

# Human-centered Data-driven Systems for Personalized Online Learning

Meng Xia

10-06-2023



# Online Learning has become widespread



A Coding Exercises  
Platform



A MOOCs platform  
(massive open online  
courses)



A videotelephony  
software



An online  
discussion forum

# Learning at scale, flexible locations and times

## Scale



## Space



## Time

CLASS TIMETABLE			
	9.00-9.30	9.30-10.30	11.00-1.00
MON	SPORT	MATHS	LITERATURE
TUE	SPORT	LITERATURE	ENGLISH
WED	SPORT	SCIENCE	COMPUTING
THU	SPORT	ENGLISH	HISTORY
FRI	SPORT	SCIENCE	COMPUTING
			GEOGRAPHY



**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



# Learning at scale, flexible locations and times

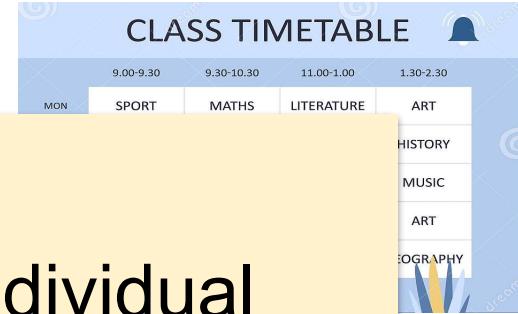
## Scale



## Space



## Time



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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# Why personalized learning?



## Non-cognitive

motivation

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

self-regulation  
skills

(Aleven & Koedinger, 2002)

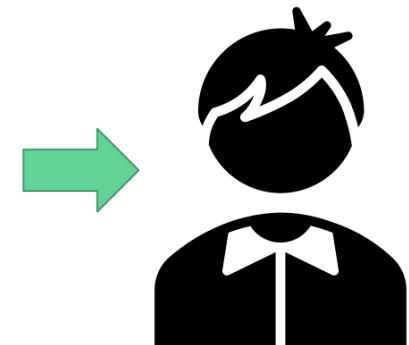
## Cognitive

knowledge

(Koedinger, Stamper, McLaughlin, & Nixon, 2013;)

problem-solving  
strategies, errors

(Adams et al., 2014)



# Learning at scale, flexible locations and times

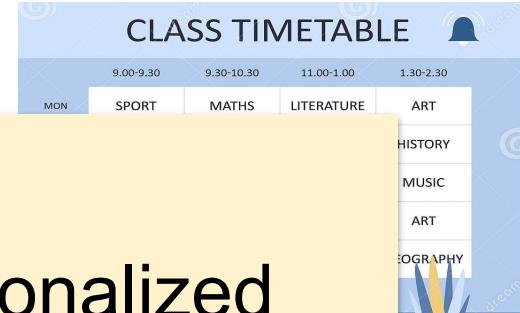
## Scale



## Space



## Time



How could we achieve personalized online learning?

Machine Le

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

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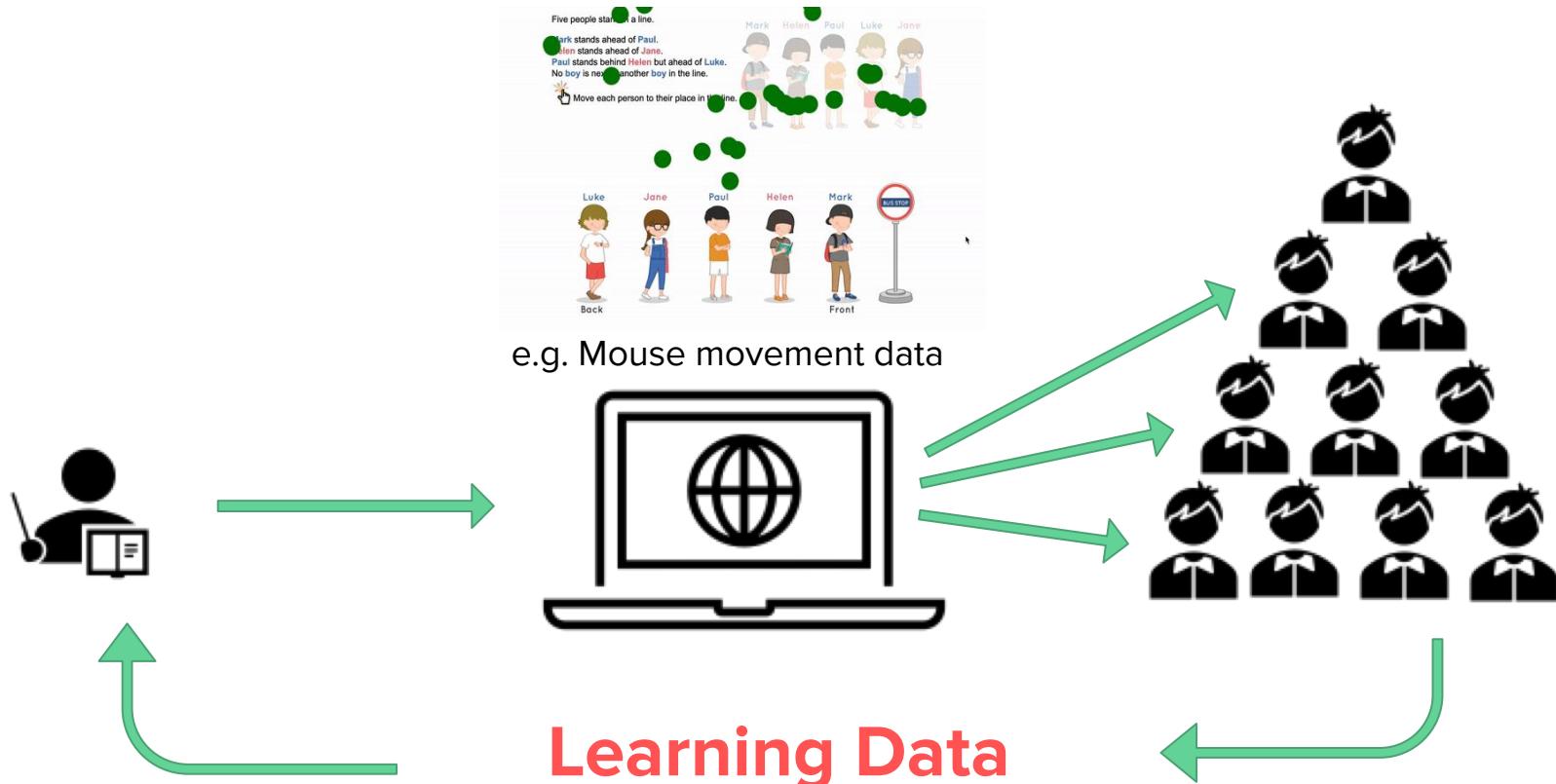
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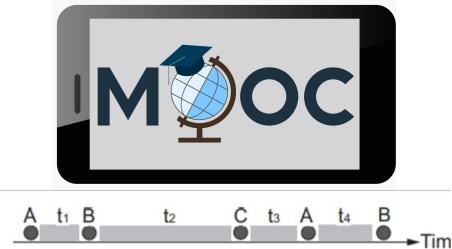
# Learning Data is a Communication Channel



# Online Learning Platforms and Data



#	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



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

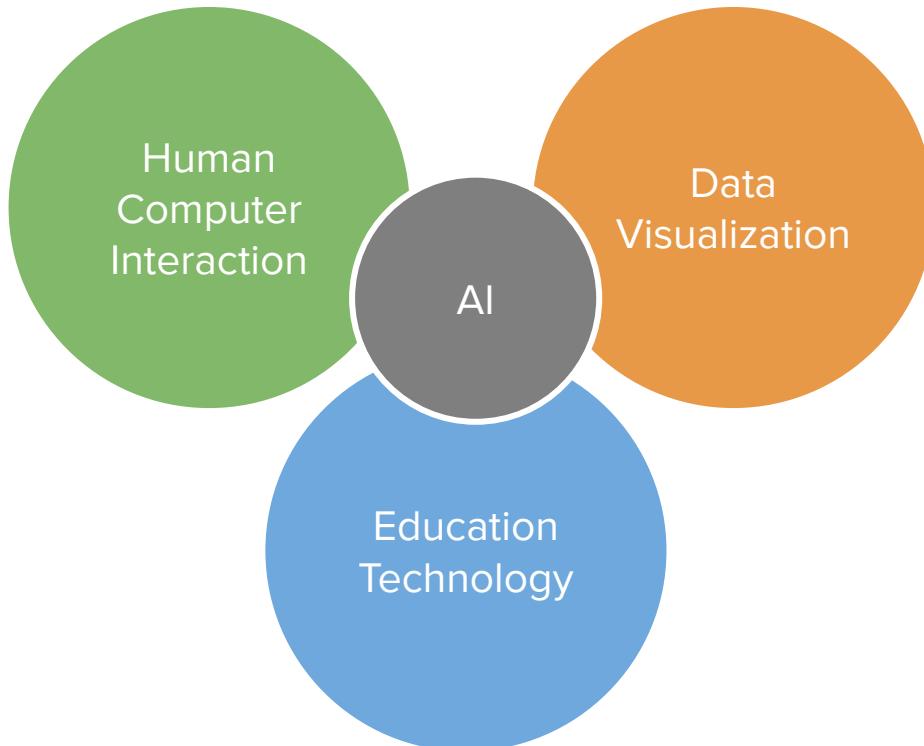
- Focus more on cognitive skills instead of non-cognitive variables (e.g., motivations, self-regulation skills)

Learning factor analysis (Cen et al., 2006) Performance factor analysis (Pavlik et al., 2009)

- Algorithms' outputs are not easy to interpret

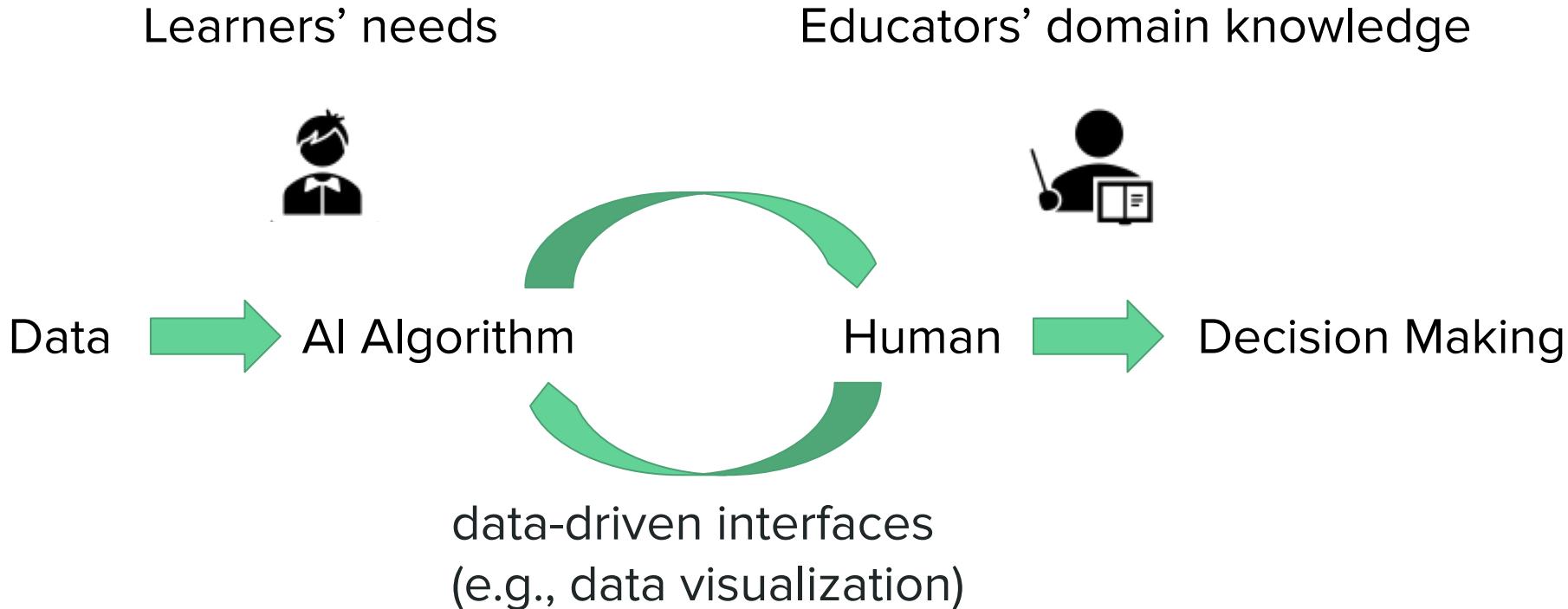
Deep knowledge tracing (Piech et al., 2015) Explanatory models for educational data (Liu et al., 2017)

# My Approach



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

# Why *human-centered* data-driven systems?



# 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**



## Educators (design loop)



## Learners (learning loop)

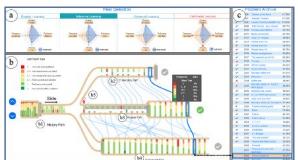
### Planning

### Performing Data

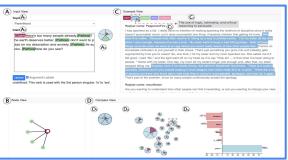
### Reflecting

### Understanding and Analyzing

### Redesigning



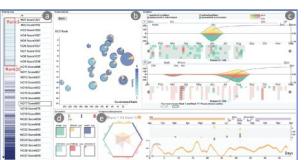
Peerlens (CHI 2019)



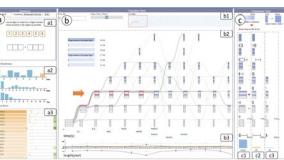
Persua (CSCW 2022)



RLens (L@S 2022)



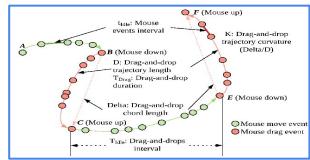
SeqDynamics (EuroVIS 2020)



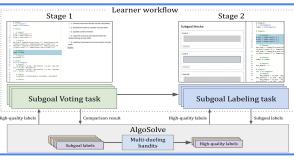
QLens (TVCG 2021)



SolutionVis (AIED 2023)



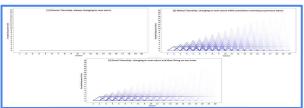
Predication (LAK 2020)



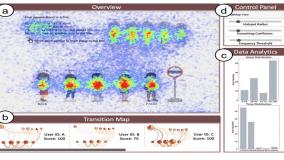
AlgoSolve (CHI 2022)



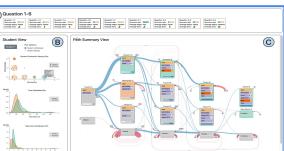
"Gaming the system"(L@S 2020)



Distributed Tutorship (LAK 2022)



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



BlockLens (L@S 2022)

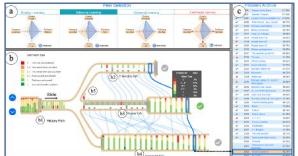


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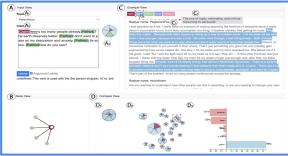
## Learners (learning loop)

### Planning



Peerlens (CHI 2019)

### Performing Data



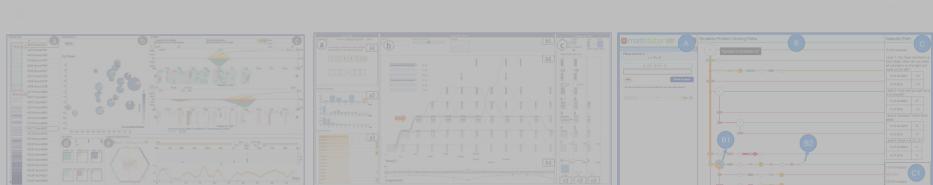
Persua (CSCW 2022)

### Reflecting



RLens (L@S 2022)

### Understanding and Analyzing



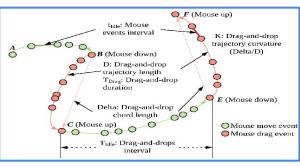
SeqDynamics (EuroVIS 2020)

### Redesigning

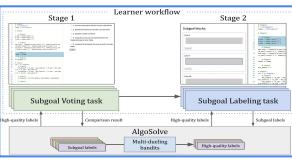


QLens (TVCG 2021)

SolutionVis (AIED 2023)



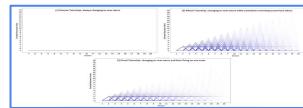
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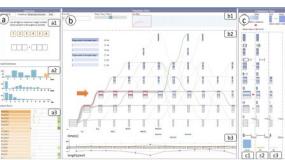
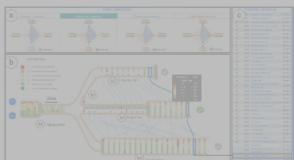
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Peerlens (CHI 2019)

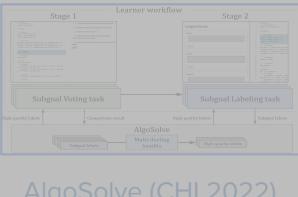
Persua (CSCW 2022)

RLens (L@S 2022)

SeqDynamics (EuroVIS 2020)

QLens (TVCG 2021)

SolutionVis (AIED 2023)



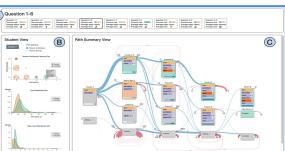
"Gaming the system"(L@S 2020)

Mobile MOOCs (CHI 2022, Best Paper Award)

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



Distributed Tutorship (LAK 2022)



BlockLens (L@S 2022)



## Educators (design loop)



## Learners (learning loop)

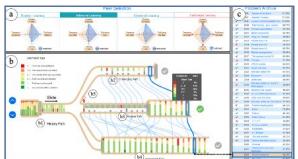
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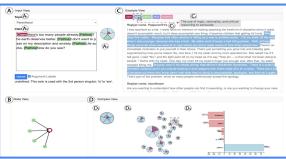
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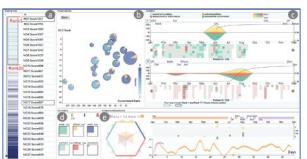
PeerLens (CHI 2019)



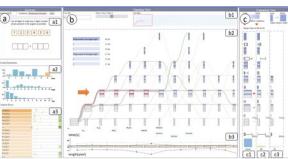
Persua (CSCW 2022)



RLens (L@S 2022)



SeqDynamics (EuroVIS 2020)



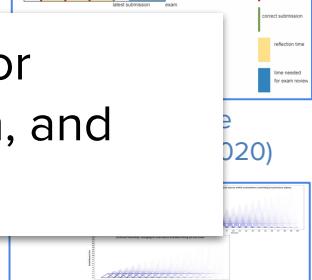
QLens (TVCG 2021)



SolutionVis (AIED 2023)



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



Distributed Tutorship (LAK 2022)

Mobile M  
2022, Be

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



BlockLens (L@S 2022)



## Educators (design loop)



## Learners (learning loop)

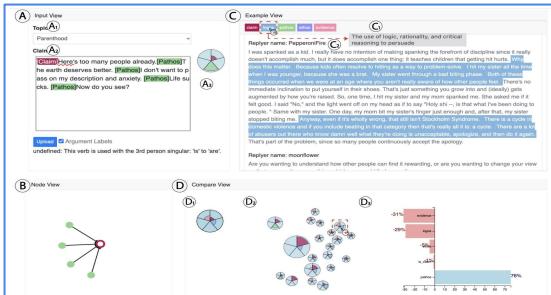
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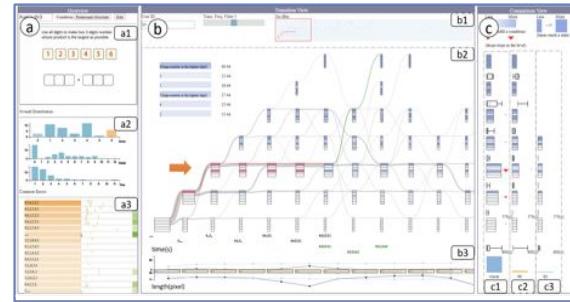
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Persua (CSCW 2022)



QLens (TVCG 2021)

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?



