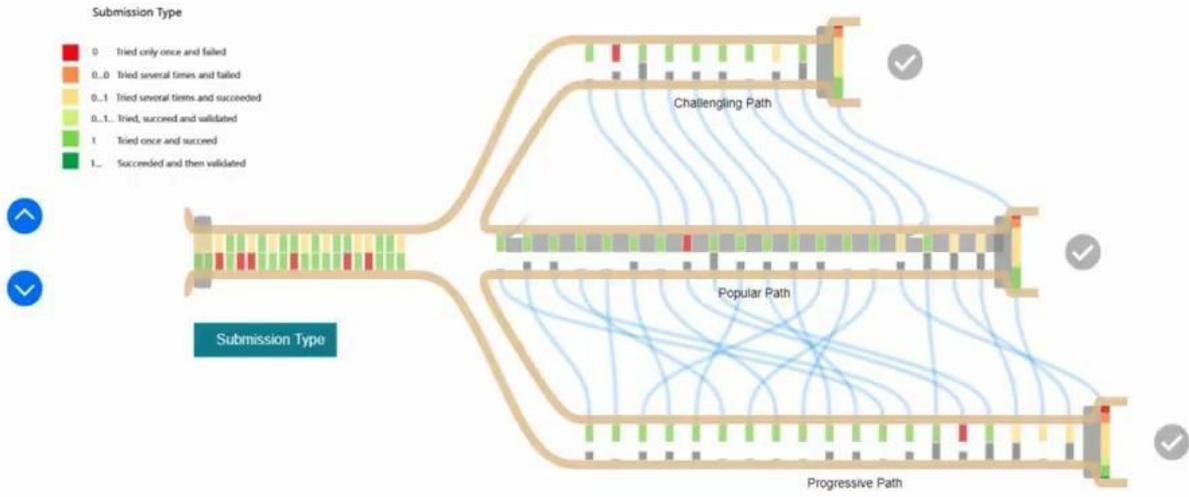
PeerLens System overflow





Problem Archive

✓	2010	水仙花数	27.56%
✓	2011	多项式求和	56.00%
✓	2012	素数判定	36.20%
✓	2013	螺旋记	74.46%
✗	2014	青年歌手大奖赛_评委打分	46.51%
✓	2015	斐波那契	39.52%
✗	2016	数据的交换输出	36.36%
✓	2017	字符串统计	55.48%
✓	2018	奶牛的故事	48.10%
✓	2019	排列计数I	40.76%
✗	2020	绝对值排序	45.44%
✓	2021	发工资啦()	50.96%
✓	2022	海选女主角	41.82%
✗	2023	字符串构造	21.66%
✓	2024	C语言合走样识别	36.85%
✓	2025	查找最大元素	51.91%
✗	2026	数字字母大写	51.76%
✓	2027	统计元素	37.43%
✓	2028	Lowest Common Multiple Plus	41.62%
✓	2029	Palindromes _easy version	60.74%
✗	2030	汉字统计	52.74%
✓	2031	进制转换	53.75%
✓	2032	杨辉三角	39.89%
✓	2033	人见人爱A+B	64.64%
✗	2034	人见人爱A-B	28.07%
✓	2035	人见人爱A*B	62.76%
✓	2036	改革春风吹满地	50.69%
✗	2037	今年暑假不AC	53.36%
✓	2039	三角形	31.43%
✓	2040	亲和数	65.23%
✗	2041	超级楼梯	52.56%
✓	2042	不容易系列之二	81.47%
✓	2043	密码	40.32%
✓	2044	一只小蜜蜂	34.54%
✗	2045	不容易系列之(3)——LELE的RPG难题	39.98%



Evaluation

RQ1: Is peer data useful?

RQ2: Is visualizing more suggestions helpful for planning compared to only one path?

RQ3: Does visualizing more suggestions using the proposed visualizations increase complexity?

Evaluation: Controlled User Study

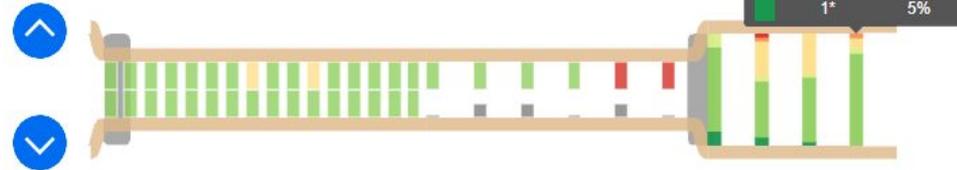
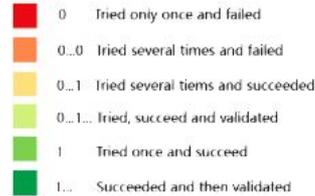
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15...33 34 35 36 37 38
39 40 41 42 43 44 45 46 47 48 49 50

Search: In

Pro. ID	Problem Title	Ratio(Accepted/Submissions)
1000	A + B Problem	30.56%(240770/787844)
1001	Sum Problem	25.38%(143110/563922)
1002	A + B Problem II	19.47%(84152/432201)
1003	Max Sum	23.76%(70413/296345)
1004	Let the Balloon Rise	39.72%(59043/148661)
1005	Number Sequence	25.25%(51499/203970)
1006	Tick and Tick	26.73%(6080/22750)
1007	Quoit Design	26.52%(17197/64856)
1008	Elevator	54.79%(46878/85565)
1009	FatMouse' Trade	34.85%(33070/94883)
1010	Tempter of the Bone	26.68%(39786/149139)

Baseline system (List View)

Submission Type



Primitive PeerLens (Only provide one path)