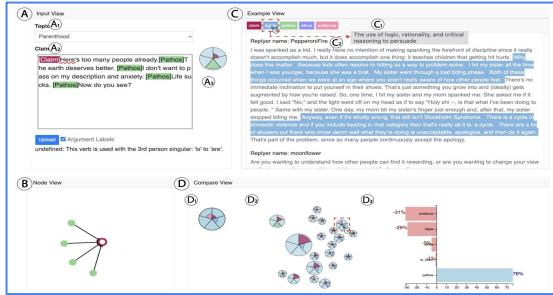
Planning

Performing  
Data

Reflecting

Understanding  
and Analyzing

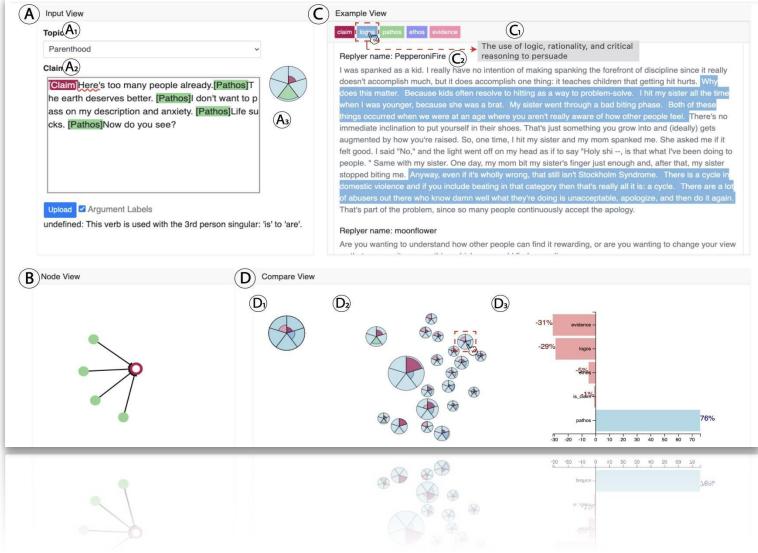
Redesigning



Persua (CSCW 2022)

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)

# Background

The screenshot shows the homepage of the r/changemyview subreddit. At the top, there's a navigation bar with the Reddit logo, a search bar containing 'r/changemyview', and buttons for 'Sign Up' and 'Log In'. Below the navigation is a purple header bar with the subreddit name 'Change My View (CMV)' and a 'Join' button. Underneath is a sub-header with 'Posts', 'Wiki', and 'Rules' tabs. The main content area has a blue header 'Hot' with other sorting options like 'New', 'Top', and '...'. A post by 'u/Ramza\_Claus' is displayed, titled 'CMV: There are no Epistemologically sound reasons to believe in any god'. The post has 65 upvotes and a comment from 'Heya CMV' responding to it. Another post by 'u/beatsmithatheathcliff' is partially visible below. To the right of the posts is a sidebar titled 'About Community' with text about accepting opinions from others and a note that it was created on Jan 16, 2013. It also shows community statistics: 1.9m Members (1.8k Online, Top 1% Ranked by Size). Below the stats are filters for 'Fresh Topic Friday', 'Delta(s) from OP', and 'Delta(s) from OP - Fresh Topic Friday', along with a 'See more' link.

1.9m

Members

1.8k

Online

Top 1%

Ranked by Size

What are the difficulties for users to write persuasive arguments and what we can learn from the existing data?

# Needs-finding Stage



A needs-finding survey with  
**123 online forum users**

- R1: Provide examples** and support filtering by persuasive strategies
- R2: Display and compare** the **composition** of different persuasive strategies
- R3: Show the logical structure** of the arguments
- R4: Offer visual augmented feedback** for the arguments writing

# Related Work

AL Home Write Progress

**Text editor**  
While writing, you can click the Analyze button to get feedback on your argumentation.  
Click on **claims** to display them in the detailed view.

**Your personal argumentation learning dashboard**  
Our algorithms found the following feedback (to know how, click [here](#))

An overview of your argumentation structure (claims & premises):  
Click on **claims** to display them in the detailed view.

**Argumentative [89%]**  
**Non-Argumentative [11%]**

**Readability** 64% **Details**  
**Coherence** 27% **Details**  
**Persuasiveness** 75% **Details**

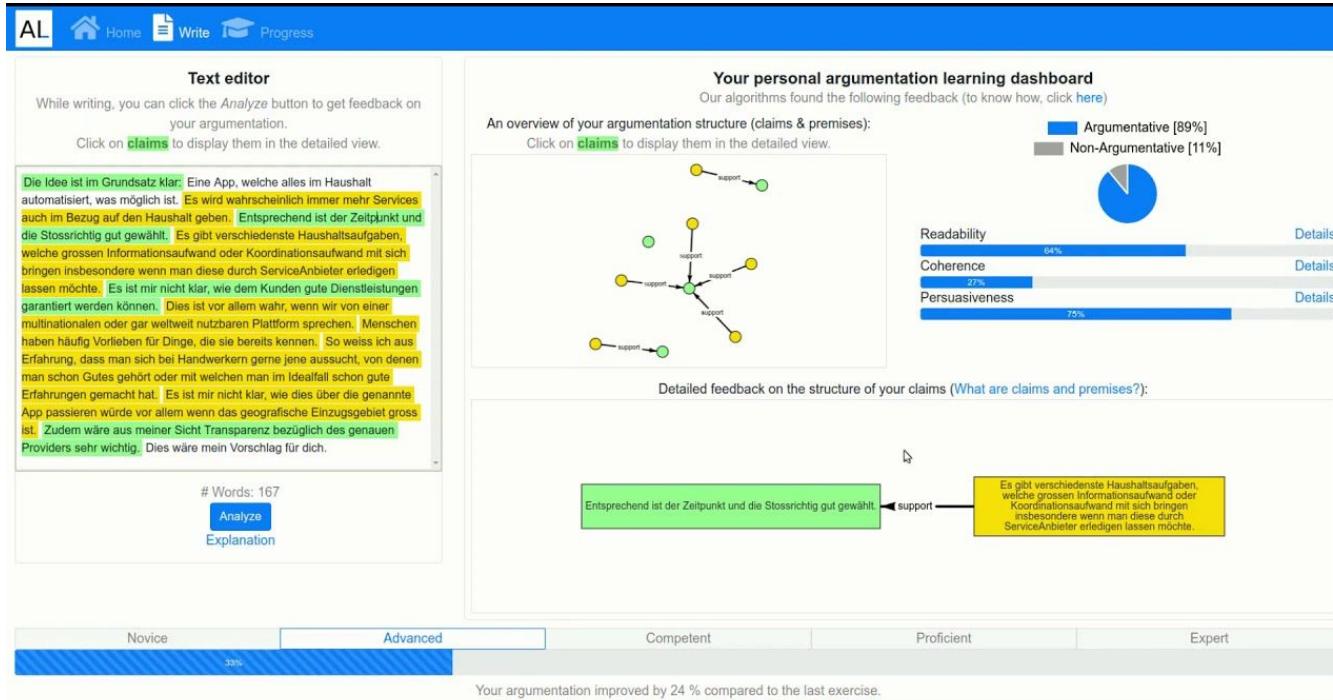
Detailed feedback on the structure of your claims (What are claims and premises?):

# Words: 167  
**Analyze**  
Explanation

Novice Advanced Competent Proficient Expert

33%

Your argumentation improved by 24 % compared to the last exercise.

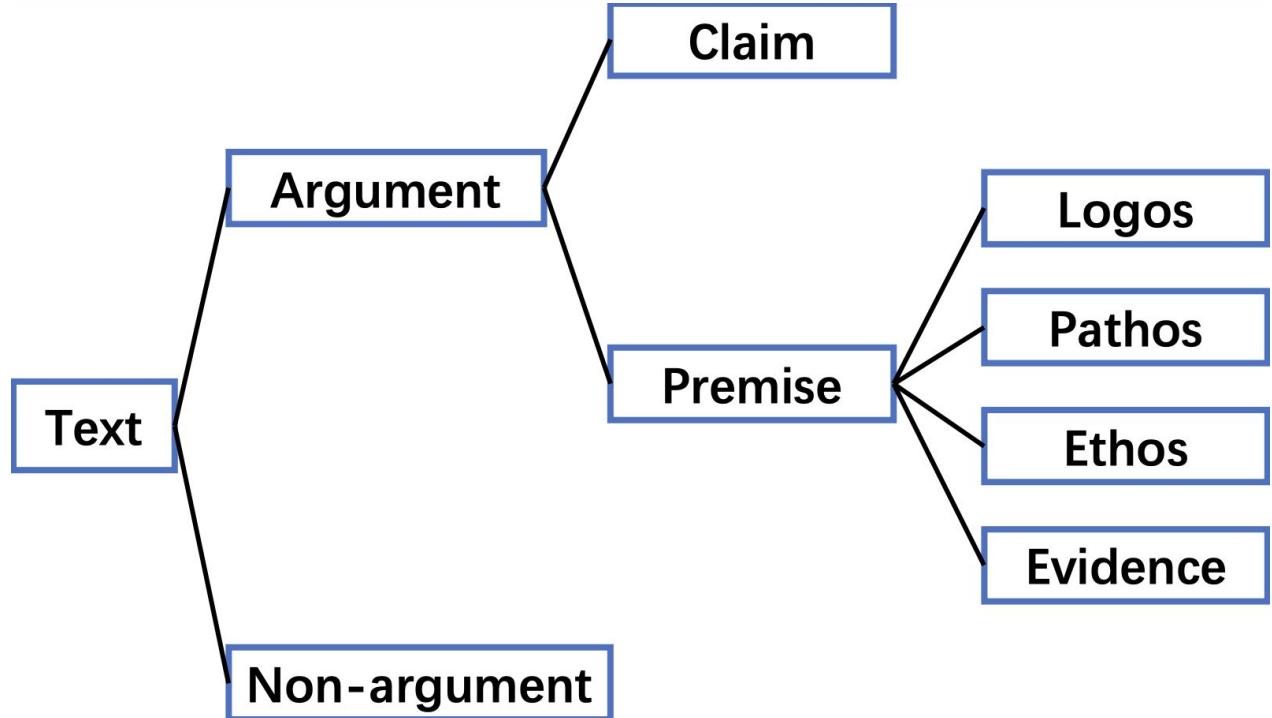


Lacking guidance on persuasive strategies

# Taxonomy of Argument Components

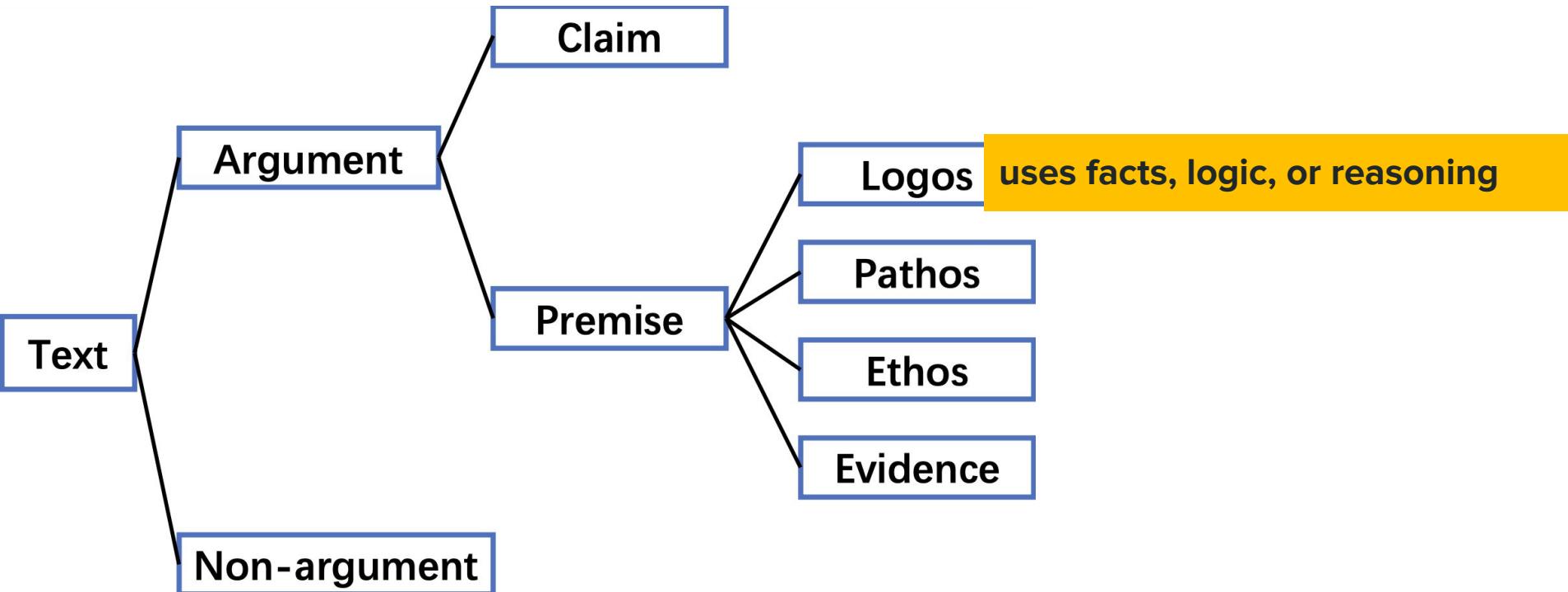


Semi-structured  
interviews with **five**  
**domain experts** on  
debating competitions

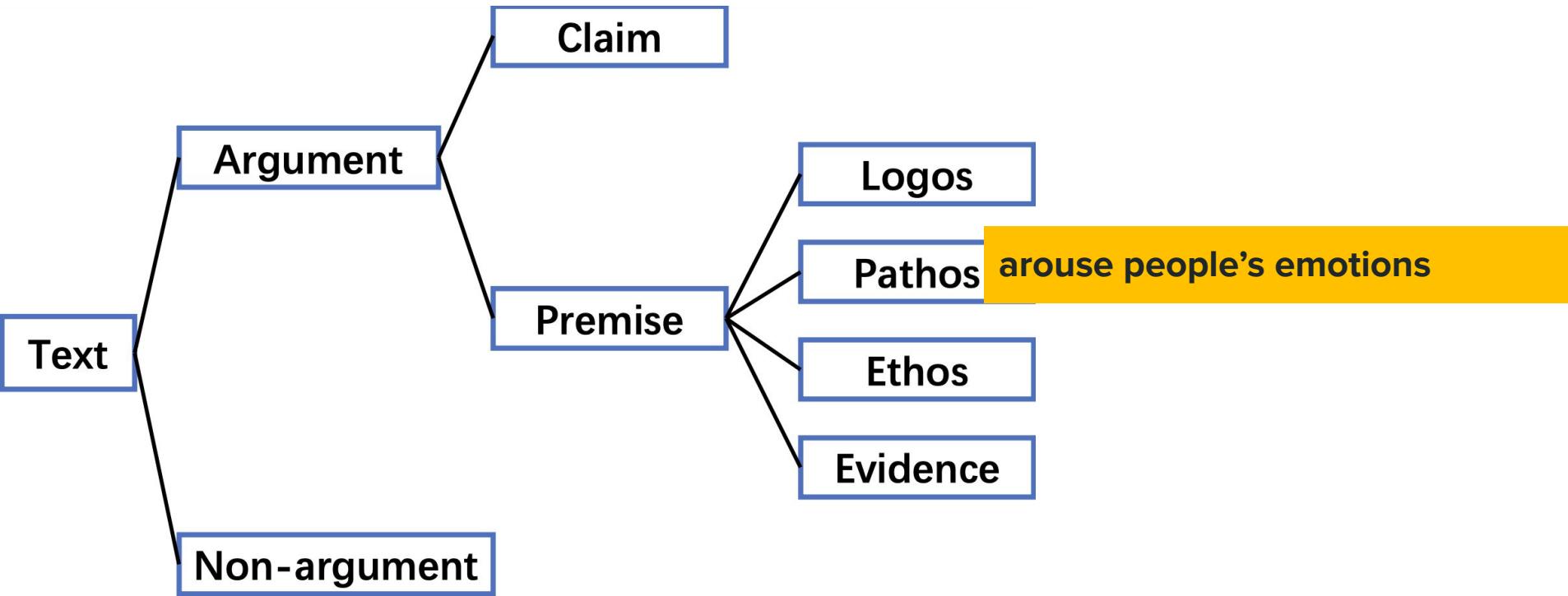


Classical persuasive strategies of Aristotle, and Rapp, 2002 and Carlile et al., 2018

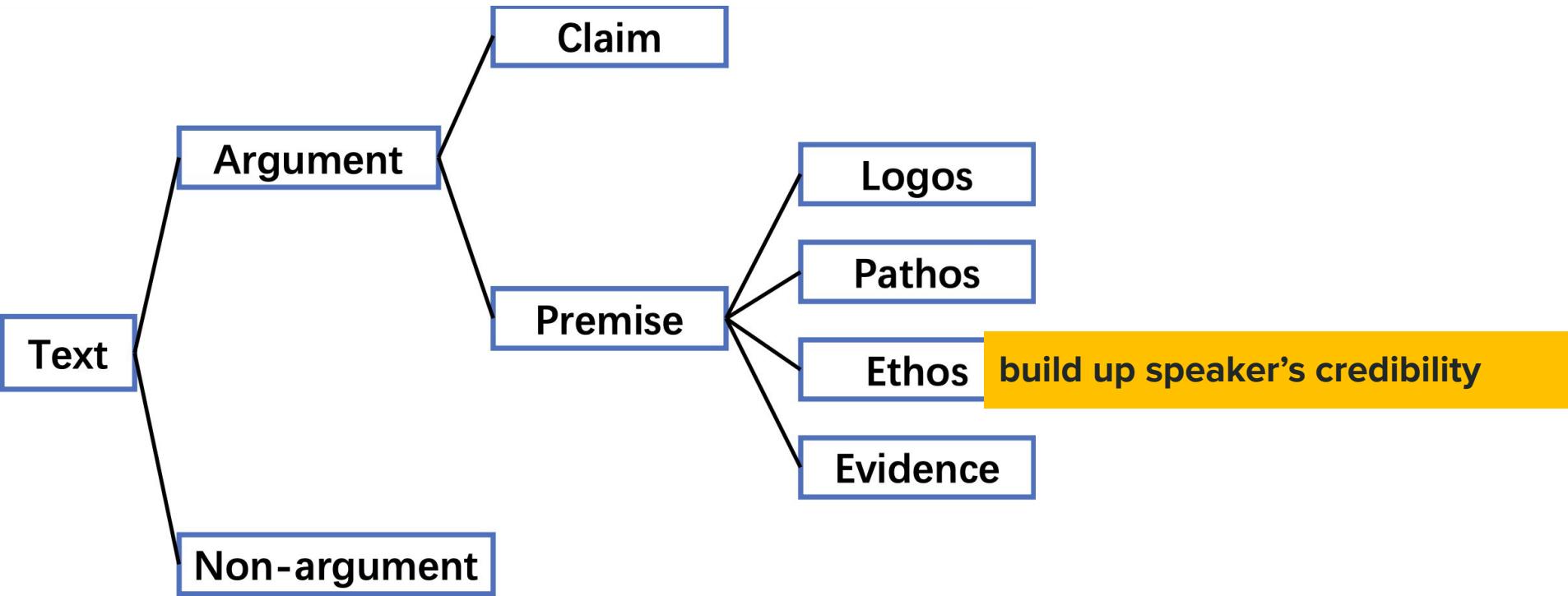
# Taxonomy of Argument Components



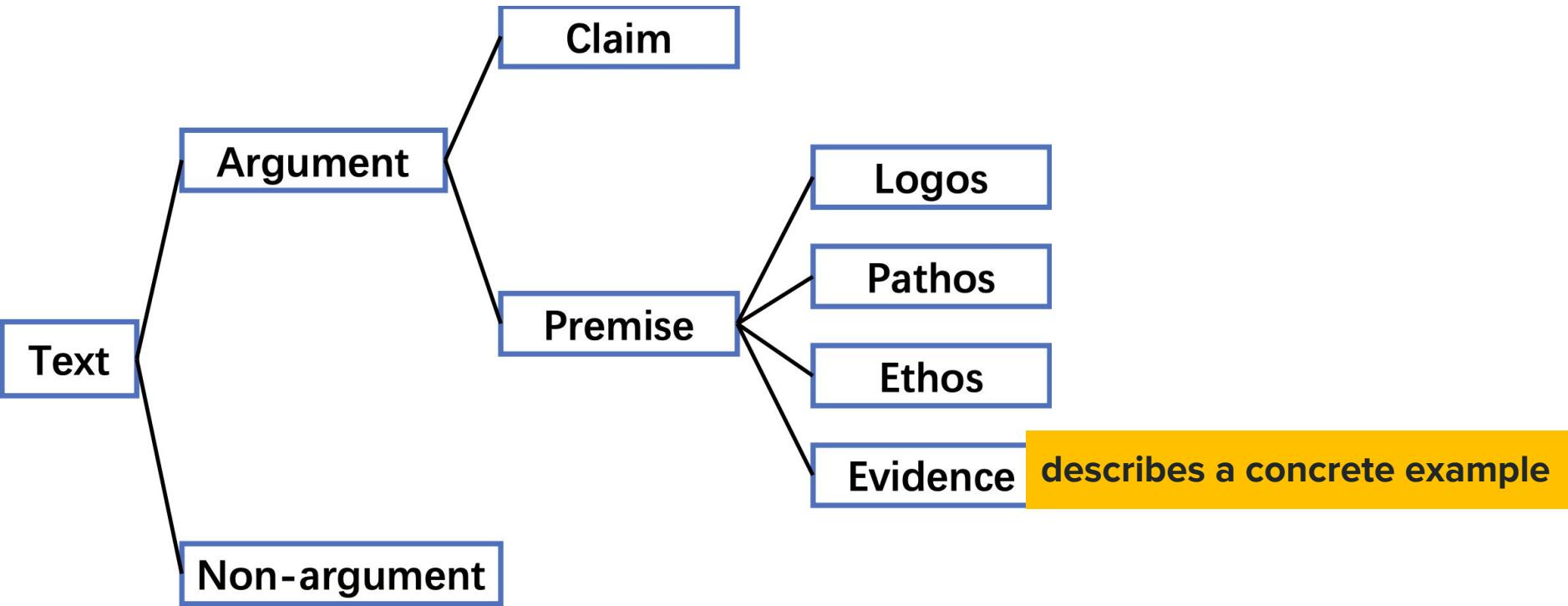
# Taxonomy of Argument Components



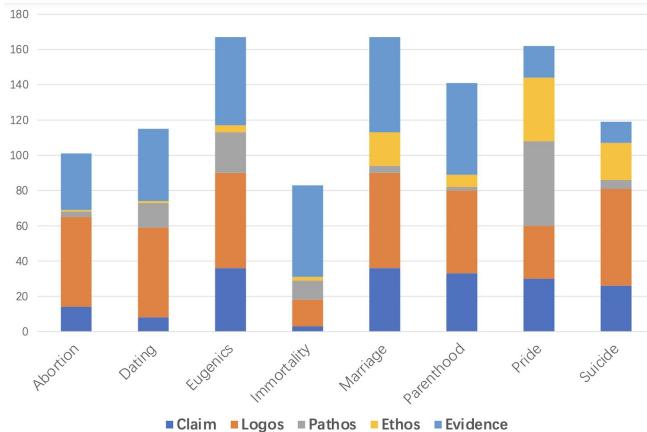
# Taxonomy of Argument Components



# Taxonomy of Argument Components



# Persuasive Strategies Mining



**164 discussion threads** with 1269 sentences covering **eight** topics and

1. **Converting the sentences into high-dimensional vector representations:**  
BERT language model
2. **Is claim or premise or non-argument?** a multi-class classification task
3. **Does a premise support a claim?** a binary classification task
4. **What are the persuasive strategies applied?** a multi-label classification

# Persua

**A** Input View

**Topic A<sub>1</sub>**  
Parenthood

**Claim A<sub>2</sub>**

[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?

**A<sub>3</sub>**

**C** Example View

claim loops pathos ethos evidence

Replyer name: PepperoniFire **C<sub>1</sub>** → 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.

Replyer name: moonflower

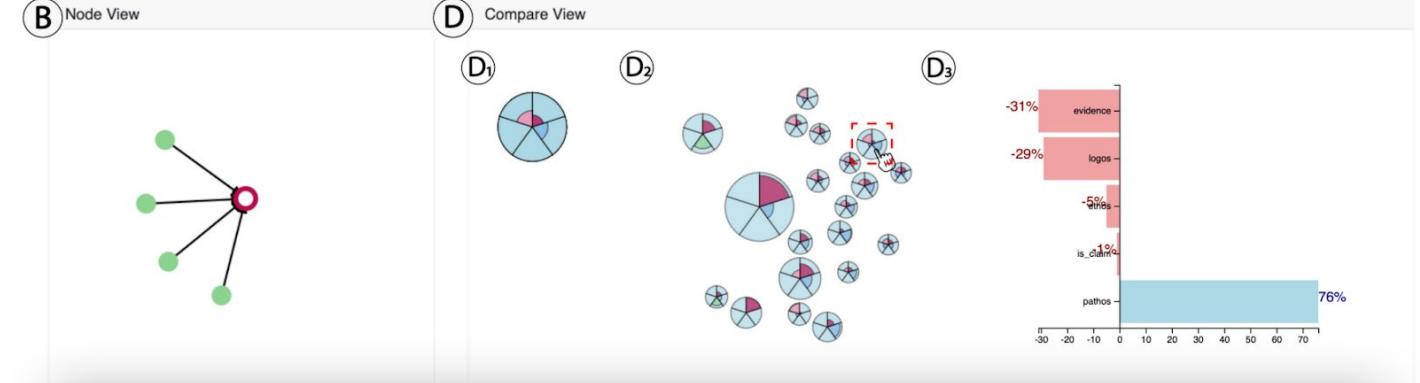
Are you wanting to understand how other people can find it rewarding, or are you wanting to change your view

**B** Node View

**D** Compare View

**D<sub>1</sub>** **D<sub>2</sub>** **D<sub>3</sub>**

Argument Type	Percentage
evidence	-31%
logos	-29%
ethos	-5%
is claim	12%
pathos	76%



# Input View

**A** Input View

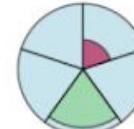
**Topic A<sub>1</sub>**

Parenthood

**Claim A<sub>2</sub>**

[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?

**A<sub>3</sub>**



**Upload**  Argument Labels

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

# Input View

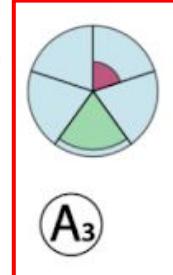
**A** Input View

Topic **A<sub>1</sub>**  
Parenthood

Claim **A<sub>2</sub>**

[Claim] Here's too many people already. [Pathos] T  
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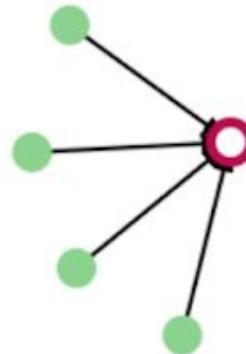
**Upload**  Argument Labels

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# Node View

B

Node View



Here's too many people already

# Example View

**C** Example View

claim logos pathos ethos evidence

**C1**

Replyer name: PepperoniFire **C2**

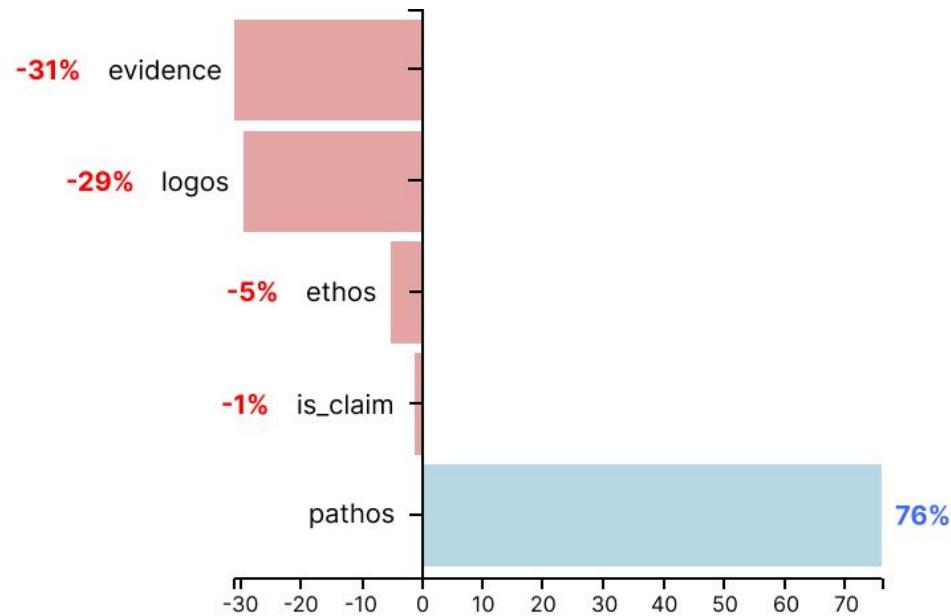
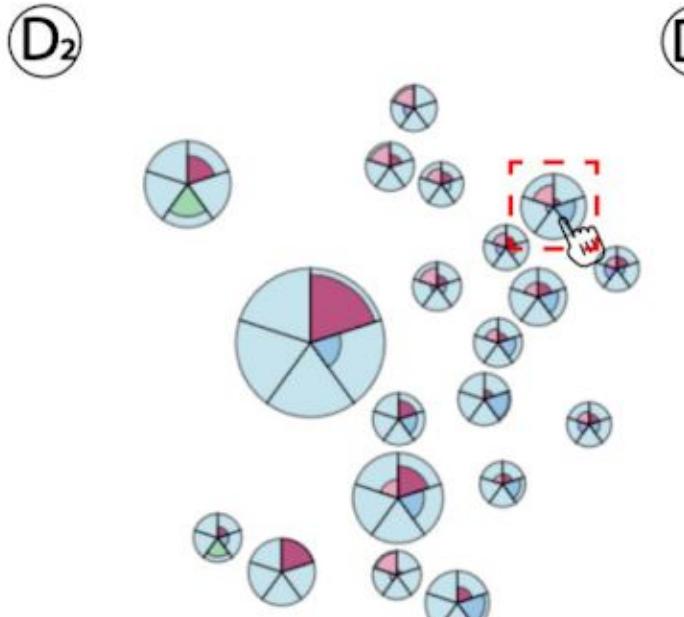
The use of logic, rationality, and critical reasoning to persuade

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.

Replyer name: moonflower

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

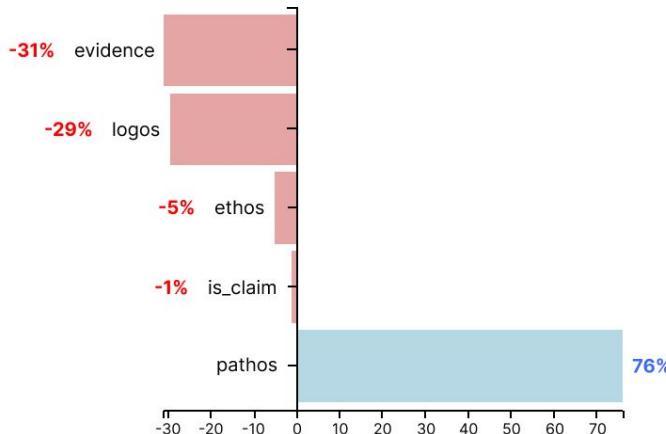
# Compare View



# 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?



**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.

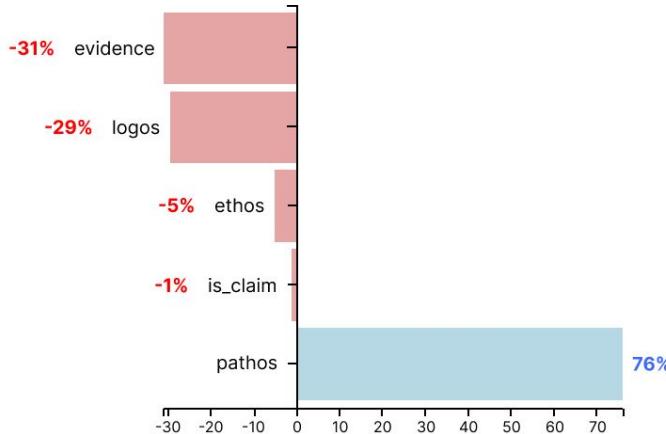
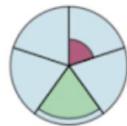
Replier name: moonflower

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

# Case Study

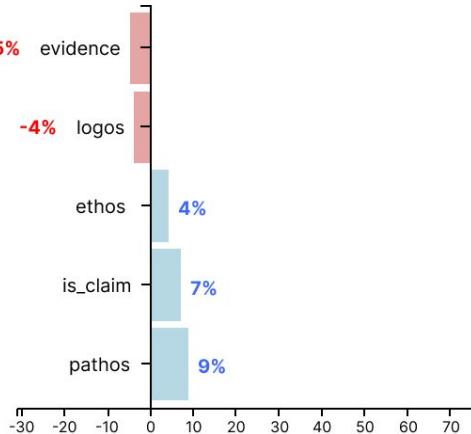
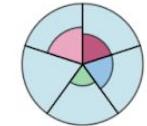
Before:

[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?

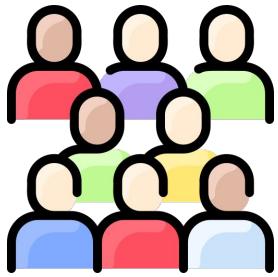


After:

[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.



# User Study



**36 participants** (20 males, 16 females)  
Baseline: 18 Persua: 18

Input Text

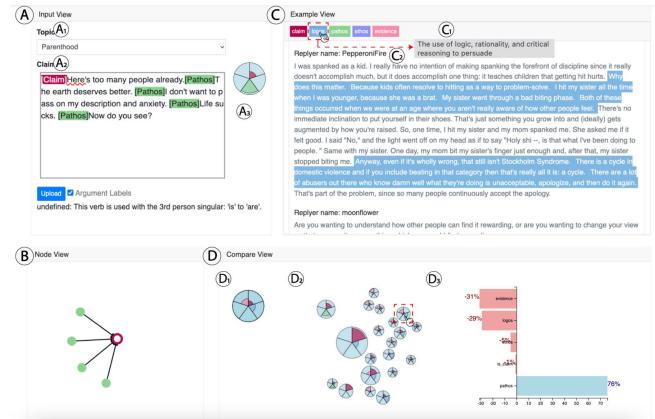
Claim:  
Here's too many people already. The earth deserves better. I don't want to pass on my depression and anxiety. Life sucks. Now do you see?

Upload

ERROR undefined: This verb is used with the infinitive: 'to better', 'to well'.

Node View

```
graph TD; C(( )) --- A1(( )); C --- A2(( )); C --- A3(( )); C --- A4(( ));
```



Baseline (Wambsgans et al., CHI 2020)

Persua

# Tasks & Results: Submit more times and more persuasive

---

Write a paragraph about the topic “Abortion”.

- Task 1 Try to persuade the person who published the following claim by taking the opposite side.  
[Claim: I’m pro-life, and I believe that abortion is essentially murder.]
- 

Refine a paragraph about the topic “Parenthood”:

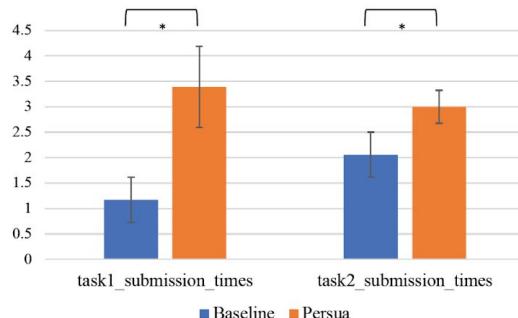
*“Here’s too many people already. The earth deserves better.”*

- Task 2 *I don’t want to pass on my depression and anxiety. Life sucks. Now do you see?”*

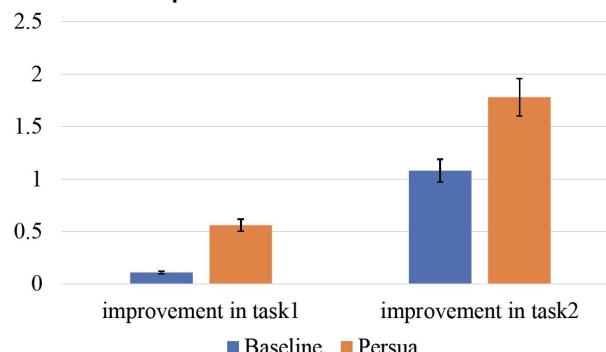
Try to make it more convincing to persuade people who published the following claim.  
[Claim: I don’t understand why people don’t want to have children.]

---

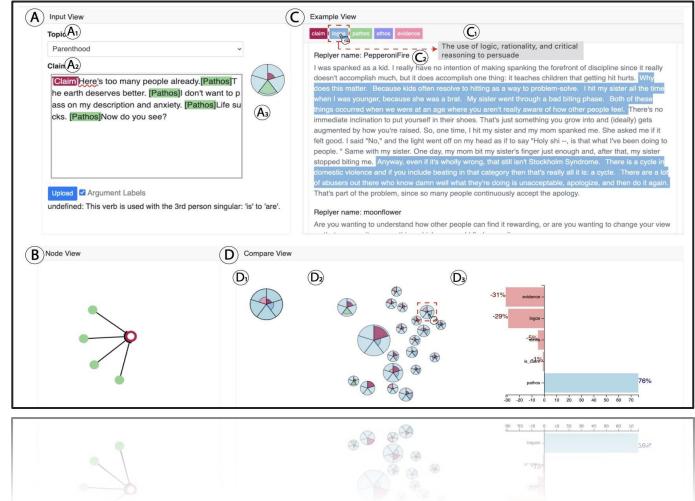
Submissions times on tasks



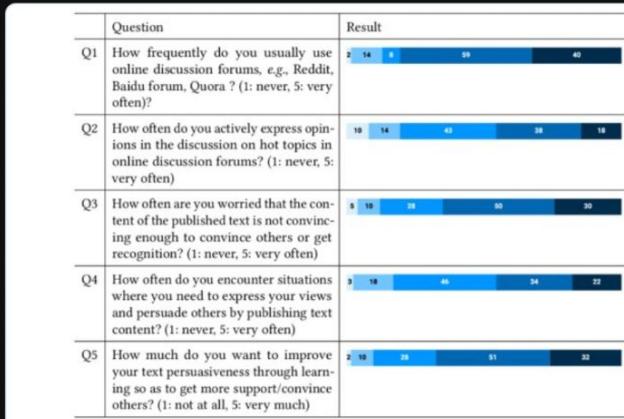
Improvements on tasks



**Perusa detects and visualizes  
persuasive strategies  
differences from peer data to  
nudge learners and provide  
examples for them to refer to.**



Component-based learning, e.g., analyze and visualize code structures and provide code examples to student



**F1: Participants frequently use online discussion forums and tend to express their opinions online.** It confirms that university students fit the behavioral profile of our target users. As shown in Table 1, nearly all participants used (121 out of 123) online discussion forums, such as Reddit<sup>1</sup> and Quora<sup>2</sup> (Q1:  $Mean = 3.98, SD = 1.00$ ) and 89% people (110 out of 123) at least once expressed their opinions on hot topics in online discussion forums (Q2:  $Mean = 3.33, SD = 1.11$ ).

**F2: Participants want to improve the persuasiveness of their arguments online.** According to the answers from participants of Q3-Q5, we found that many participants (118 out of 123) were at least once worried that their arguments are not convincing enough (Q3:  $Mean = 3.73, SD = 1.05$ ), and 120 out of 123 participants at least once encountered the situations to persuade others (Q4:  $Mean = 3.44, SD = 1.03$ ). Most of the participants (121 out of 123) wanted to improve text persuasiveness through learning to some degree (Q5:  $Mean = 3.82, SD = 0.97$ ).

**F3: Participants find it hard to come up with evidence to support their arguments.** Many participants wrote that writing or finding appropriate examples to support their opinions and make arguments persuasive is most time-consuming and challenging. P46 (F, 20) explained the difficulty of finding proper examples. “I want to find some relevant statistics to persuade others, but it is hard

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

04/16/2022 · by Meng Xia, et al. ·

The Hong Kong University of Science and Technology · ❤️ 21 ·

↗ share

Persuading people to change their opinions is a common practice in online discussion forums on topics ranging from political campaigns to relationship consultation. Enhancing people's ability to write persuasive arguments could not only practice their critical thinking and reasoning but also contribute to the effectiveness and civility in online communication. It is, however, not an easy task in online discussion settings where written words are the primary communication channel. In this paper, we derived four design goals for a tool that helps users improve the persuasiveness of arguments in online discussions through a survey with 123 online forum users and interviews with five debating experts. To satisfy these design goals, we analyzed and built a labeled dataset of fine-grained persuasive strategies (i.e., logos, pathos, ethos, and evidence) in 164 arguments with high ratings on persuasiveness from

# Ruffle&Riley: Towards the Automated Induction of Conversational Tutoring Systems (submitted to NeuralIPS workshop23)

Student Chat:

a

Nice to meet you, Teacher! I am Ruffle.  
Thank you so much for helping me study biology. I love to learn!