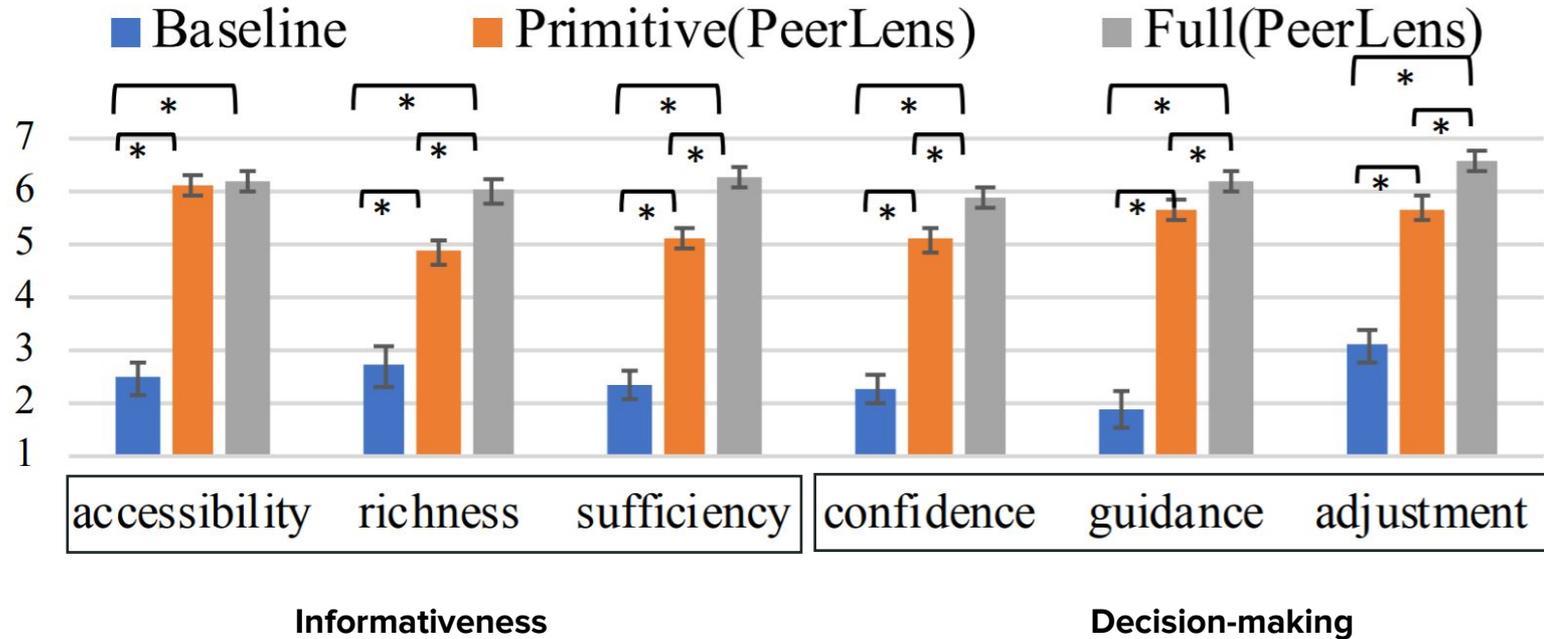
18 CS students :

- determine the starting question under a specific learning scenario
- find the next question to solve given an existing historical learning path

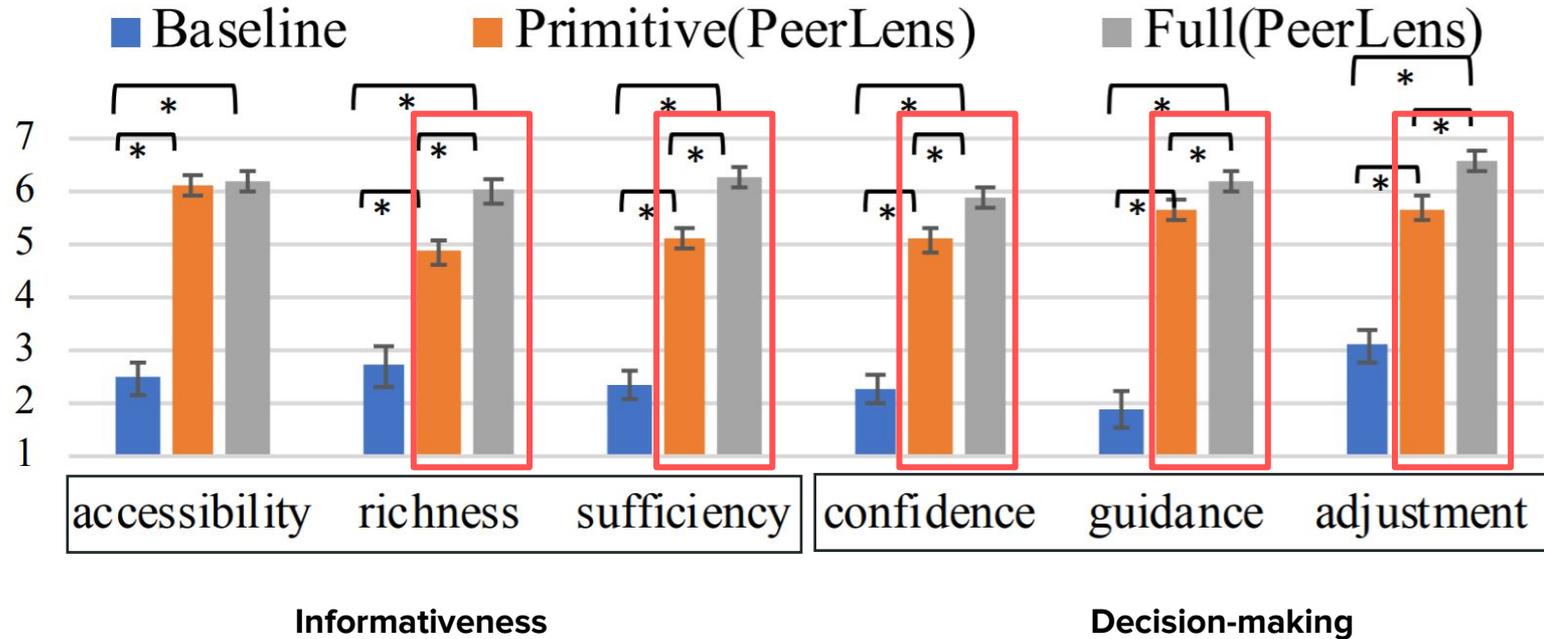
Evaluation: Questionnaires

Informativeness	Q1	The information needed to plan a learning path is easy to access.
	Q2	The information needed to plan a learning path is rich.
	Q3	The information is sufficient to plan a learning path.
Decision making	Q4	The system was helpful for me to find a proper learning path for a specific learning scenario.
	Q5	I am confident that I find a suitable learning path for the learning scenario.
	Q6	The system helps make adjustment according to previous performance.
Visual design	Q7	The learning path design is intuitive.
	Q8	The learning path design helps me understand the suggested path.
System Usability	Q9	It was easy to learn the system.
	Q10	It was easy to use the system.
	Q11	I would like to recommend this system to others.