Hello! I'm eager to learn about cell biology. Could you please explain what the phrase "form follows function" means in this context?

The structure of cell components and organelles evolved to support their specialized functions.

Thank you for your explanation! So, "form follows function" in cell biology means the structure of cell components and organelles supports their specialized functions.

Could you provide an example to illustrate this concept?

type here

Send

Professor: Request Help

b

## Organelles in Eukaryotic Cells

"Form follows function" is a philosophy that many industries follow. In architecture, this means that buildings should be constructed to support the activities housed within them. For example, a skyscraper should include several elevator banks. A hospital should have an easily accessible emergency room.

Our natural world also utilizes the principle of form following function, especially in cell biology. The structure of cell components and organelles evolved to support their specialized functions. For example, in the pancreas there are cells that are responsible for producing digestive enzymes, which are specific types of proteins that help with food digestion. In these cells, ribosomes, the organelle responsible for protein synthesis, are found in high numbers. Here the form (high number of ribosomes) follows the function (protein production). Apart from ribosomes, cells have numerous other organelles. These organelles are specialized compartments inside the cells, and similar to the organs in your body, each organelle has a unique role. In this lesson, we will dive into several examples of organelles and discuss their specific functions.

c

I don't know.

No worries at all! If you could request help from the professor, that would be fantastic. I'm really interested in understanding this concept better with an example.

d

Professor: Request Help

Of course! You could use the example of ribosomes in the pancreas cells. These cells have a high number of ribosomes because they are responsible for producing digestive enzymes, a type of protein. Here, the form (high number of ribosomes) follows the function (protein production).

e

Enzymes that are produced by mitochondria

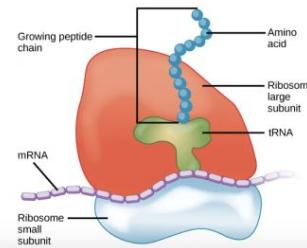
⚠ Revision required

type here

Send

Professor: Request Help

It seems there's a small mistake in your response. Mitochondria are actually responsible for producing ATP, not enzymes. Could you please revise your response?





Educators (design loop)



Learners (learning loop)

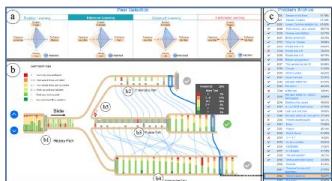
Planning

Performing  
Data

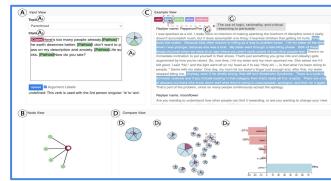
Reflecting

Redesigning

Understanding  
and Analyzing



Peerlens (CHI 2019)



Persua (CSCW 2022)



RLens (L@S 2022)



QLens (TVCG 2021)

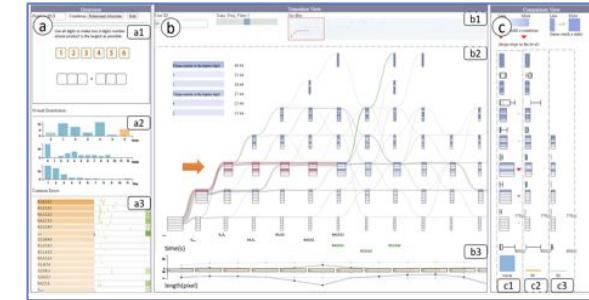
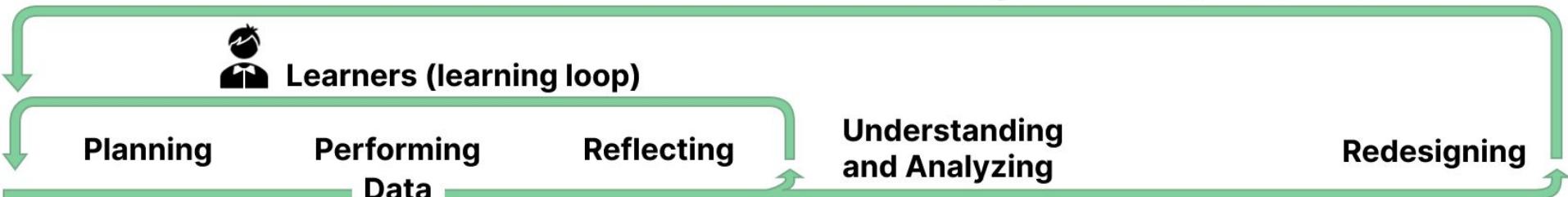


SolutionVis (AIED 2023)

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



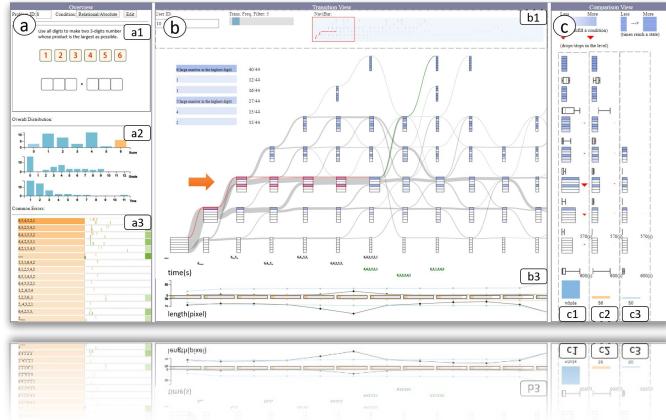
Educators (design loop)



QLens (TVCG 2021)

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 - I

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.

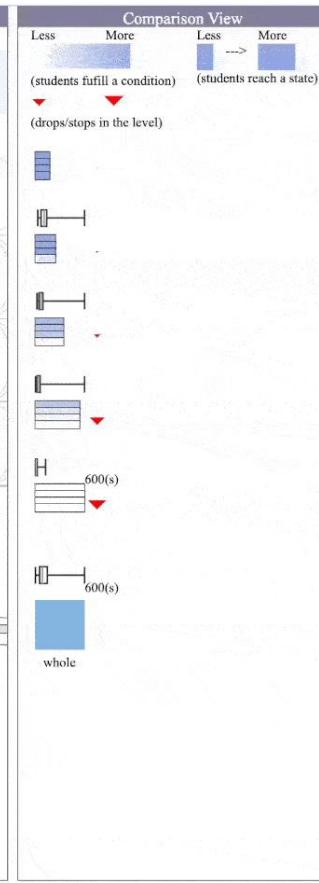
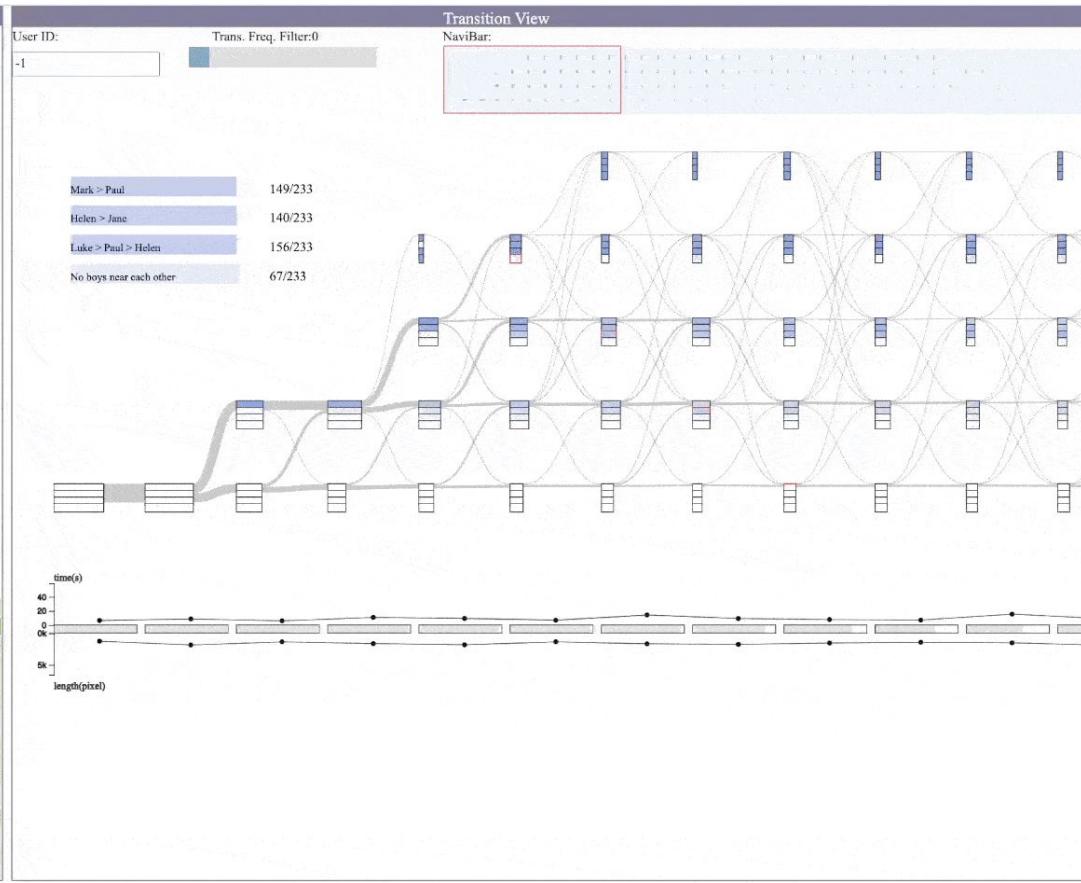
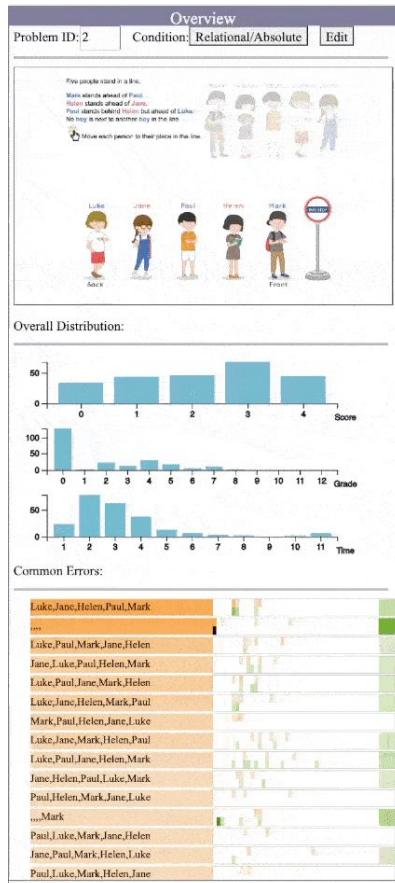


Move each person to their place in the line.

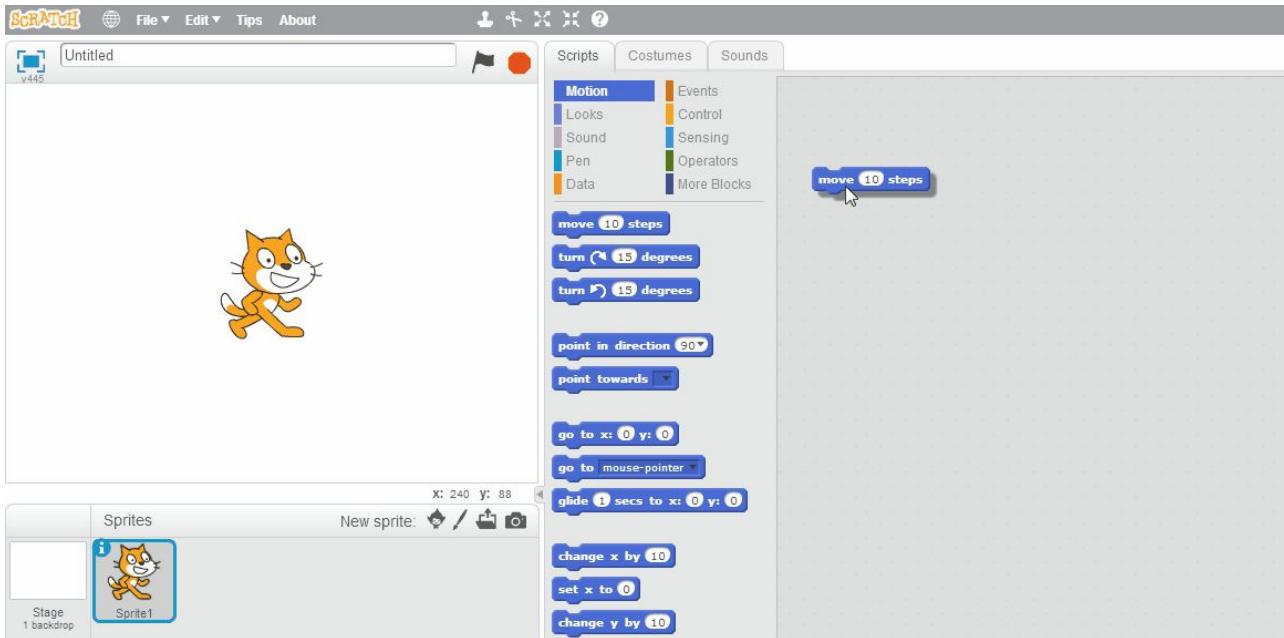


Back

Front



# A Multi-step Problem - II



# A Multi-step Problem - III

Please solve for x

$$-18 = 3(2x + 2)$$

$$-18 = 3 \cdot 2x + 3 \cdot 2$$

| {

Subtract Variable

Subtract Constant

Simple Division

Complex Division

Distribute Division

Distribute Multiplication

Simplify Division

Combine Like Variable Terms

Combine Like Constant Terms

Cancel Variable Terms

Cancel Const Terms

?  
Hint

✓  
Finish  
Problem

# BlockLens: Visual Analytics of Student Coding Behaviors in Block-Based Programming Environments

Sean Tsung, Huan Wei, Haotian Li, **Meng Xia**, Yong Wang, Huamin Qu  
L@S 2022 (Short Paper)

**A Question 1-6**

**B Student View**

Plot Options: Select Individual (blue dot), Select Group (white circle).

Student Checkpoint-Warning Plot: Shows warning signs (0.0 to 2.0) vs checkpoints (0 to 4). A legend indicates 'Correct' (green dots) and 'Incorrect' (orange dots). A tooltip shows User ID: 73427, Score: 800, Steps: 100, Checkpoints: 3, Average Step: 10, Average Time: 2m 52s.

Time Distribution Plot: Shows density (0.00 to 0.04) vs time taken (s) from 0 to 180. A legend indicates 'Correct' (green) and 'Incorrect' (orange).

Step Count Distribution Plot: Shows density (0.0 to 0.4) vs step count (0 to 50). A legend indicates 'Correct' (green) and 'Incorrect' (orange).

**C Path Summary View**

The Path Summary View displays a network of student paths through a set of code blocks. Nodes represent different sequences of blocks, such as 'start', 'set motors AB', 'move', 'speed (%)', and 'stop'. Edges show the frequency of transitions between these blocks, categorized by path length (2, 3, 4, 5, 6+ blocks). The graph highlights frequent paths (e.g., Frequent 1, Frequent 2, Frequent 3, Frequent 4, Frequent 5, Frequent 6, Frequent 7, Frequent 8) and other solutions (e.g., Other Solution 1, Other Solution 2).

# Involving Teachers in the Data-driven Improvement of Intelligent Tutors: A Prototyping Study

Meng Xia, Xinyi Zhao, Dong Sun, Yun Huang, Jonathan Seawall, Vincent Aleiven

AIED 2023

**A**

**B**

Students Problem-Solving Paths

**C**

Selected Path

(1) hint request

Level 1: You have constants on both sides. How can you have all constants on the right and none on the left?

# of student	10
# of time	13

Level 2: How can you get rid of 3 on the left?

# of student	6
# of time	12

Level 3: Subtract 3 from both sides.

# of student	6
# of time	11

Level 4: Enter  $x-3+3 = 5-3$

# of student	4
# of time	4

(1) hint request  
(2)  $x-3+3$   
(3) hint request  
(4) 2  
(5) 2x

**C1**



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



Educators (design loop)



Learners (learning loop)

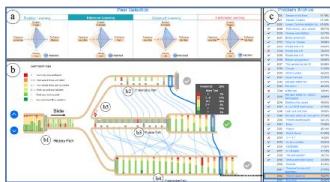
Planning

Performing  
Data

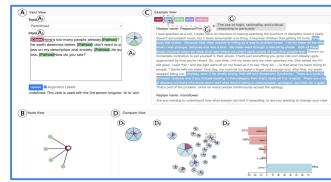
Reflecting

Understanding  
and Analyzing

Redesigning



Peerlens (CHI 2019)



Persua (CSCW 2022)



RLens (L@S 2022)



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**.



Educators (design loop)



Learners (learning loop)

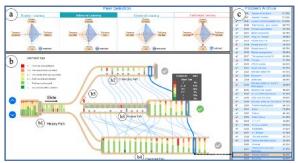
Planning

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Data

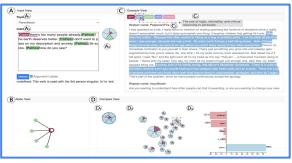
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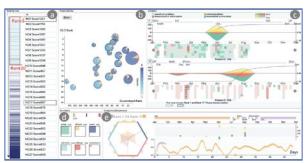
Peerlens (CHI 2019)



Persua (CSCW 2022)



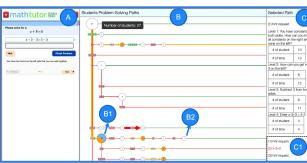
RLens (L@S 2022)



SeqDynamics (EuroVIS  
2020)



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**.