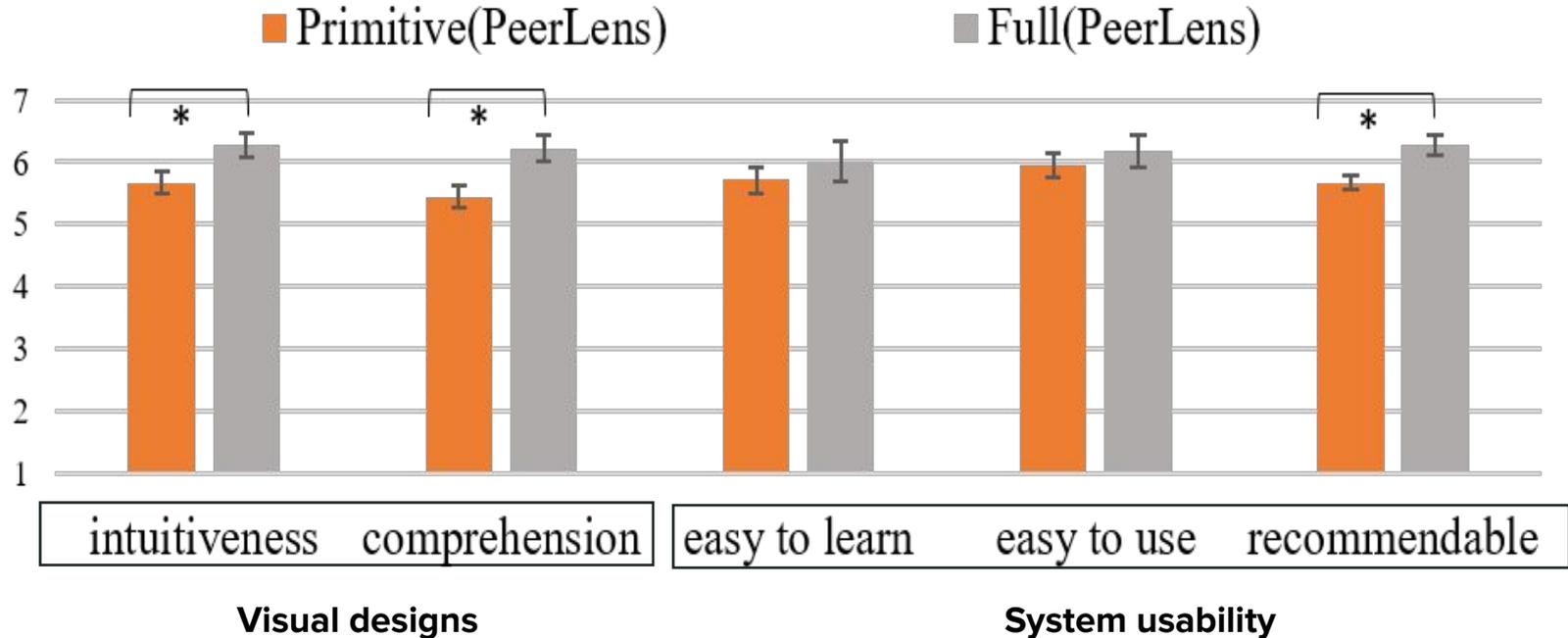
Results: Using peer data is useful (RQ1)



Results: Visualizing more suggestions is useful (RQ2)



Results: Visualizing more suggestions using the proposed visualizations did not increase the complexity (RQ3)



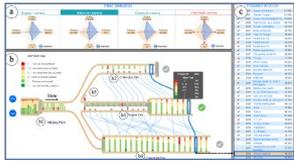
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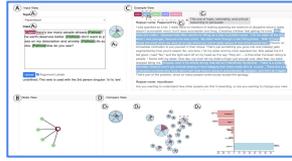
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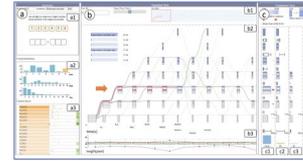
Redesigning



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Persua (CSCW 2022)



QLens (TVCG 2021)



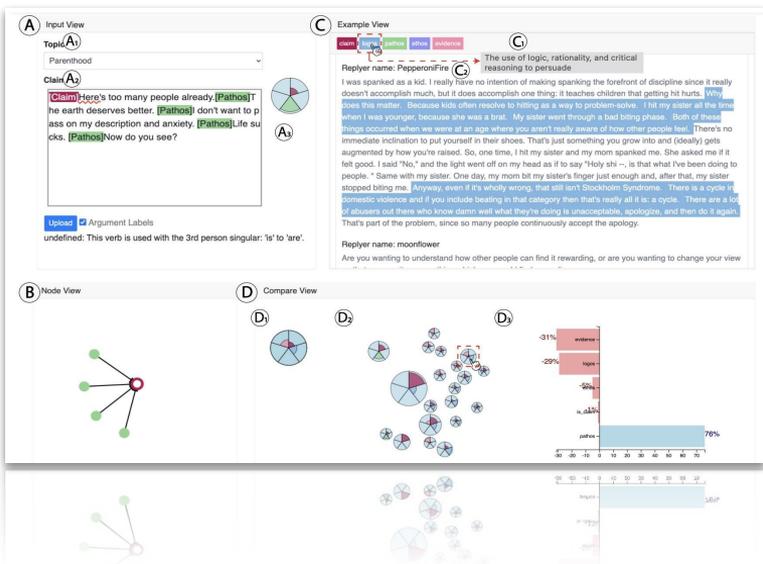
StuGPTVis (TVCG 2024)

How data can be used for learners to plan, **perform**, and reflect on their learning?

Persua: A Visual Interactive System to Enhance the Persuasiveness of Arguments in Online Discussion