Distributed Tutorship (LAK  
2022)



BlockLens (L@S 2022)

## Future Research Direction

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

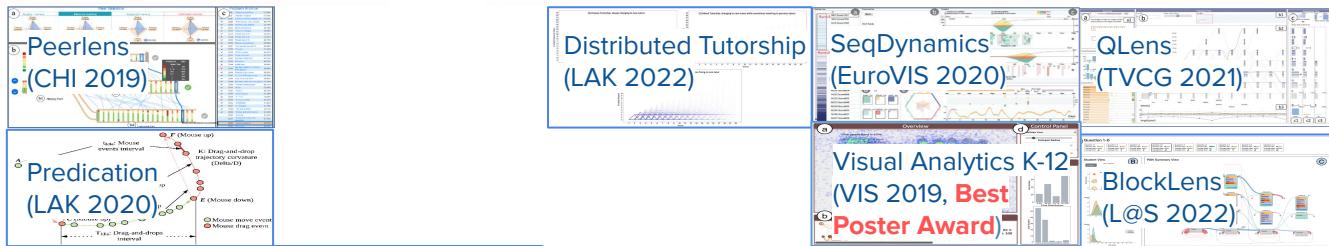
# More Comprehensive



Educators (design loop)



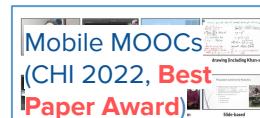
Event Sequence



Text

Code

Video



# More Comprehensive - Education data visualization library

Important factors to be considered and explored comprehensively

Target users

e.g. educators, learners

Data Types

e.g. mouse trajectory, event sequence, code, text, video/audio, facial expression, body gestures, performance

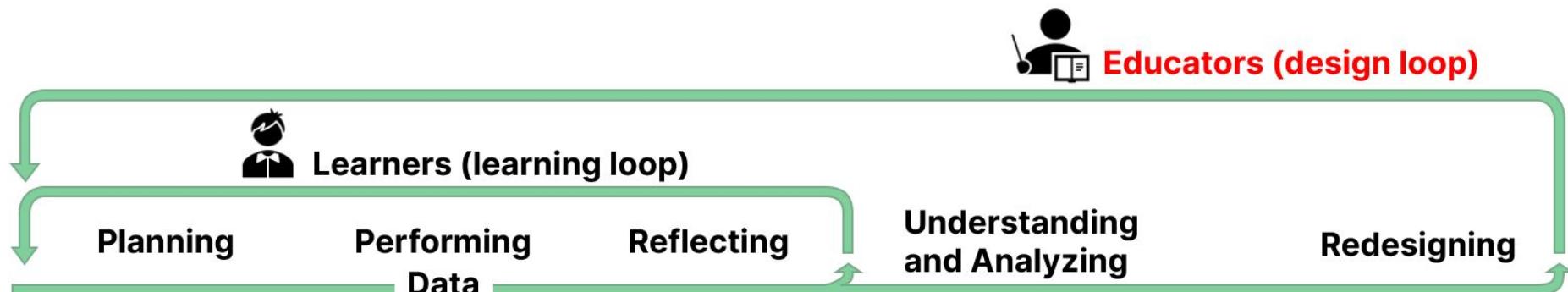
Data Tasks

e.g. summarization, comparison, trend, correlation

Time dimension

Real-time analysis, offline analysis

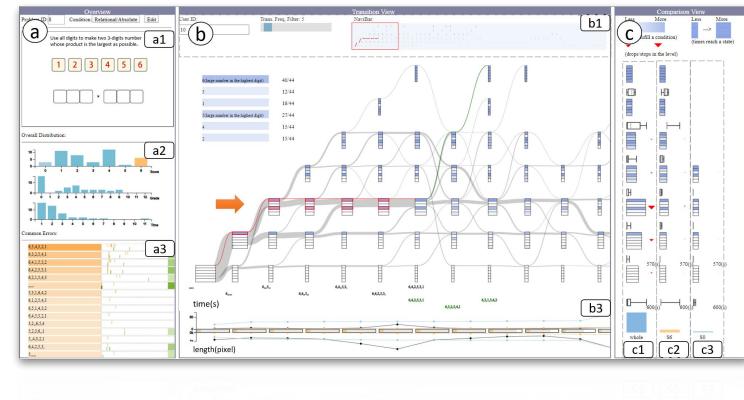
# More Actionable



*How to push forward learning analytics towards learning design via teacher-AI collaboration?*



# More Actionable



The figure shows the CTAT (cognitive tutor authoring tools) interface. It includes:  
1. A left sidebar with a tree view of packages: FractionAdditionData, CognitiveModel, and FinalBPDs.  
2. A central workspace showing a flowchart of a fraction addition problem:

```
graph LR; 1[1] --> 2[2]; 1 --> 4[4]; 2[2] --> 3[3]; 4[4] --> 5[5]; 5[5] --> 6[6]; 3[3] --> 5[5]; 5[5] --> 6[6]; 5[5] --> 12[12]; 12[12] --> 6[6]
```

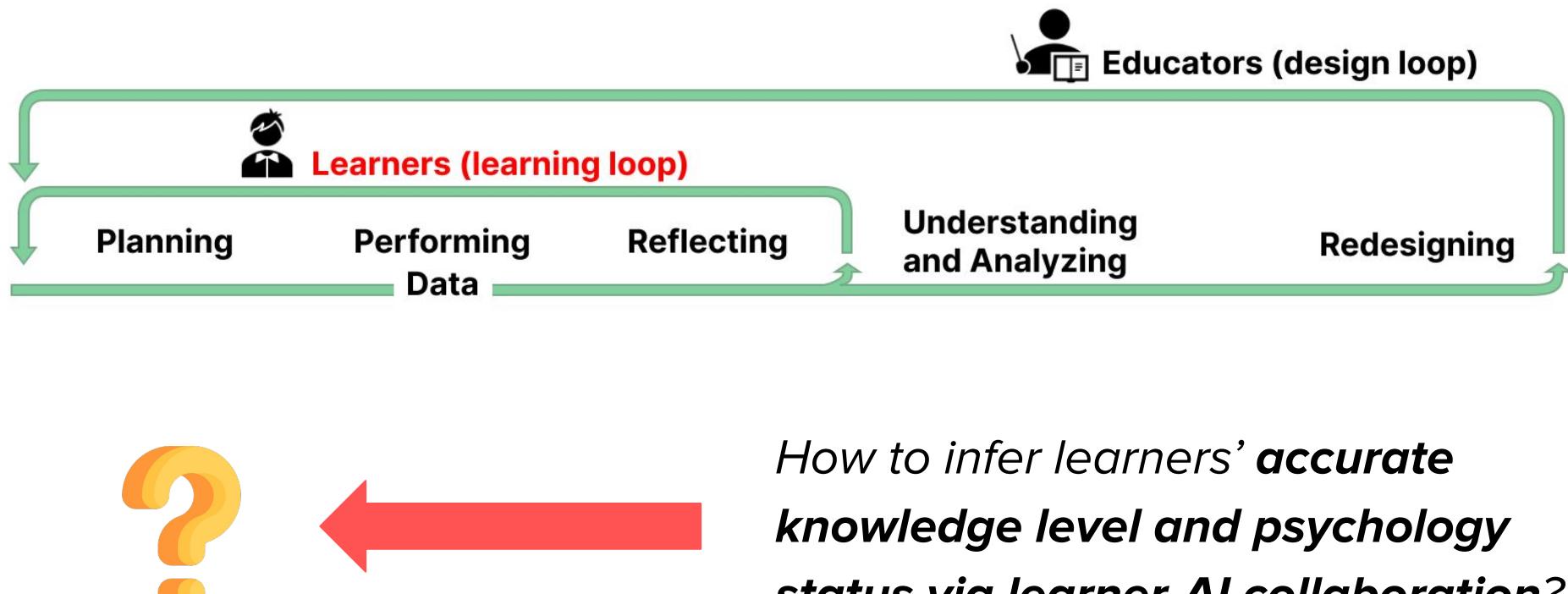
Annotations include: 1.firstNumGiven, 1; 2.firstDenGiven, 4; 3.secNumGiven, 1; 4.secDenGiven, 6; 5.firstDenConv, 12; 6.  
3. A right panel titled "Perform the Fraction Addition Problem" with fields for "Given Fractions" (1/4, 1/6) and "Converted Fractions" (1/12, 1/12).  
4. A bottom panel for "Link ID" (5), "General", "SAI Matching", and "Hints".  
5. A status bar at the bottom with "Link ID: 5", "FirstDenConv: 12", "General", "SAI Matching", and "Hints Skills".

QLens: Learning analytics

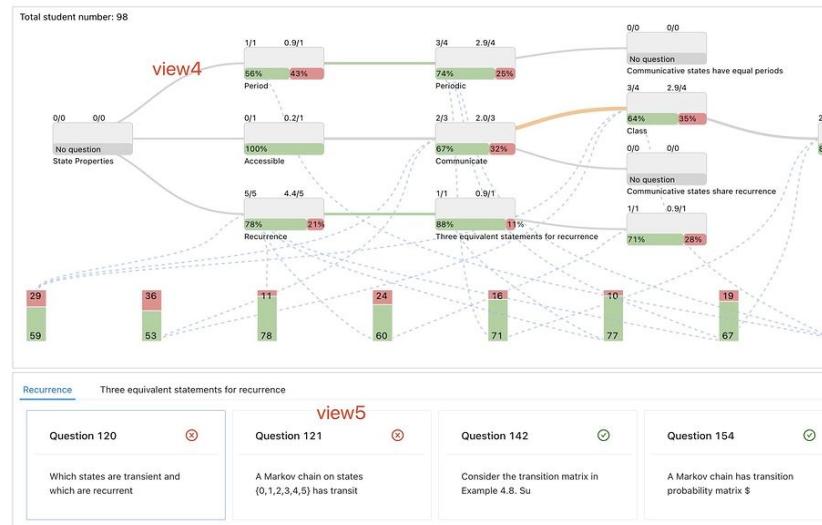
**Teacher-AI collaboration:** data-driven optimization for learning materials

CTAT (cognitive tutor authoring tools):  
Learning design

# More Effective



# More Effective

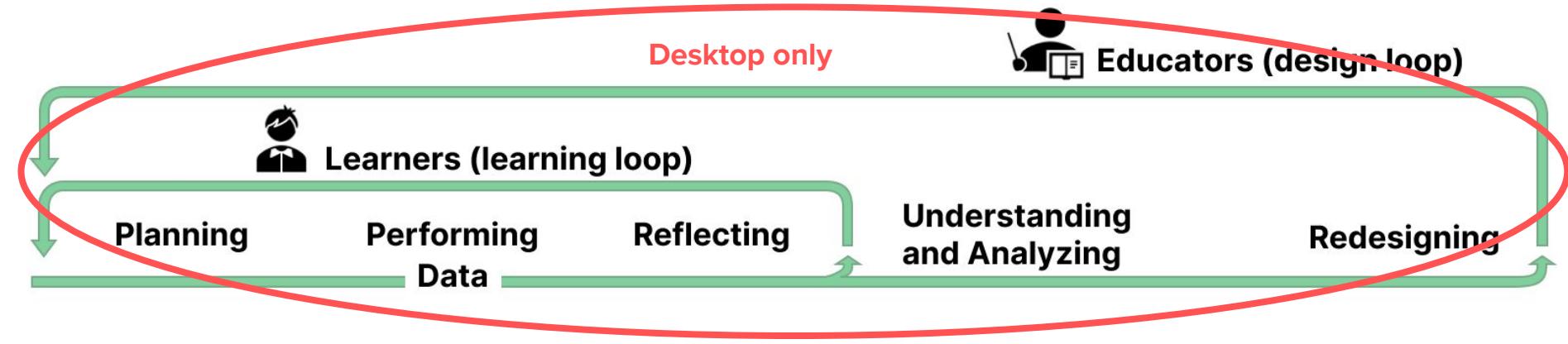


Multiple Rounds Conversations/Interactive Knowledge Map

Other data

**Learner-AI collaboration:** Reason the Knowledge Level and psychology status

# More Context-aware



*What are the **needs**, **challenges**, and **opportunities** of personalized online learning in contexts other than desktop?*

# More Context-aware - *Immersive Online Learning*



## Learning in VR?

- **Cinematography Education** on a Soundstage in VR (ongoing, poster, VR 2023)
- VR Story for **Awareness of Covid Spread Threats** (Zhu et al., IJHCI 2023)
- Towards an Understanding of Asymmetric **Collaborative Visualization on Problem-solving** (Tong et al., VR 2023)

## Learning in AR?

- Exploring Interactions with Printed Data Visualizations in Augmented Reality (Tong et al., TVCG 2023, **Honorable Mention Award**)

Other opportunities, e.g., **on-the-go learning**, digital twin campus?



# More Context-aware - *Ubiquitous Online Learning*



Mobile-Friendly Content Design for MOOCs:  
Challenges, Requirements, and Design Opportunities  
(Kim et al., CHI 2022; **Best Paper Award**)



Intelligent tutors on smartphones  
(4-year IES project; ongoing)

Interactions on  
intelligent tutors?





Educators (design loop)



Learners (learning loop)

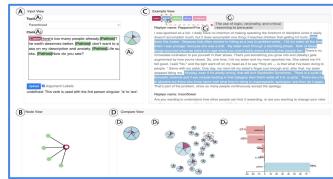
Planning

Performing  
Data

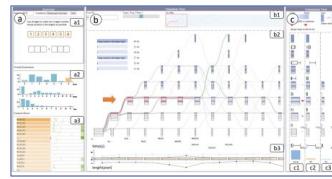
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Redesigning



Persua (CSCW 2022)



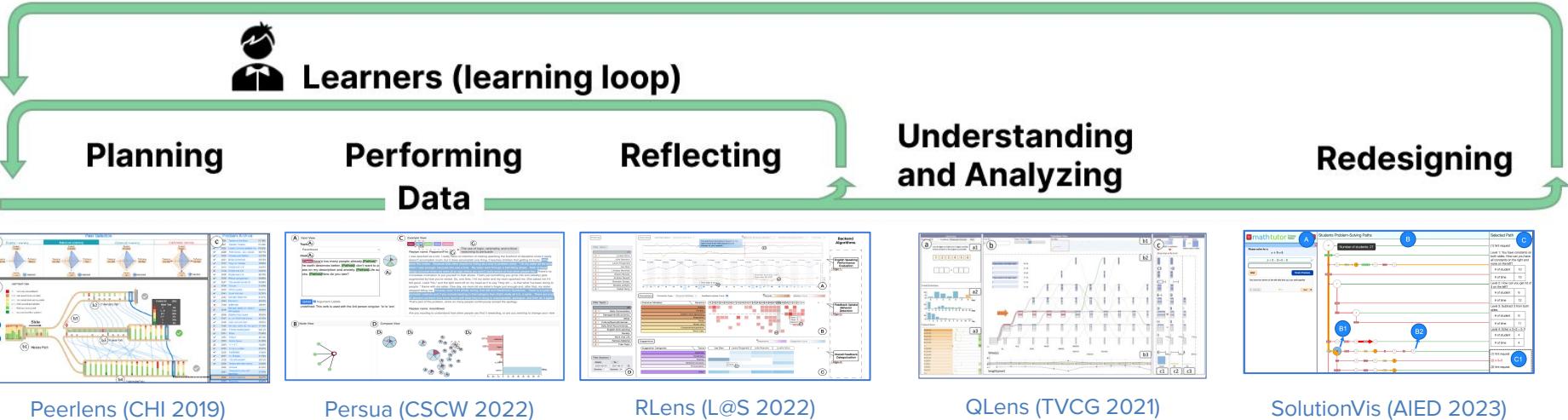
QLens (TVCG 2021)

## Human-centered Data-driven Systems for Personalized Online Learning

Welcome to join our lab!

Personal page: <https://www.xiameng.org> Email: [xiameng9355@gmail.com](mailto:xiameng9355@gmail.com)



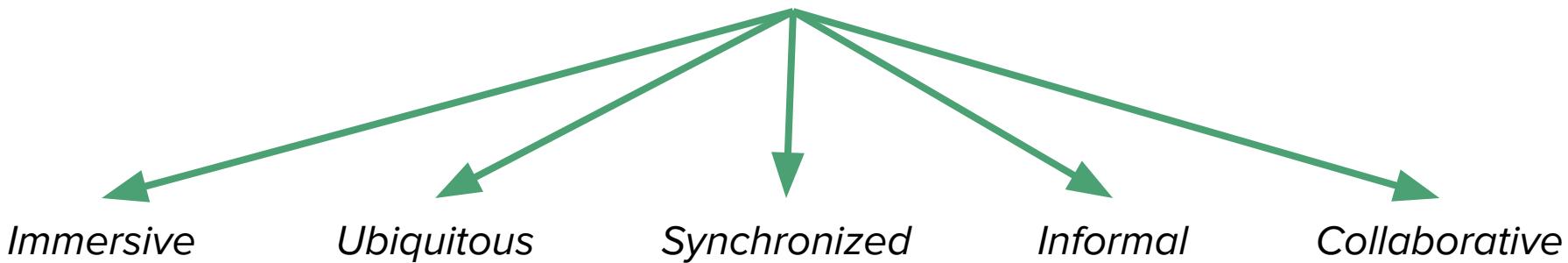


## Human-centered Data-driven Systems for Personalized Online Learning

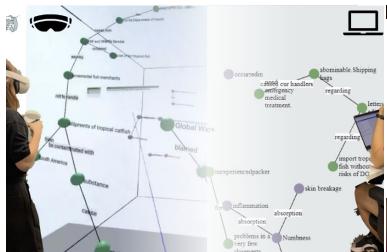
Personal page: <https://www.xiameng.org> Lab page: <https://www.xiameng.org/DreamLab/>

# More Context-aware

Stationary PC environment



Immersive



Ubiquitous



Synchronized



Informal



Collaborative

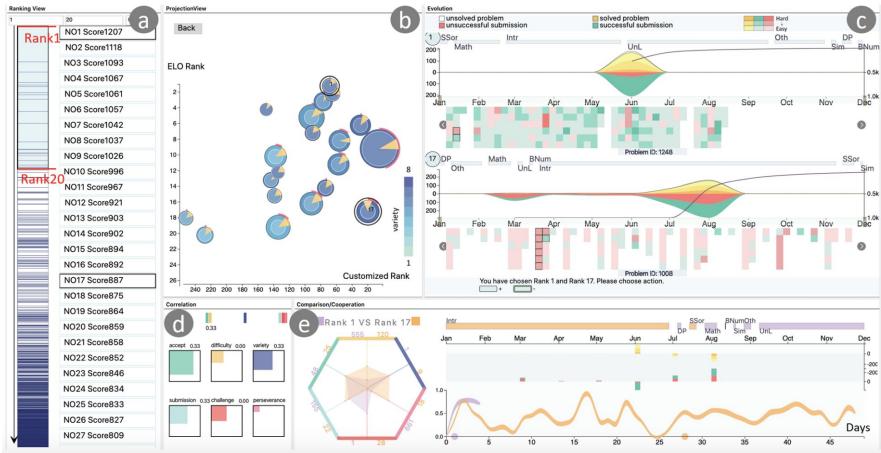


- Towards an Understanding of  
Asymmetric Collaborative Visualization  
on Problem-solving VR2023

- Exploring Interactions with Printed Data  
Visualizations in Augmented Reality  
(Tong, et al., VIS 2022; **Honorable  
Mention Award**)

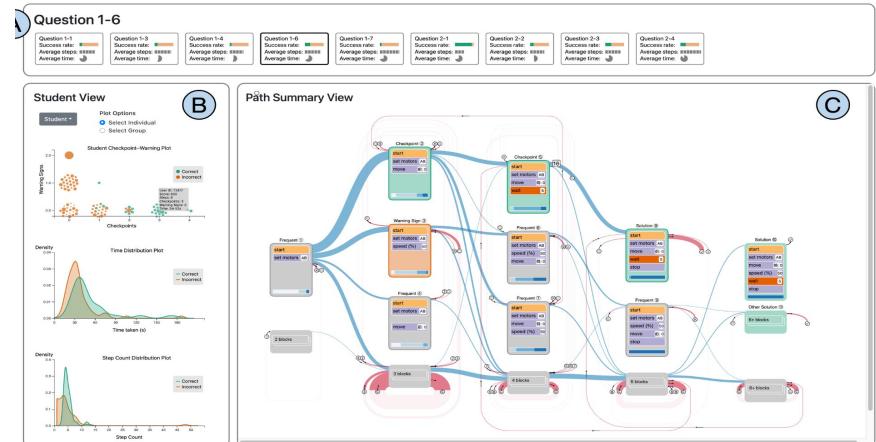
Mobile-Friendly Content Design for  
MOOCs: Challenges, Requirements, and  
Design Opportunities (Kim et al., CHI  
2022; **Best Paper Award**)

# Other work



SeqDynamics: Visual Analytics for Evaluating Online Problem-solving Dynamics (EuroVis 2020)

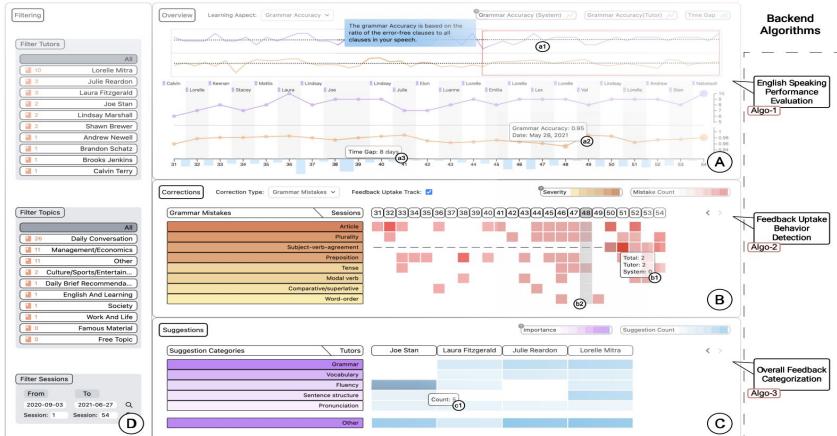
Analyze students' learning habits  
on online question pools



BlockLens: Visual Analytics of Student Coding Behaviors in Block-Based Programming Environments (L@S WIP 2022)

Analyze block-based programming process  
(e.g. Scratch)

# Other work

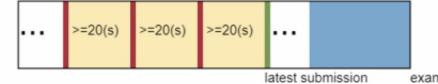


RLens: A Computer-aided Visualization System for Supporting Reflection on Language Learning under Distributed Tutorship (L@S 2022)

Help students' reflect their language learning progress

Here is how people spend their time on this problem:

Good students: more reflection time + less review time:



Struggling students: less reflection time + more review time:



Your recent submission records:



Using Information Visualization to Promote Students' Reflection on “Gaming the system” in Online Learning (L@S 2020)

Help students reduce “gaming the system” behaviors

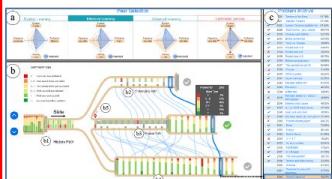


Educators (design loop)



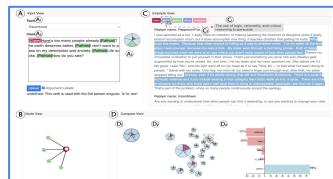
Learners (learning loop)