Meng Xia, Qian Zhu, Xingbo Wang, Fei Nie, Huamin Qu, Xiaojuan Ma

CSCW 2022



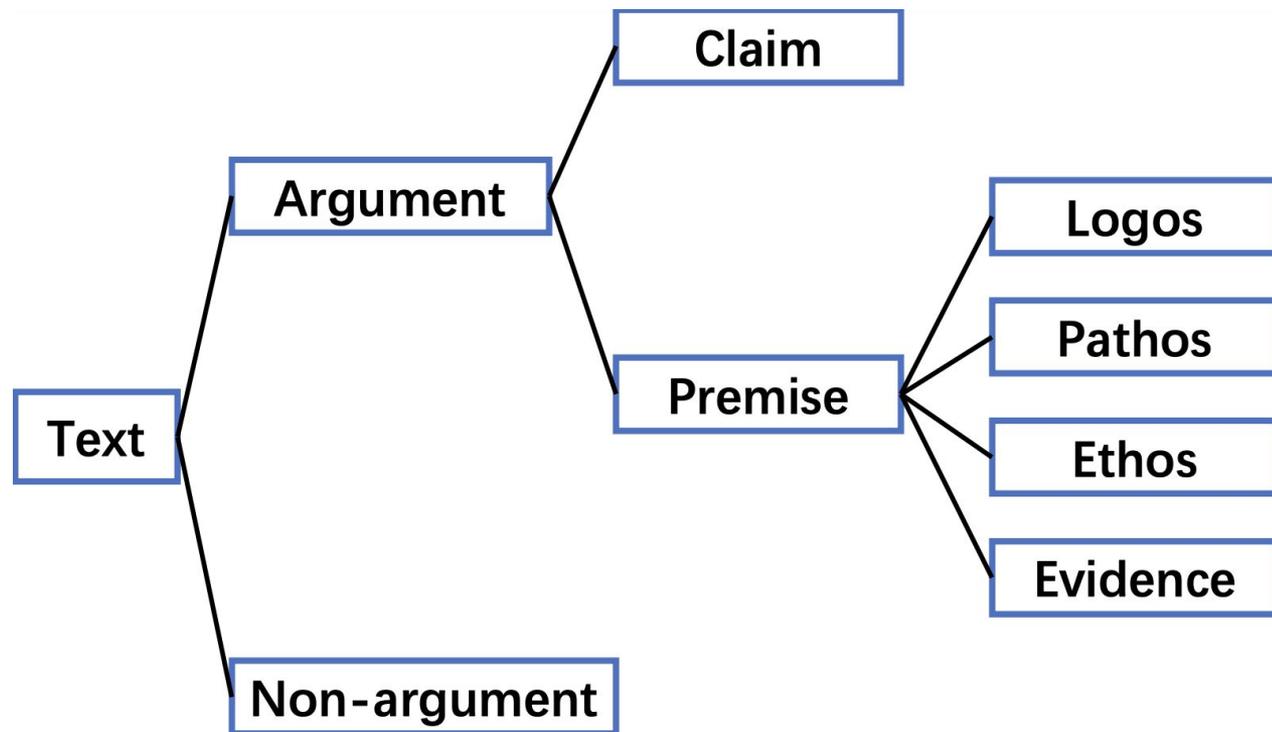
Background

- **Real-time adaptive feedback**
- **Critical thinking skills, e.g., arguments writing**, a major element of learning framework 2030 by the Organization for Economic Co-operation and Development (OECD)

Taxonomy of Argument Components



Semi-structured interviews with **five domain experts** on debating competitions



Classical persuasive strategies of Aristotle, and Rapp, 2002 and Carlile et al., 2018

Rapp, Christof. "Aristotle's rhetoric." (2002).

Carlile, Winston, et al. "Give me more feedback: Annotating argument persuasiveness and related attributes in student essays." *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*. 2018.

Persua

A Input View

Topic **A₁**
 Parenthood

Claim **A₂**
 [Claim] Here's too many people already. [Pathos] The earth deserves better. [Pathos] I don't want to pass on my depression and anxiety. [Pathos] Life sucks. [Pathos] Now do you see?

Upload Argument Labels
 undefined: This verb is used with the 3rd person singular: 'is' to 'are'.

A₃

C Example View

claim | logos | pathos | ethos | evidence

Replier name: **PepperoniFire** **C₂** → The use of logic, rationality, and critical reasoning to persuade

I was spanked as a kid. I really have no intention of making spanking the forefront of discipline since it really doesn't accomplish much, but it does accomplish one thing: it teaches children that getting hit hurts. Why does this matter. Because kids often resolve to hitting as a way to problem-solve. I hit my sister all the time when I was younger, because she was a brat. My sister went through a bad biting phase. Both of these things occurred when we were at an age where you aren't really aware of how other people feel. There's no immediate inclination to put yourself in their shoes. That's just something you grow into and (ideally) gets augmented by how you're raised. So, one time, I hit my sister and my mom spanked me. She asked me if it felt good. I said "No," and the light went off on my head as if to say "Holy shi --, is that what I've been doing to people." Same with my sister. One day, my mom bit my sister's finger just enough and, after that, my sister stopped biting me. Anyway, even if it's wholly wrong, that still isn't Stockholm Syndrome. There is a cycle in domestic violence and if you include beating in that category then that's really all it is: a cycle. There are a lot of abusers out there who know damn well what they're doing is unacceptable, apologize, and then do it again. That's part of the problem, since so many people continuously accept the apology.

Replier name: moonflower
 Are you wanting to understand how other people can find it rewarding, or are you wanting to change your view

B Node View

D Compare View

D₁

D₂

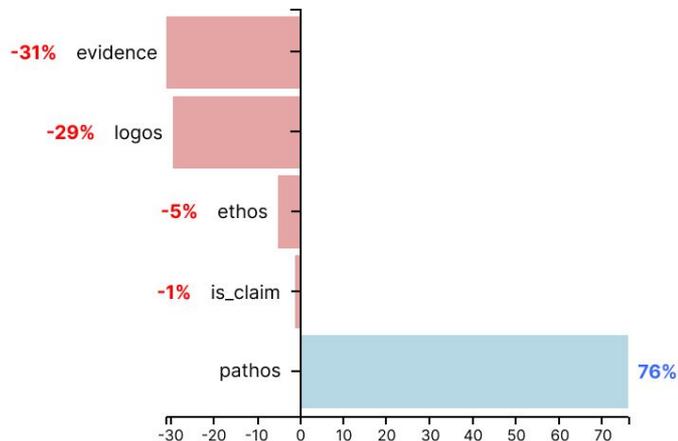
D₃

Label	Percentage
pathos	76%
evidence	-31%
logos	-29%
ethos	-5%
is_claim	-1%
claim	1%

Case Study

Before:

[Claim] Here's too many people already. [Pathos] The earth deserves better. [Pathos] I don't want to pass on my depression and anxiety. [Pathos] Life sucks. [Pathos] Now do you see?



C Example View

claim logos pathos ethos evidence **C₁**

Replier name: PepperoniFire **C₂** The use of logic, rationality, and critical reasoning to persuade

I was spanked as a kid. I really have no intention of making spanking the forefront of discipline since it really doesn't accomplish much, but it does accomplish one thing: it teaches children that getting hit hurts. Why does this matter. Because kids often resolve to hitting as a way to problem-solve. I hit my sister all the time when I was younger, because she was a brat. My sister went through a bad biting phase. Both of these things occurred when we were at an age where you aren't really aware of how other people feel. There's no immediate inclination to put yourself in their shoes. That's just something you grow into and (ideally) gets augmented by how you're raised. So, one time, I hit my sister and my mom spanked me. She asked me if it felt good. I said "No," and the light went off on my head as if to say "Holy shi --, is that what I've been doing to people." Same with my sister. One day, my mom bit my sister's finger just enough and, after that, my sister stopped biting me. Anyway, even if it's wholly wrong, that still isn't Stockholm Syndrome. There is a cycle in domestic violence and if you include beating in that category then that's really all it is: a cycle. There are a lot of abusers out there who know damn well what they're doing is unacceptable, apologize, and then do it again. That's part of the problem, since so many people continuously accept the apology.