### Planning



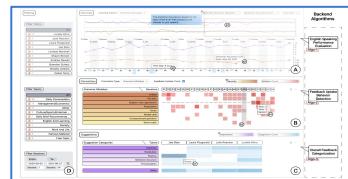
Peerlens (CHI 2019)

### Performing Data



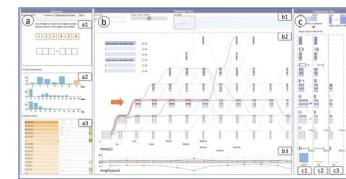
Persua (CSCW 2022)

### Reflecting



RLens (L@S 2022)

### Understanding and Analyzing



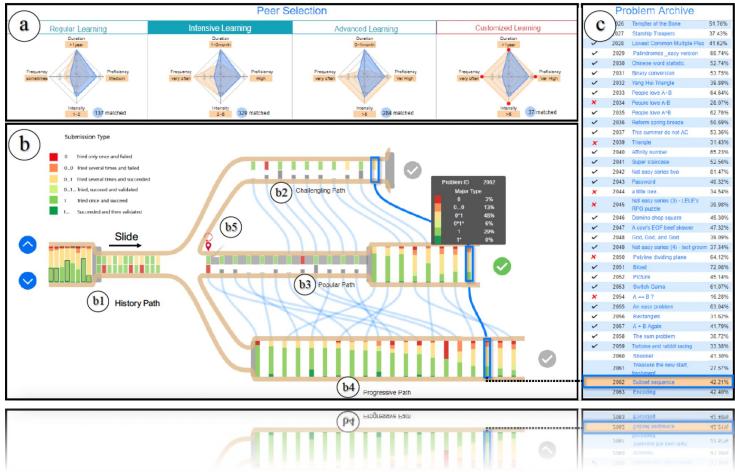
QLens (TVCG 2021)

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

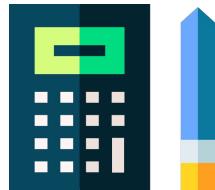
Meng Xia, Mingfei Sun, Huan Wei, Qing Chen, Yong Wang,  
Lei Shi, Huamin Qu, Xiaojuan Ma

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?**

# Related work: Educational Recommendation Techniques

(Drachsler et al., 2008) Content-based (e.g., Chu et al., 2011), Collaborative Filtering (e.g., Toledo et al., 2018), Hybrid approach (e.g., Salehi et al., 2013)

=> **We lack the problem label information for use**

Deep learning models (e.g., Piech et al., 2015), other models, such as Markov Chain (e.g., Rajapakse and Ho, 2005; Sarukkai 2000; Huang et al., 2009)

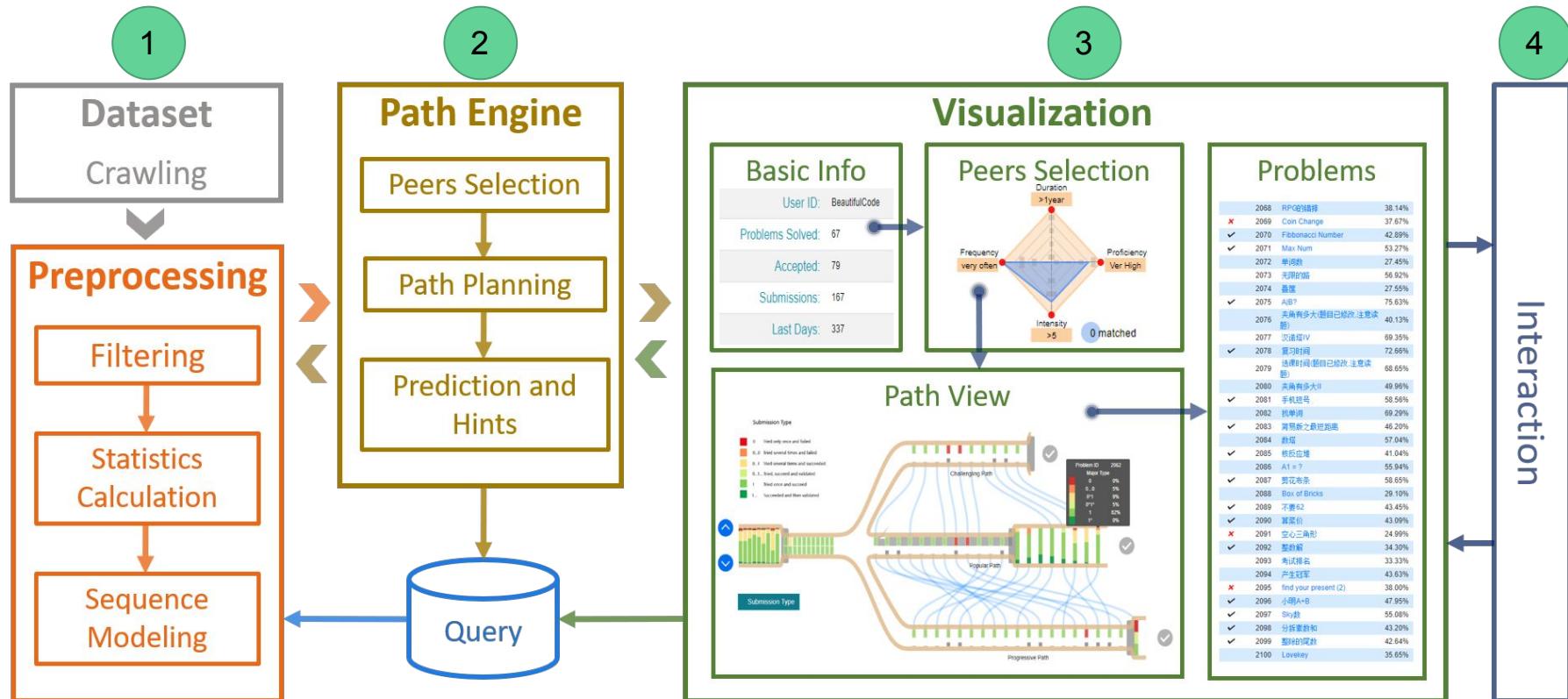
=> **Learners' intent is not well considered, and no explanation is provided for the results**

**How learning data can be used for planning the learning path?**

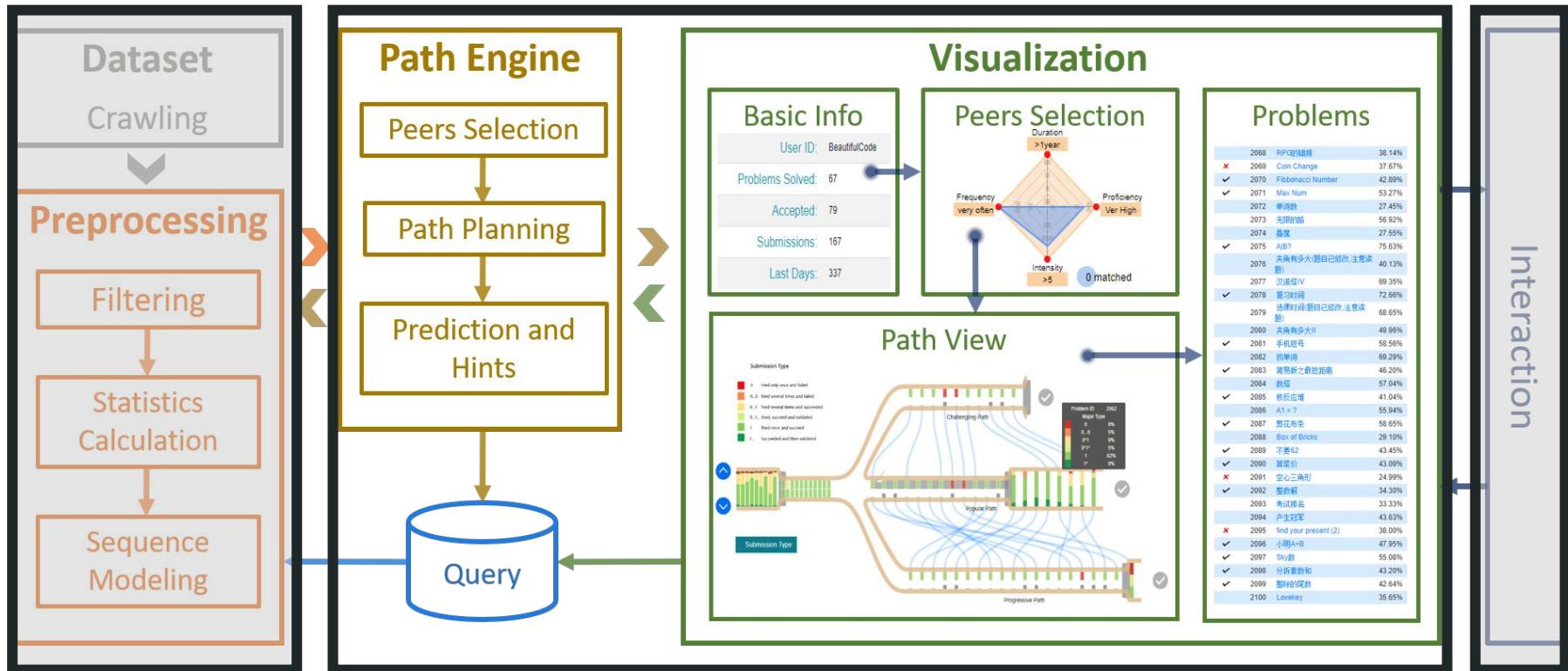
# A user-centered design process

- Four participants: two question pool designers and two 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



# System overview



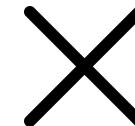
# How to quantify learner's performance?

R1: **Find peers** for a target learning scenario.

R2: **Compare with peers'** performance to understand the gap.

## Difficulty of the questions

Accept rate?



Q1



1/5 => Hard problem

Q1

P1



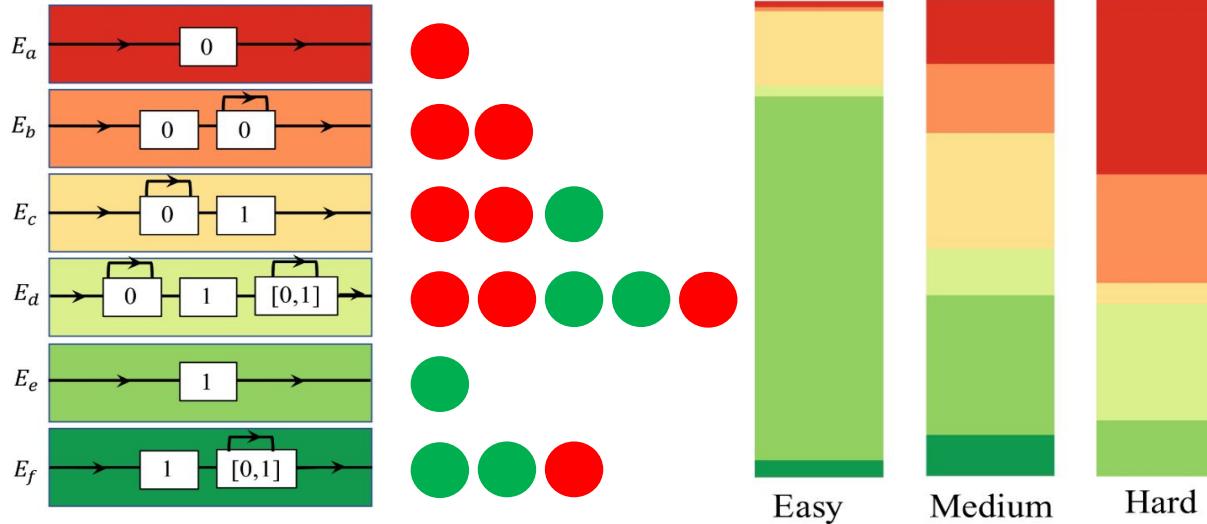
P2



Accept rate: 1/5 => **Still a hard problem?**

# How to quantify learner's performance?

**Submission type:** the way a learner submits a question.



- Captures learners' knowledge proficiency and attitude
- Enables the inference of question difficulty level

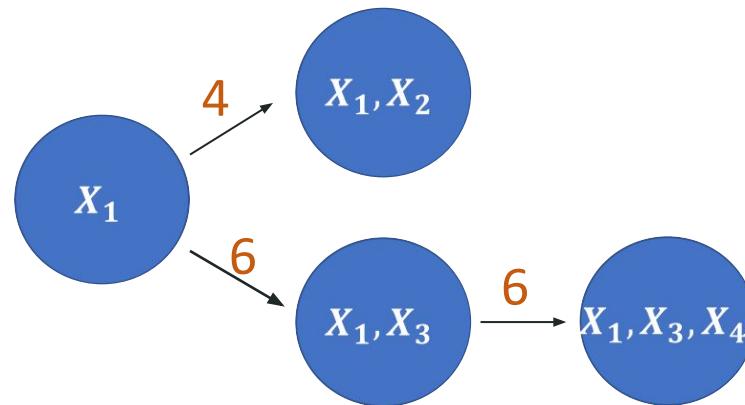
incorrect      correct

# How to recommend?

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.



Popular path:  $X_1 \rightarrow X_3 \rightarrow X_4$

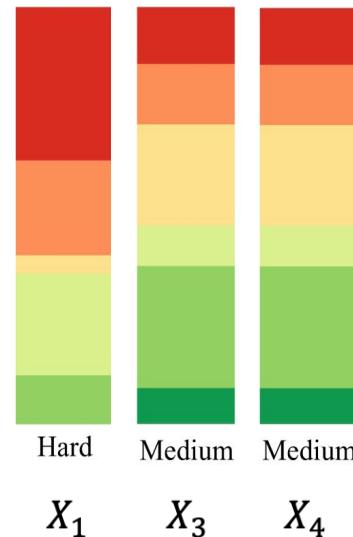
# How to recommend?

R1: **Find peers** for a target learning scenario.

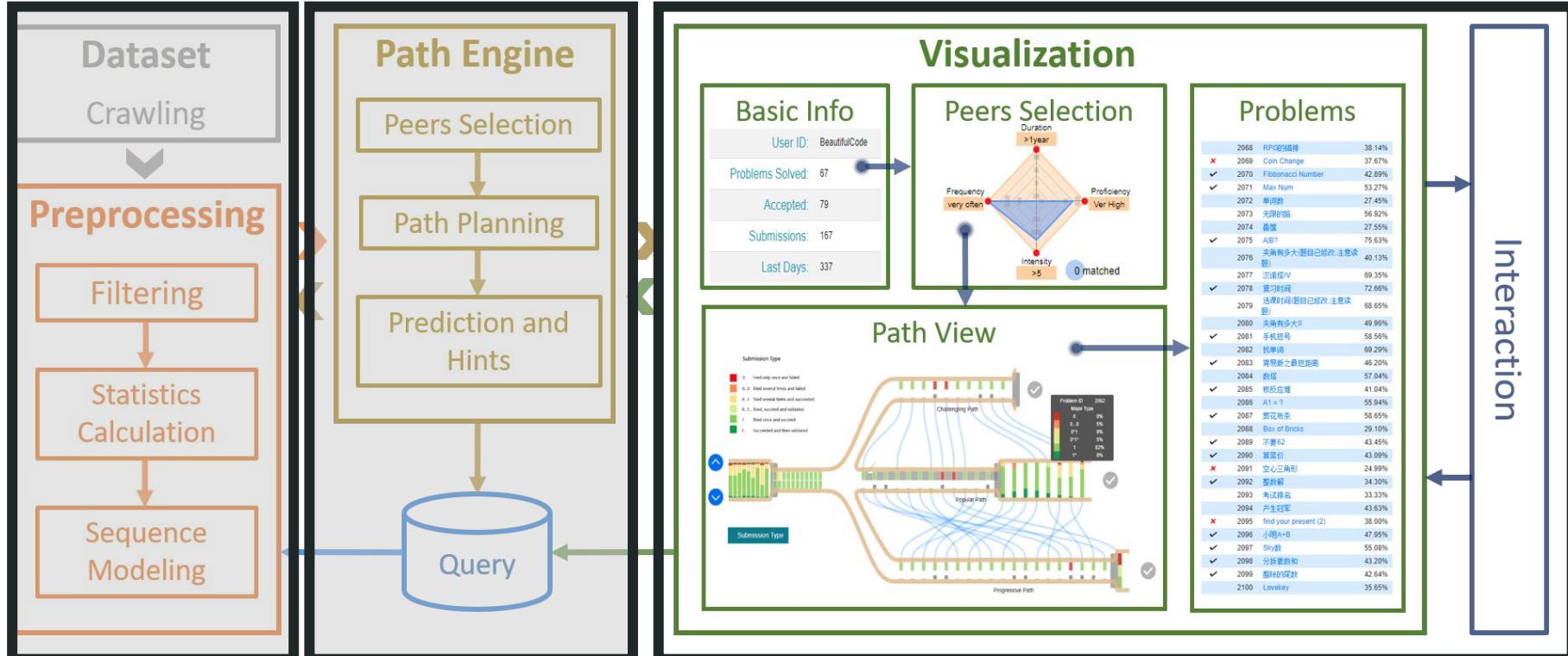
R2: **Compare with peers'** performance to understand the gap.

R3: Offer flexible learning **path suggestions** with explanations.

- Popular path:  $X_1 \rightarrow X_3 \rightarrow X_4$
- Challenging path:  $X_1 \rightarrow X_4$
- Progressive path:  $X_3 \rightarrow X_4 \rightarrow X_1$



# System overview



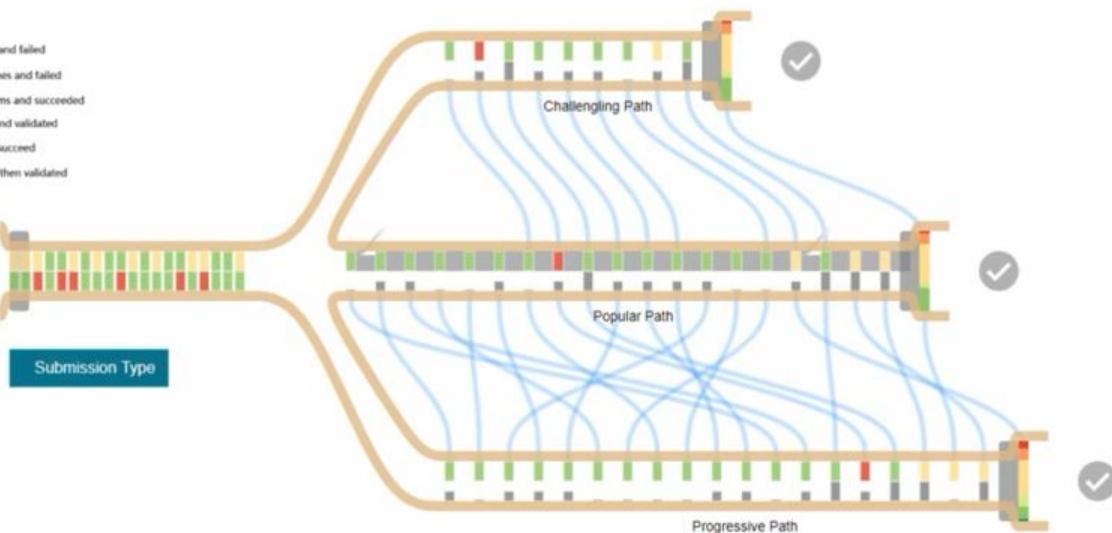
Basic Info	
User ID:	67
Problems Solved:	67
Accepted:	79
Submissions:	167
Last Days:	337

### Peer Selection



### Submission Type

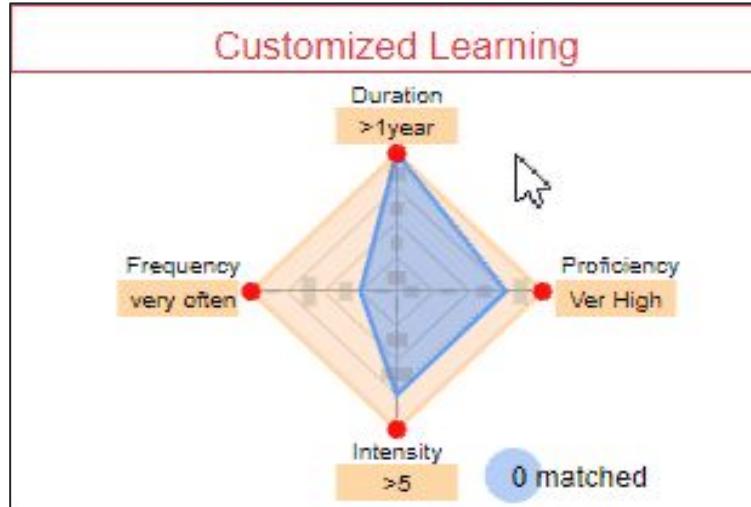
- 0 Tried only once and failed
- 0..0 Tried several times and failed
- 0..1 Tried several times and succeeded
- 0...1 Tried, succeed and validated
- 1 Tried once and succeed
- 1... Successed and then validated