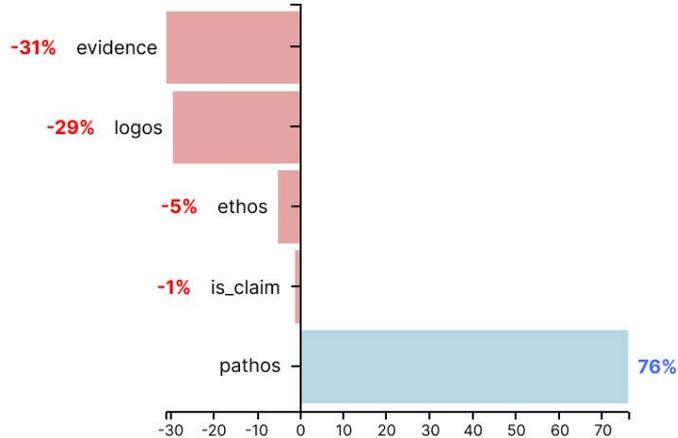
Replier name: moonflower

Are you wanting to understand how other people can find it rewarding, or are you wanting to change your view

Case Study

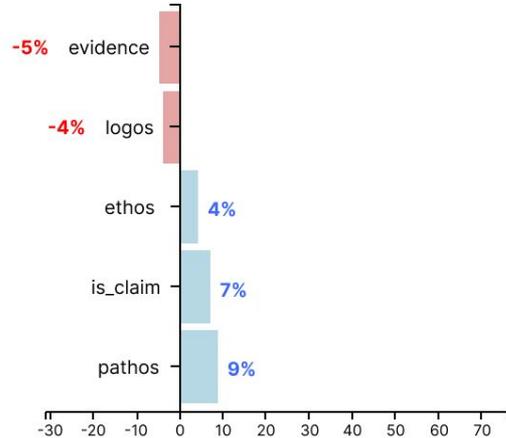
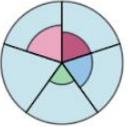
Before:

[Claim] Here's too many people already. [Pathos] The earth deserves better. [Pathos] I don't want to pass on my depression and anxiety. [Pathos] Life sucks. [Pathos] Now do you see?



After:

[Claim] There is no need to have children. [Logos][Evidence] The world population is dramatically increasing, leading to more consumption of the natural resources. [Pathos][Evidence] In addition, I saw my uncle's children fight with each other. [Logos][Evidence] Some people even abuse children. [Claim] Thus, I disagree with having children.



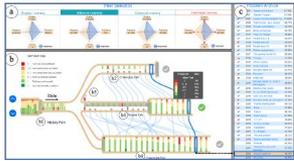
Planning

**Performing
Data**

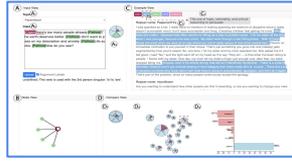
Reflecting

**Understanding
and Analyzing**

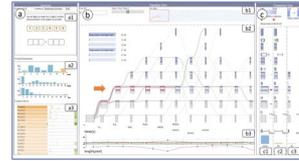
Redesigning



Peerlens (CHI 2019)



Persua (CSCW 2022)

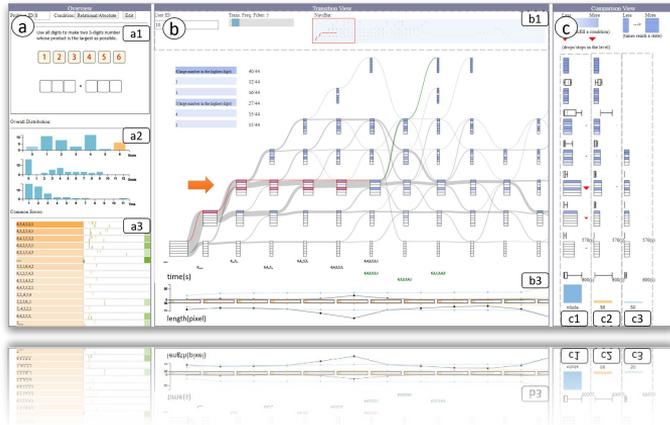


QLens (TVCG 2021)



StuGPTVis (TVCG 2024)

How data can be used for educators to improve the design of learning materials?



QLens: Visual Analytics of Multi-step Problem-solving Behaviors for Improving Question Design

Meng Xia, Reshika Palaniyappan Velumani, Yong Wang, Huamin Qu,
Xiaojuan Ma

TVCG 2021

A Multi-step Problem

Five people stand in a line.

Mark stands ahead of Paul.
Helen stands ahead of Jane.
Paul stands behind Helen but ahead of Luke.
No boy is next to another boy in the line.

 Move each person to their place in the line.

Mark Helen Paul Luke Jane



Back Front



Mark stands ahead of Paul.

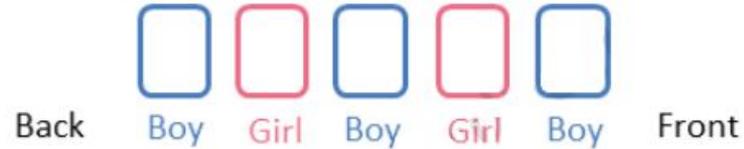
Helen stands ahead of Jane.

Paul stands behind Helen but ahead of Luke.

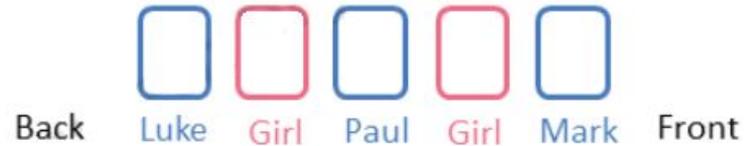
No boy is next to another boy in the line.

Consider the condition with the most restrictions: "No boy is next to another boy in the line."

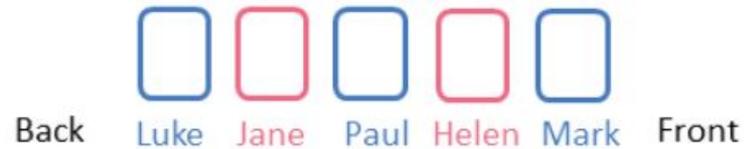
There are only 3 boys and 2 girls, so we have



"Mark stands ahead of Paul", "Paul stands ahead of Luke". Therefore,



"Helen stands ahead of Jane". Therefore,





Our collaborator, TrumpTech, uses QLens to improve questions design. The company serves more than **500 schools** in Hong Kong.



StuGPTViz: A Visual Analytics Approach to Understand Student-ChatGPT Interactions

Under review

VIS 2024

Motivation

To empower students to fully leverage the capabilities of ChatGPT in educational scenarios, **understanding students' interaction patterns with ChatGPT** is crucial for instructors.



You
what is data visualization?