### Problem Archive

✓ 2010	水仙花数	27.56%
✓ 2011	多项式求和	56.00%
✓ 2012	素数判定	36.26%
✓ 2013	墙砖记	74.46%
✗ 2014	青年歌手大奖赛_评委打分	48.51%
✓ 2015	偶数求和	39.52%
✗ 2016	数据的交换输出	36.36%
✓ 2017	字符串统计	55.48%
✓ 2018	母牛的故事	48.10%
✓ 2019	数列有序!	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	求平均成绩	21.66%
✓ 2024	C语言合法标识符	36.85%
✓ 2025	查找最大元素	51.91%
✗ 2026	首字母大写	51.76%
✓ 2027	统计元组	37.43%
✓ 2028	Lowest Common Multiple Plus	41.62%
✓ 2029	Palindromes _easy version	60.74%
✗ 2030	汉字统计	52.74%
✓ 2031	逆时转换	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	不普通系列之二	81.47%
✓ 2043	密码	40.32%
✓ 2044	一只小蜜蜂……LELE的RPG进阶	34.54%
✗ 2045	不普通系列之(3)——LELE的RPG进阶	39.98%

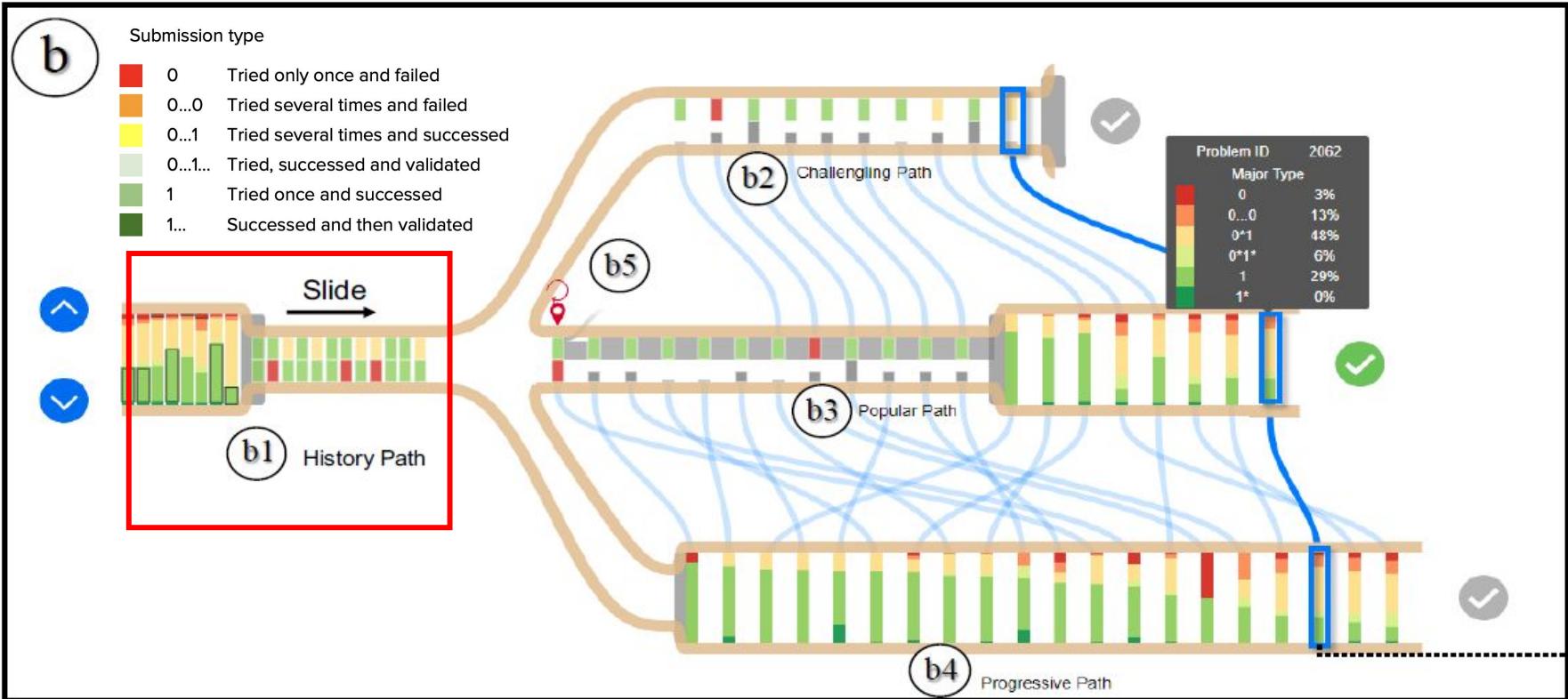
# Visual Design: Peer Selection View



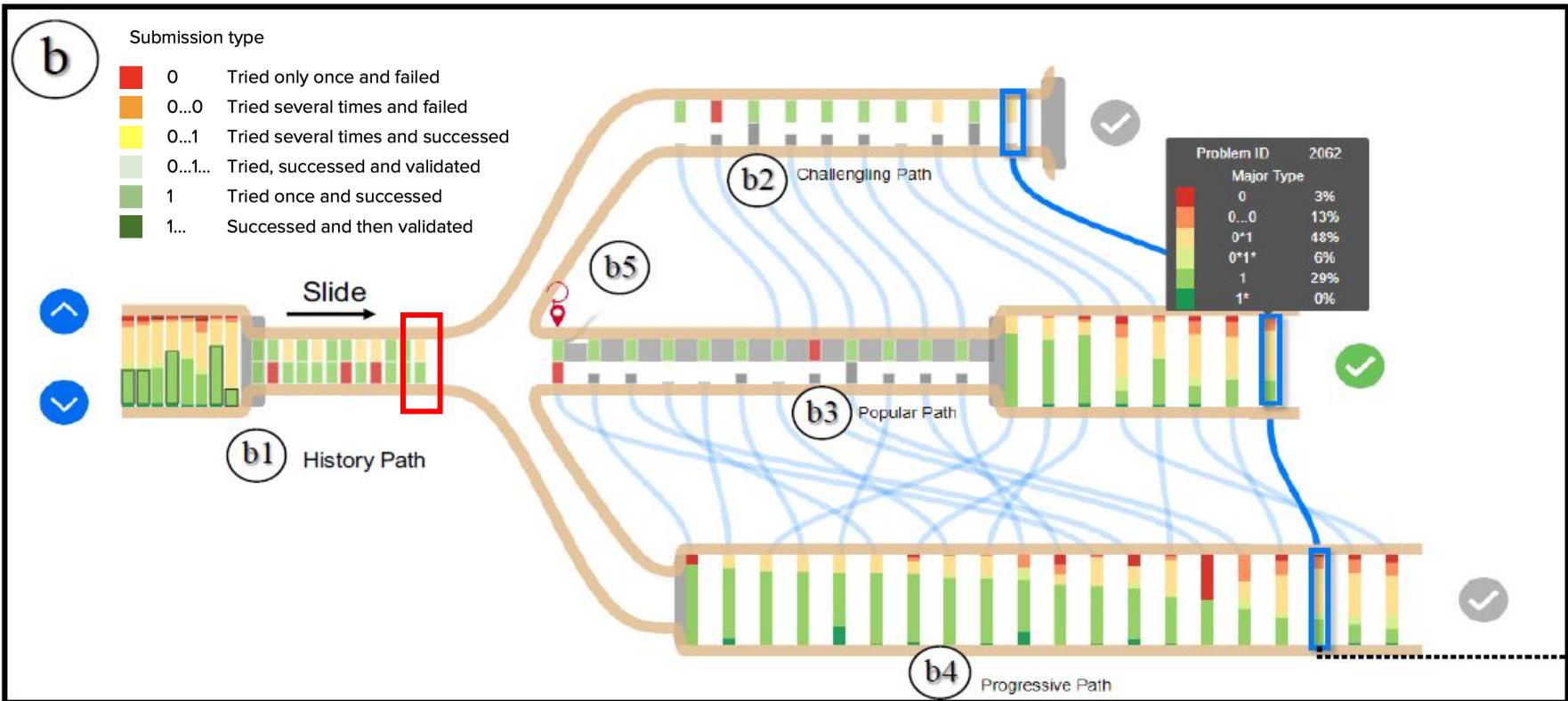
Yellow diamond plot: selected peers

Blue diamond plot: learner himself

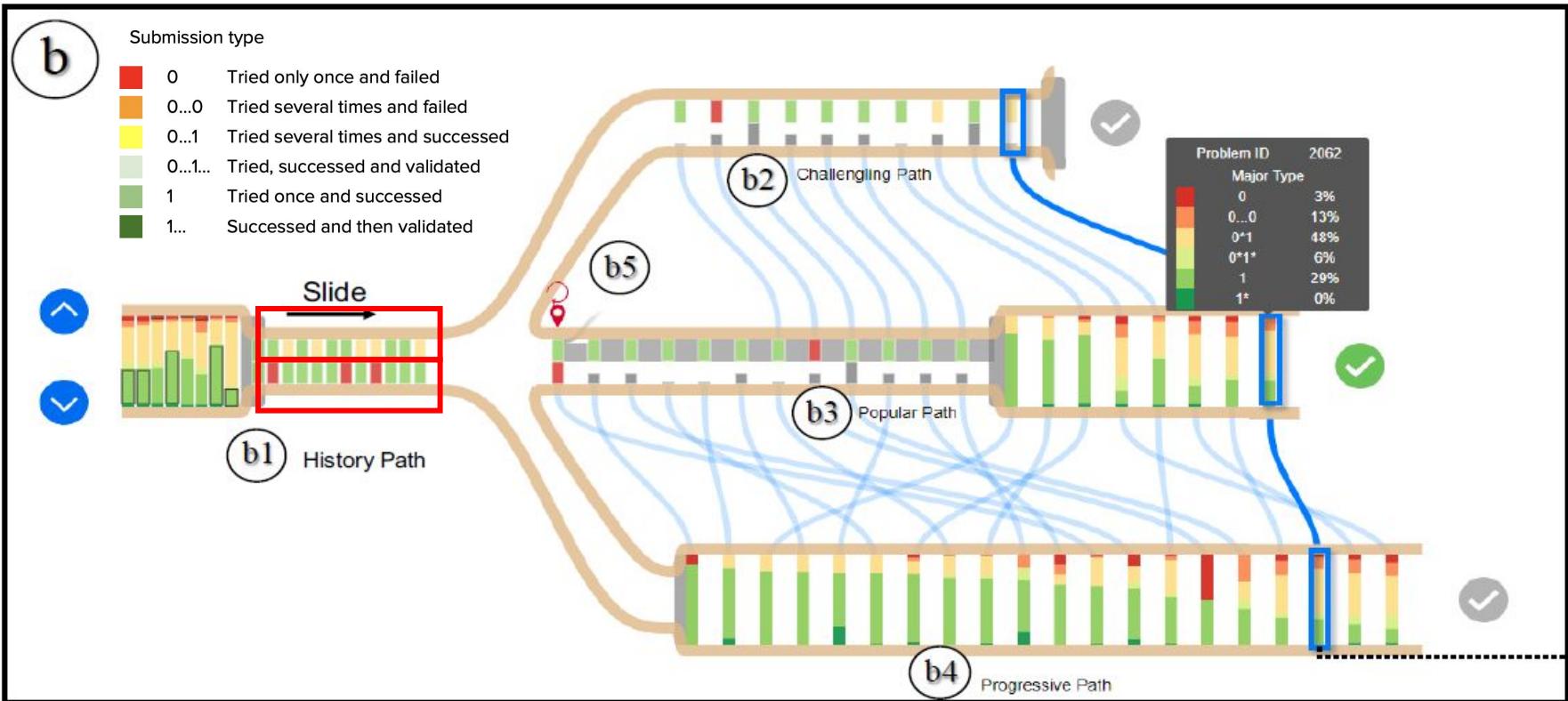
# Visual Design: Learning Path View



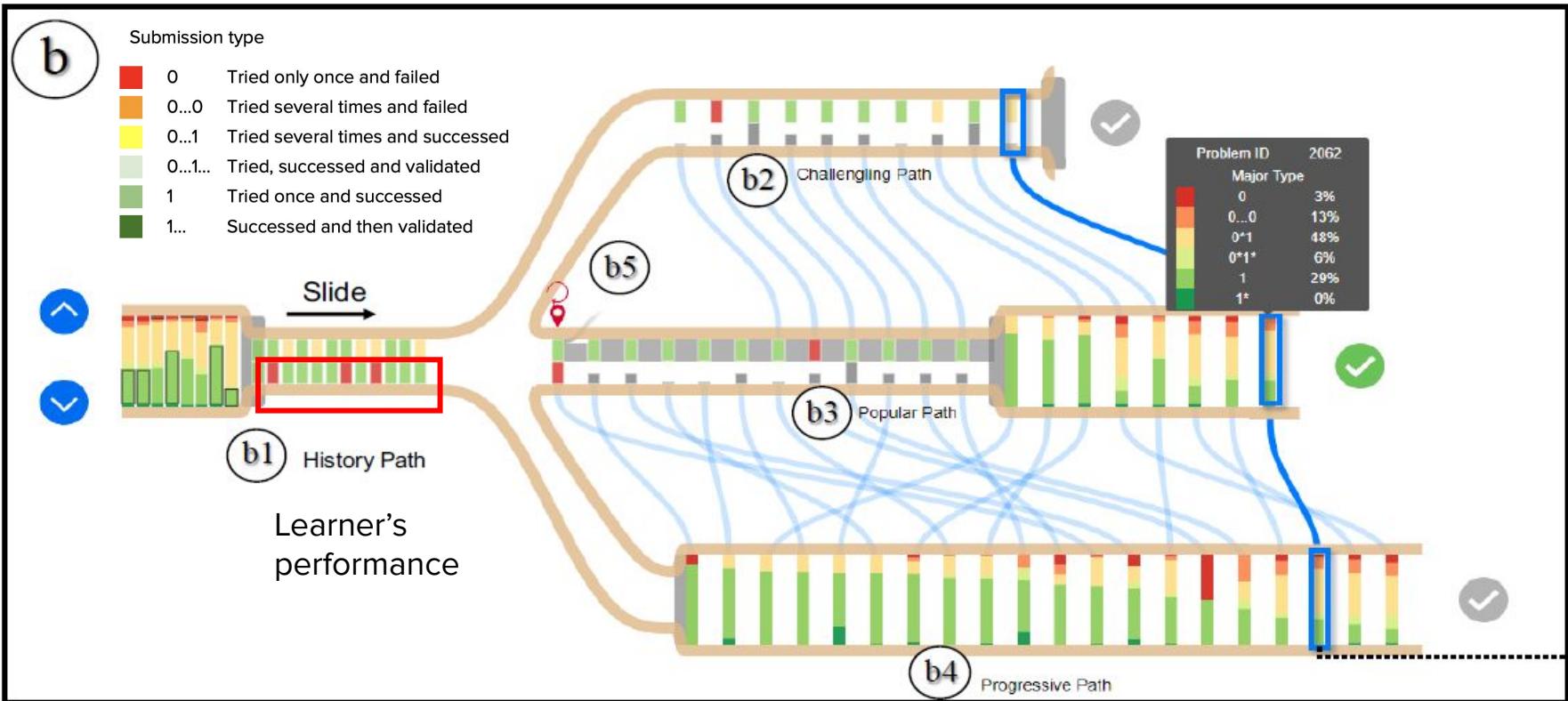
# Visual Design: Learning Path View



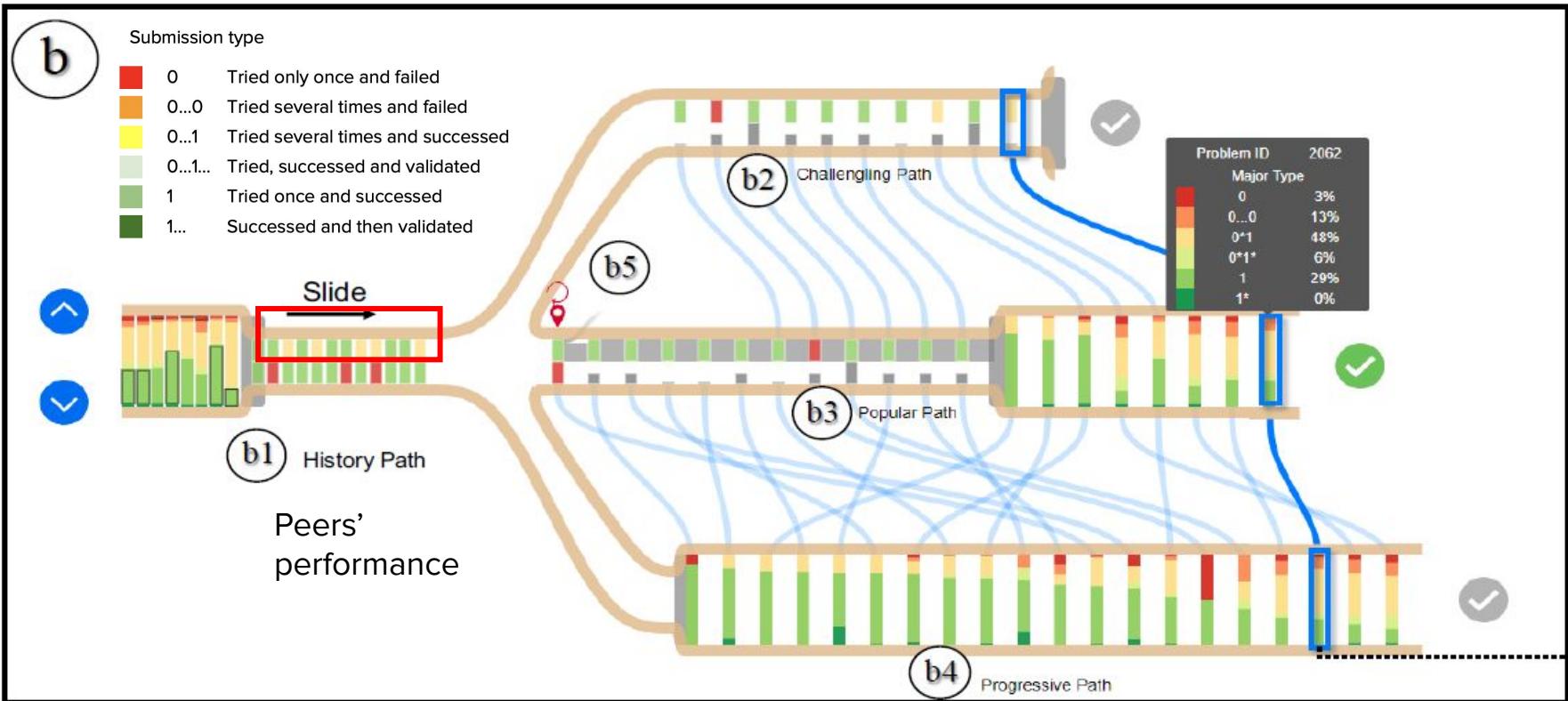
# Visual Design: Learning Path View



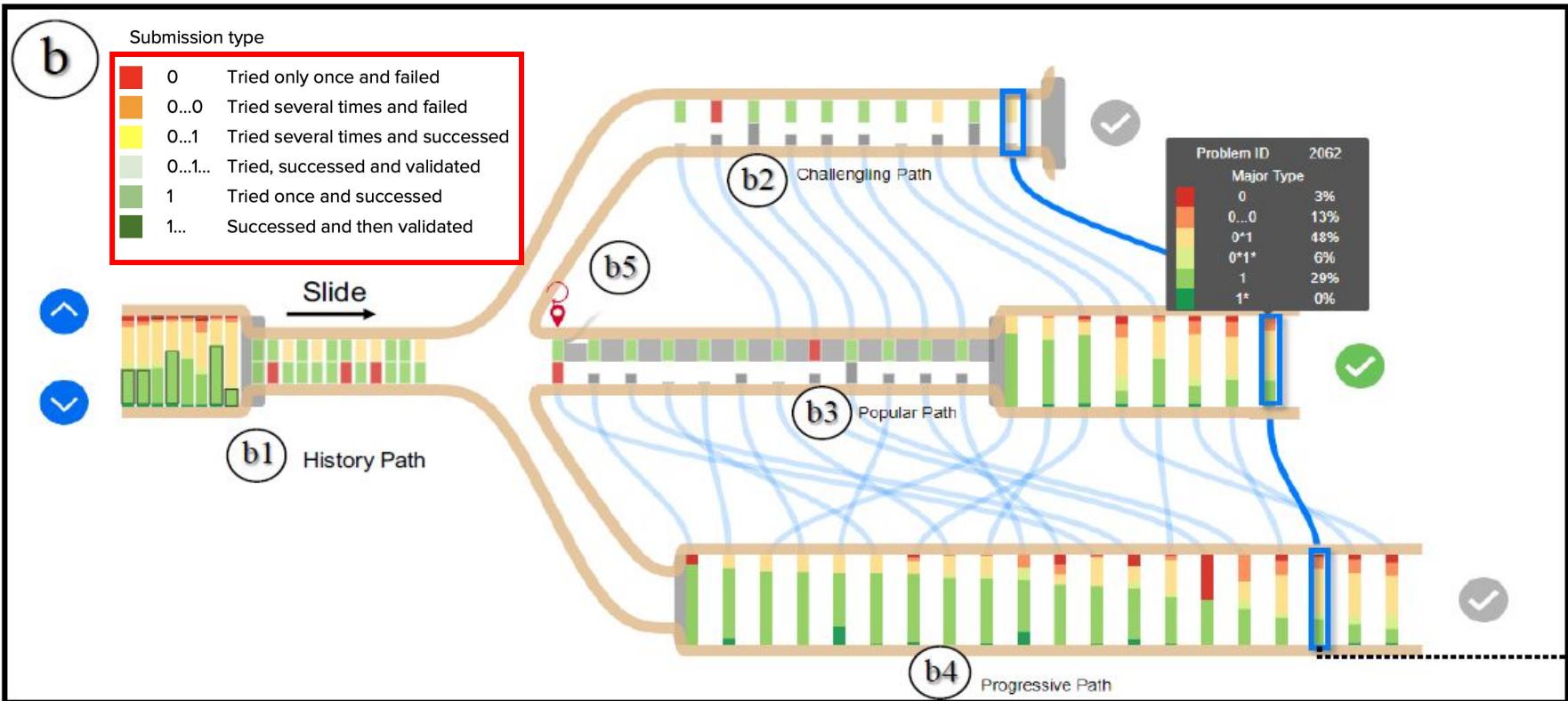
# Visual Design: Learning Path View



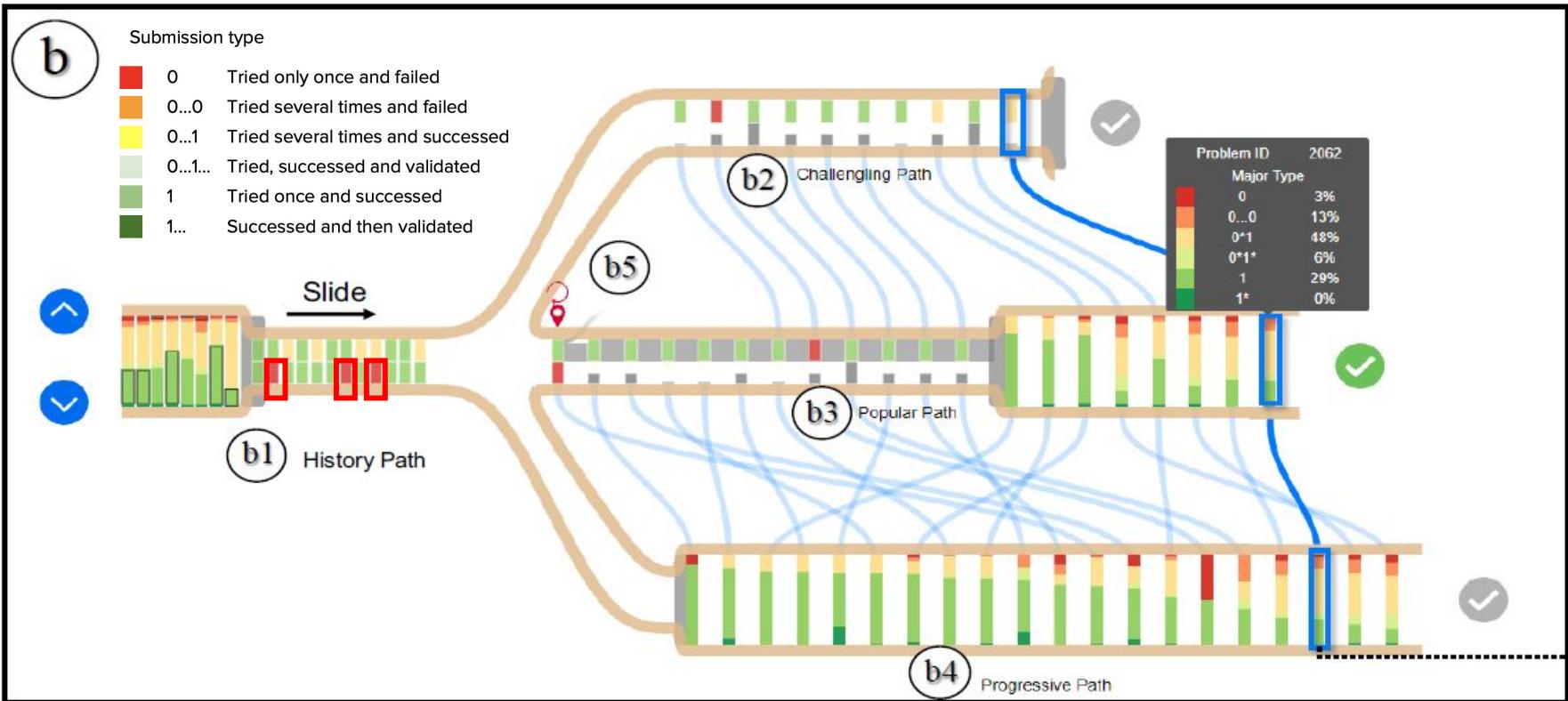