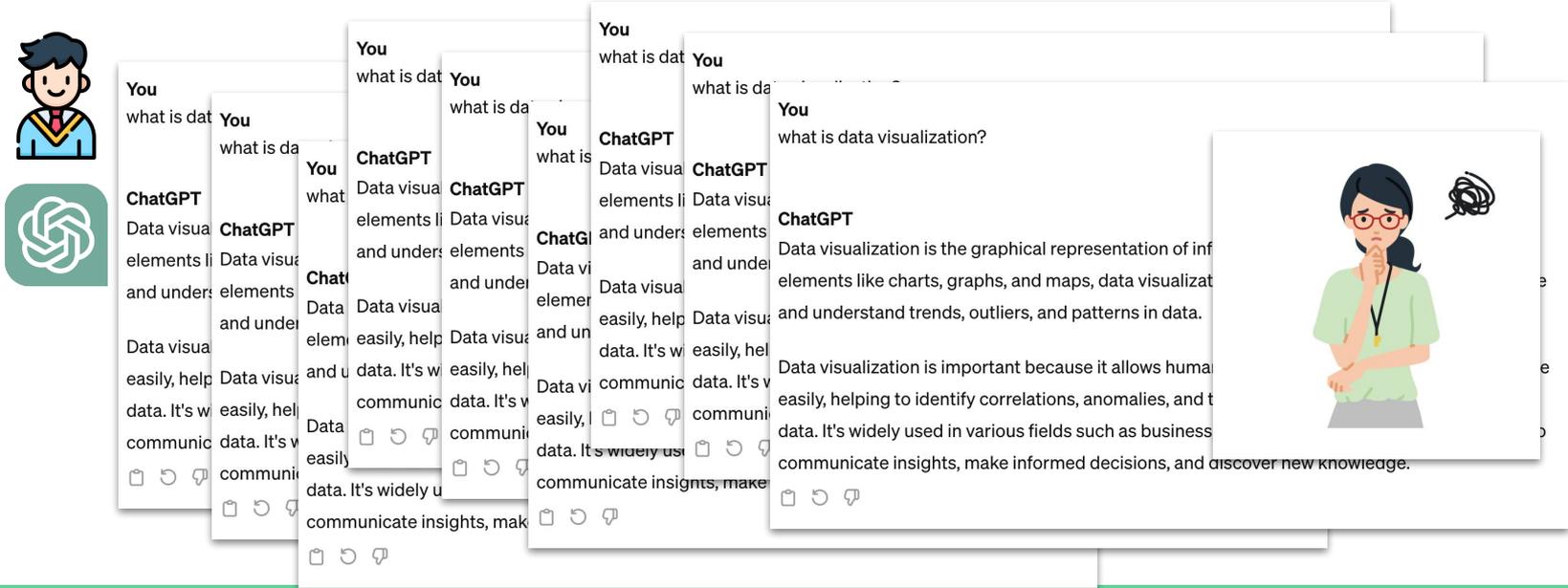
ChatGPT
Data visualization is the graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.

Data visualization is important because it allows humans to comprehend complex datasets more easily, helping to identify correlations, anomalies, and trends that might not be apparent in raw data. It's widely used in various fields such as business, science, healthcare, finance, and more to communicate insights, make informed decisions, and discover new knowledge.



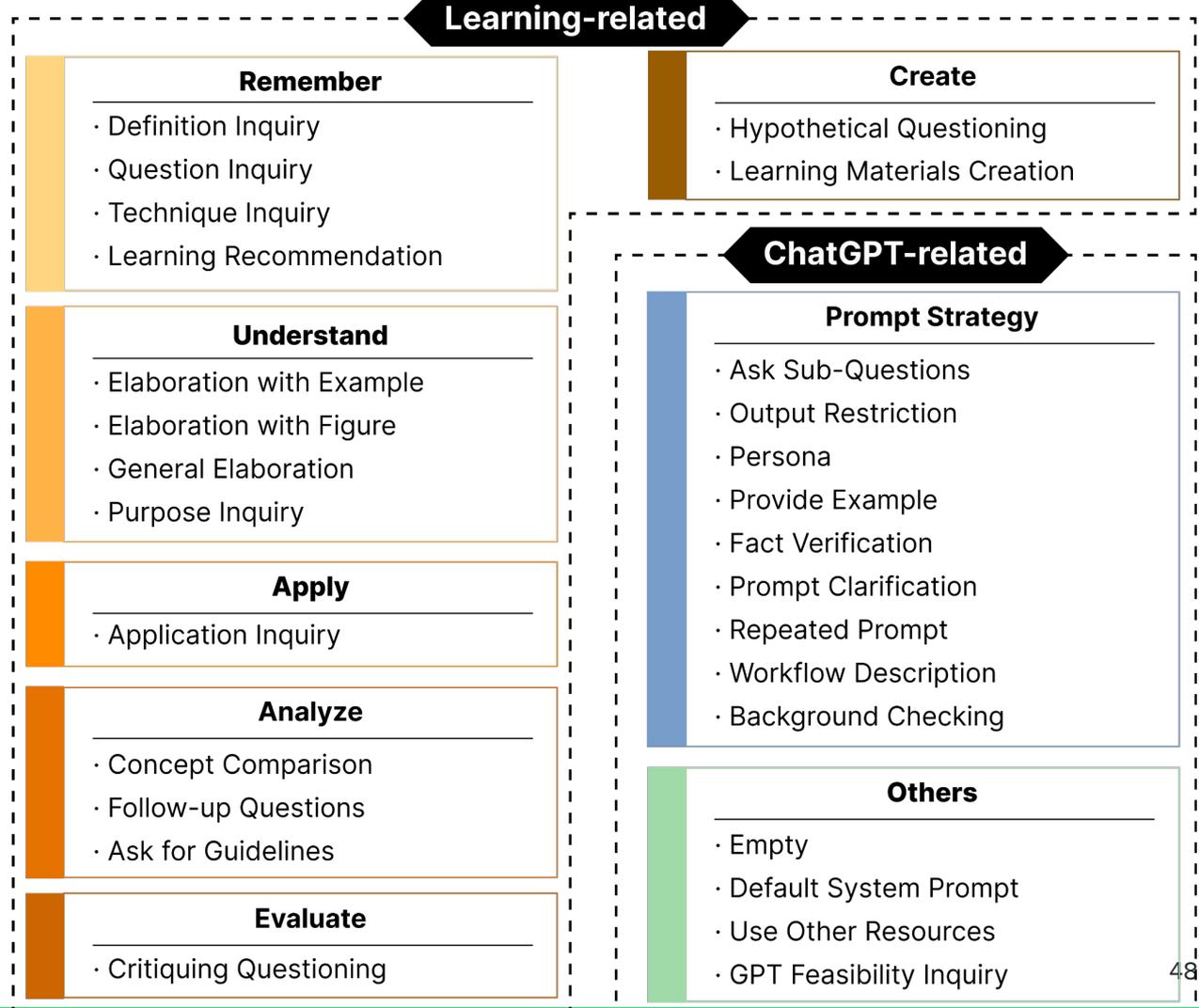
Problem

However, this endeavor is challenging due to **the absence of datasets** focused on student-ChatGPT conversations and the **complexities in identifying and analyzing the evolutional interaction patterns** within conversations.



Context

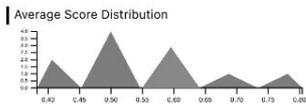
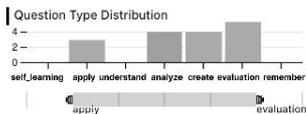
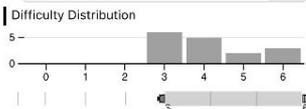
- Graduate – level data visualization
- 48 students
- 10 exercise



Filter View

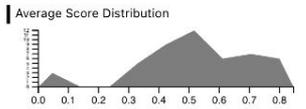
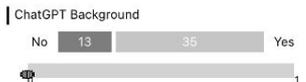
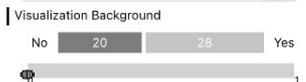
Task Overview

Search for Task ID Set



Student Overview

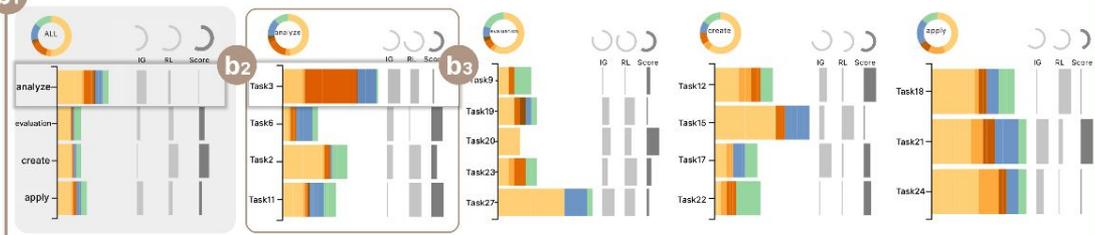
Search for Student ID Set



Pattern View

StudentG TaskG

Pattern Summary

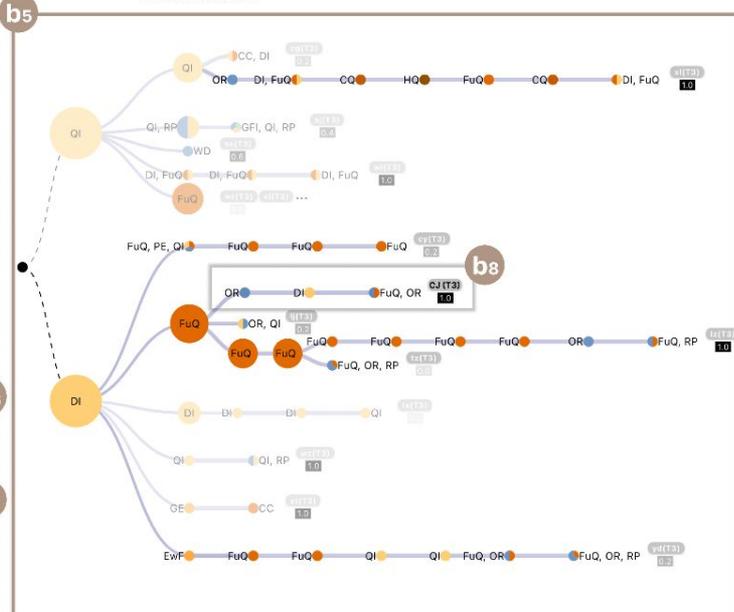


Select Pattern

L...	Pattern	C...	Avg.
1	{ Follow up Questions }	17	0.806...
1	{ Question Inquiry }	16	0.5615...
1	{ Definition Inquiry }	12	0.326...
2	{ Follow up Questions Follow up Questions }	8	0.589...
2	{ Follow up Questions Definition Inquiry }	7	0.870...
1	{ Output Restriction }	7	0.828...

First Prev Next Last

Pattern Nuance



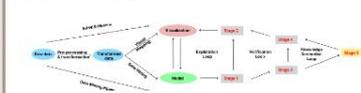
Detail View

Task Description

This diagram illustrates the updated Visual Analytics Pipeline (named the knowledge generation model), which involves a series of operations, representations, and analytical stages. Using GPT's assistance, please identify and fill in the blank nodes which associated Analytical Stages (1 to 5) in the process.

Analytical Stages

- Stage 1 is [Stage_A]
- Stage 2 is [Stage_B]
- Stage 3 is [Stage_C]
- Stage 4 is [Stage_D]
- Stage 5 is [Stage_E]



Student Answer

Finding, Action, Insight, Hypothesis, Knowledge

Raw Conversation

Do you know the diagram of updated visual analytics pipeline

Yes, the updated visual analytics pipeline typically consists of the following stages: 1. Data acquisition and integration 2. Data cleaning and preprocessing 3. Data transformation and feature extraction 4. Data mining and analysis 5. Visualization and exploration 6. Knowledge representation and reasoning 7. Decision making and action This pipeline is iterative and interactive, allowing analysts to refine their understanding of the data and adjust their analysis and visualization approaches as needed.



Educators (design loop)



Learners (learning loop)

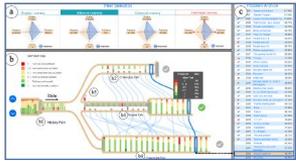
Planning

Performing
Data

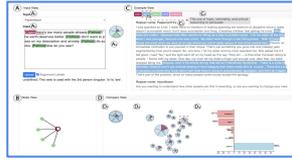
Reflecting

Understanding
and Analyzing

Redesigning



Peerlens (CHI 2019)



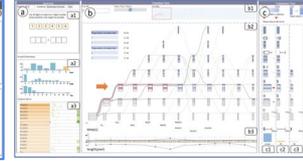
Persua (CSCW 2022)



RLens (L@S 2022)



StuGPTVis (TVCG 2024)



QLens (TVCG 2021)

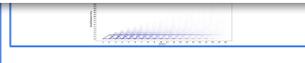


SolutionVis (AIED 2023)

*Enable **learners and educators** to **find insights** from learning data and use the insights to **make decisions** for achieving **personalized online learning**.*



Ruffle&Riley (AIED 2024)



Distributed Tutorship (LAK 2022)



SeqDynamics (EuroVIS 2020)

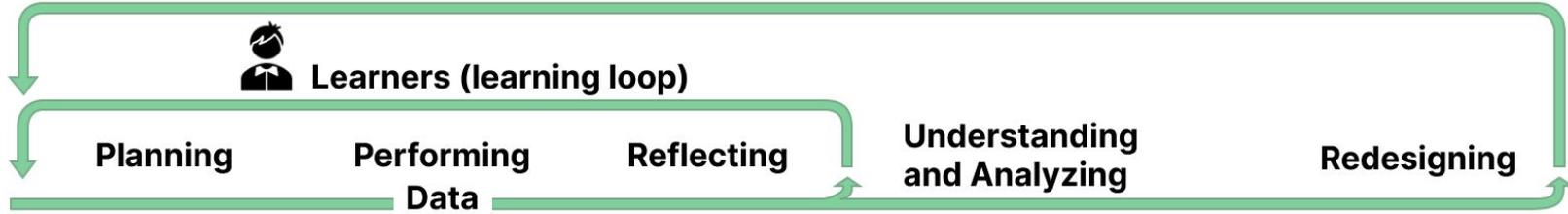


BlockLens (L@S 2022)

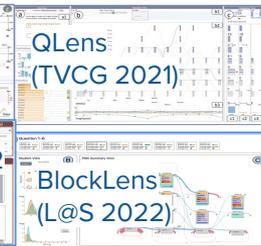
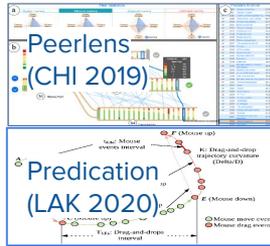
Future HAI in Education

- More Comprehensive
- More Actionable
- More Effective
- More Context-aware

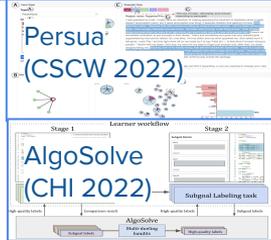
More Comprehensive



Event Sequence



Text

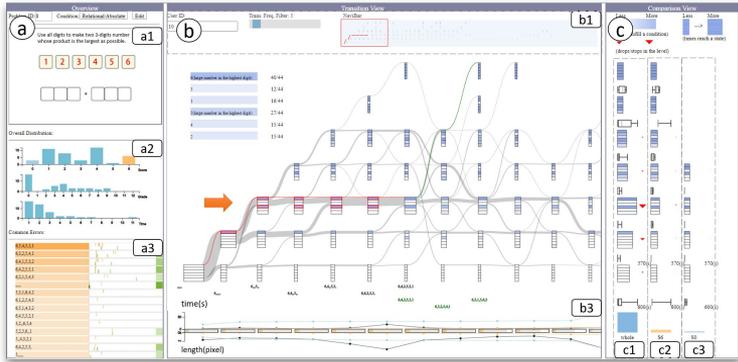


Code

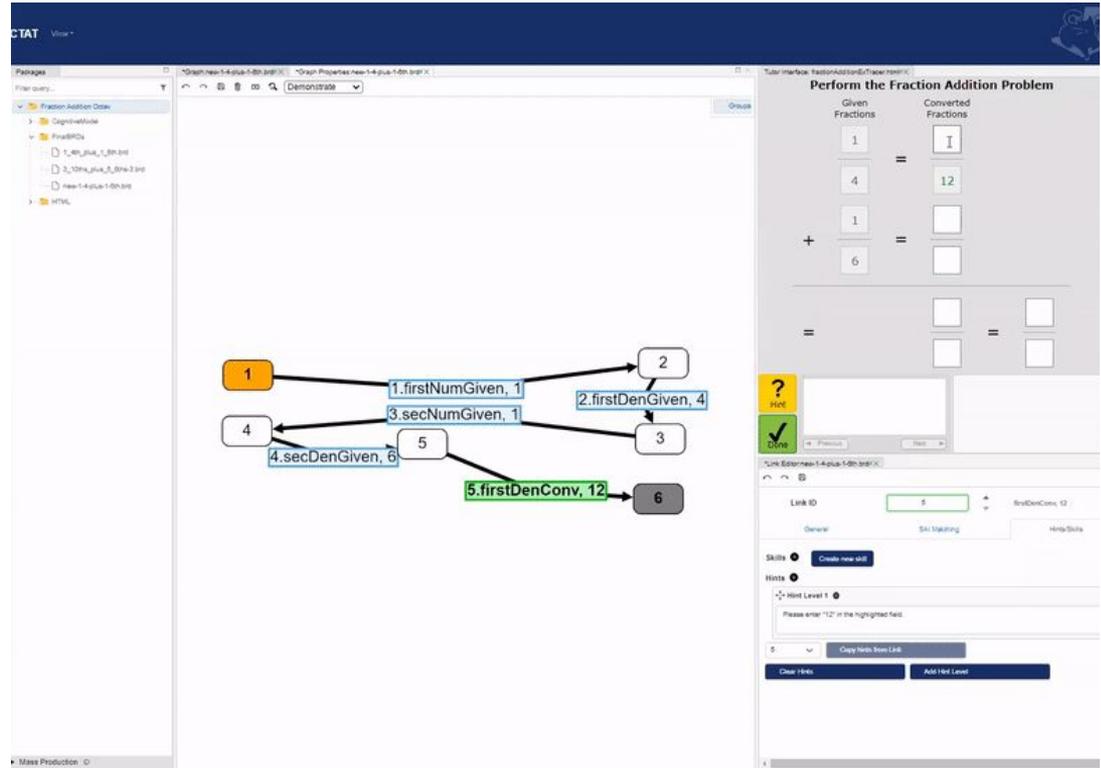
Video



More Actionable



QLens: Learning analytics



CTAT (cognitive tutor authoring tools):
Learning design

Teacher-AI collaboration: data-driven optimization for learning materials

Future Education for HAI

- Fairness
- Accountability
- Transparency
- Social responsibility

Human-AI Interaction in other domains?

- Autonomous Driving
- Robot Surgery
- Sports



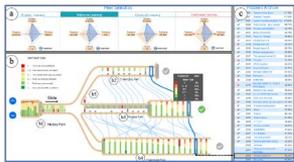
Planning

Performing
Data

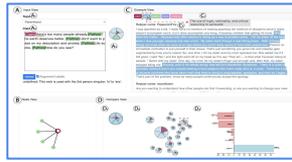
Reflecting

Understanding
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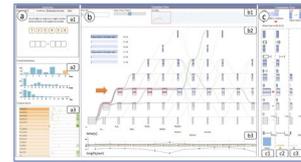
Redesigning



Peerlens (CHI 2019)



Persua (CSCW 2022)



QLens (TVCG 2021)



StuGPTVis (TVCG 2024)

Human-AI Interaction for Personalized Online Learning

Welcome to join our lab!

Personal page: <https://www.xiameng.org> Email: mengxia@tamu.edu



TEXAS A&M UNIVERSITY

Department of Computer
Science & Engineering