# Visual Design: Learning Path View



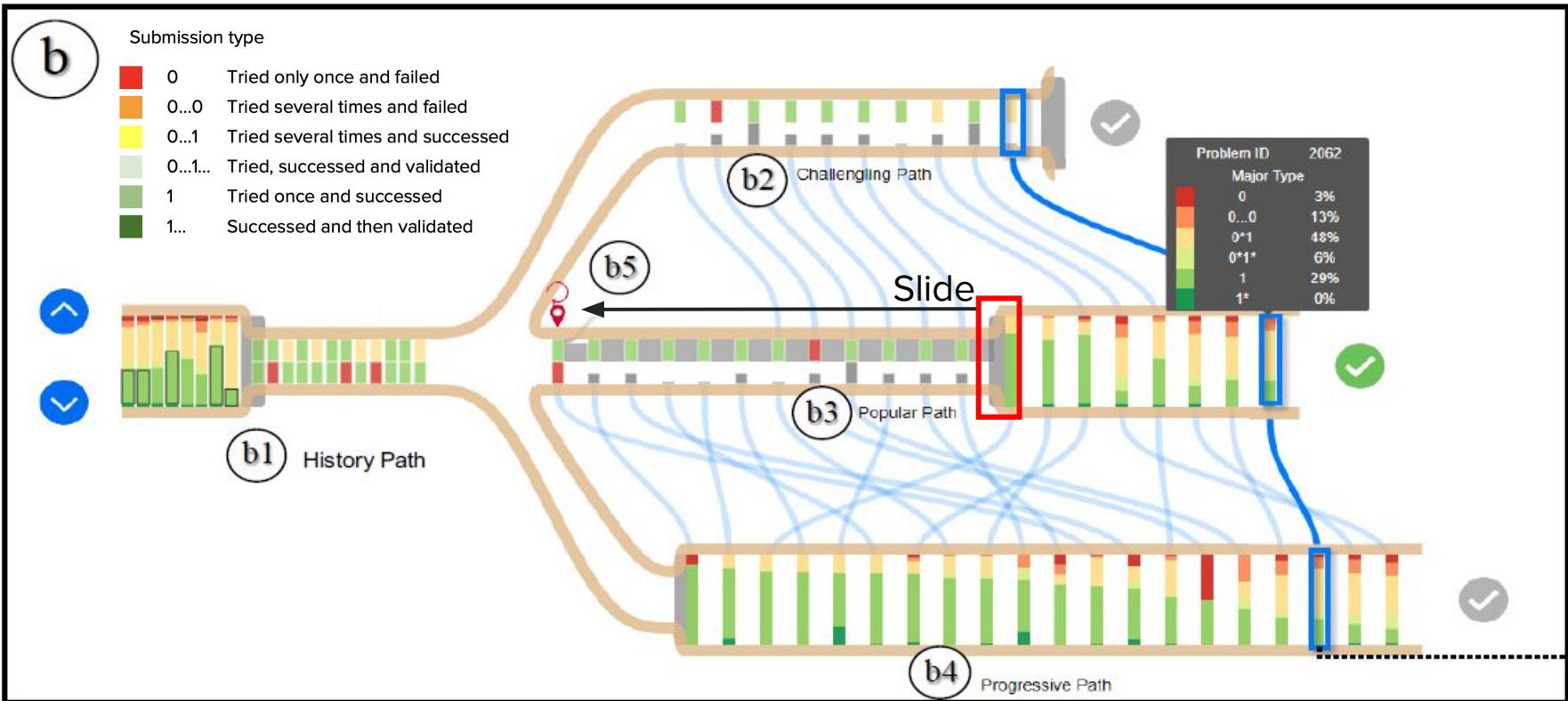
# Visual Design: Learning Path View



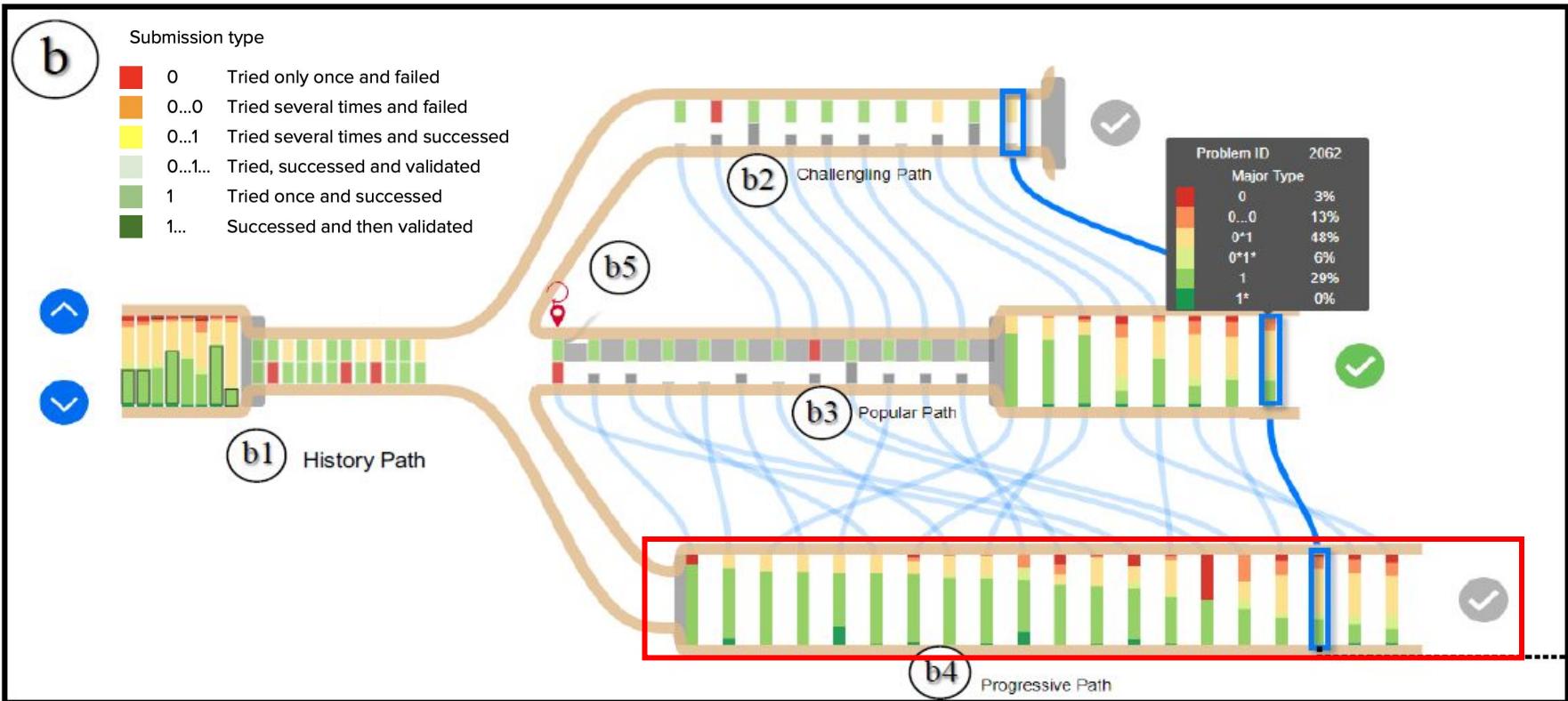
# Visual Design: Learning Path View



# Visual Design: Learning Path View



# Visual Design: Learning Path View



# 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 Title ▾ Go

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)

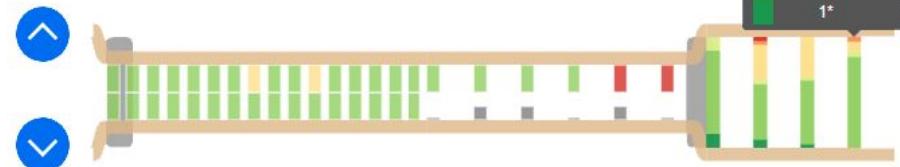
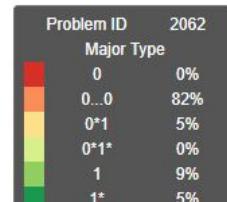
Baseline system (List View)

18 CS students:

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

Submission Type

- 0 Tried only once and failed
- 0..0 Tried several times and failed
- 0..1 Tried several times and succeeded
- 0...1... Tried, succeed and validated
- 1 Tried once and succeed
- 1... Succeeded and then validated

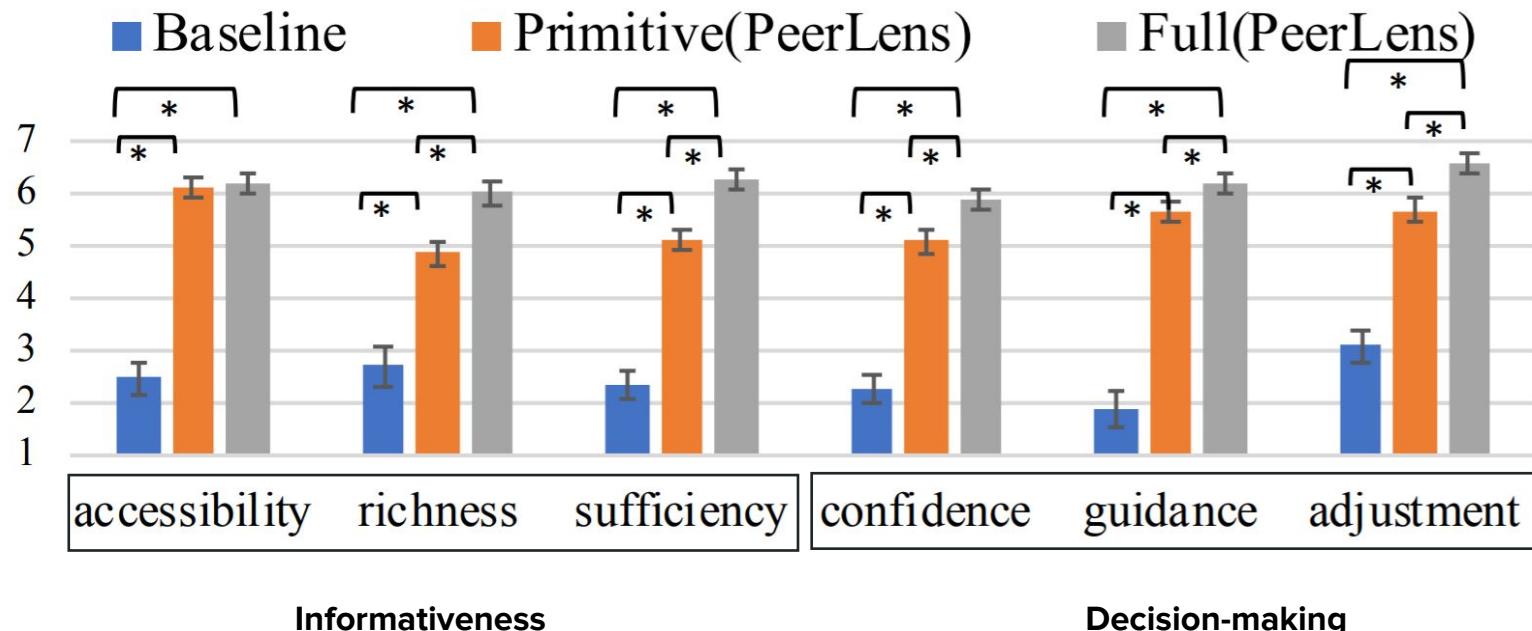


Primitive PeerLens (Only provide one path)

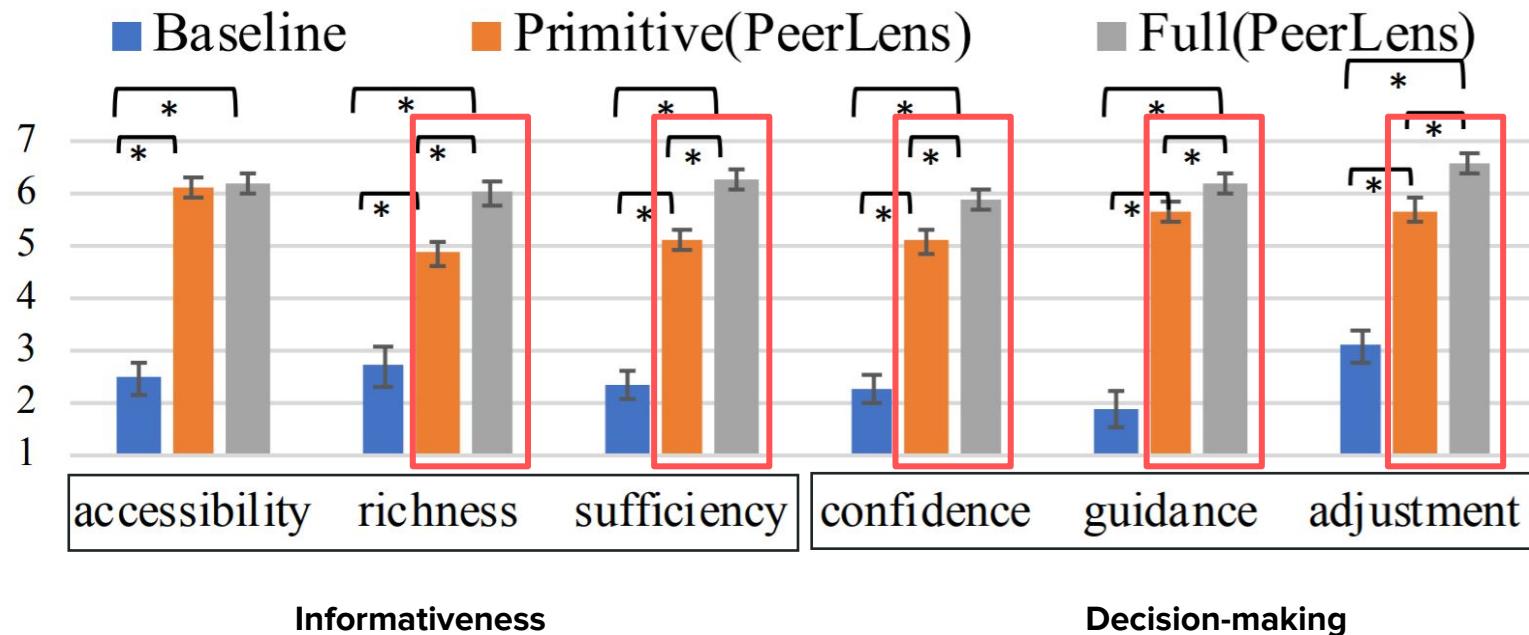
# Evaluation: Questionnaires

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.
	Q9	It was easy to learn the system.
System Usability	Q10	It was easy to use the system.
	Q11	I would like to recommend this system to others.

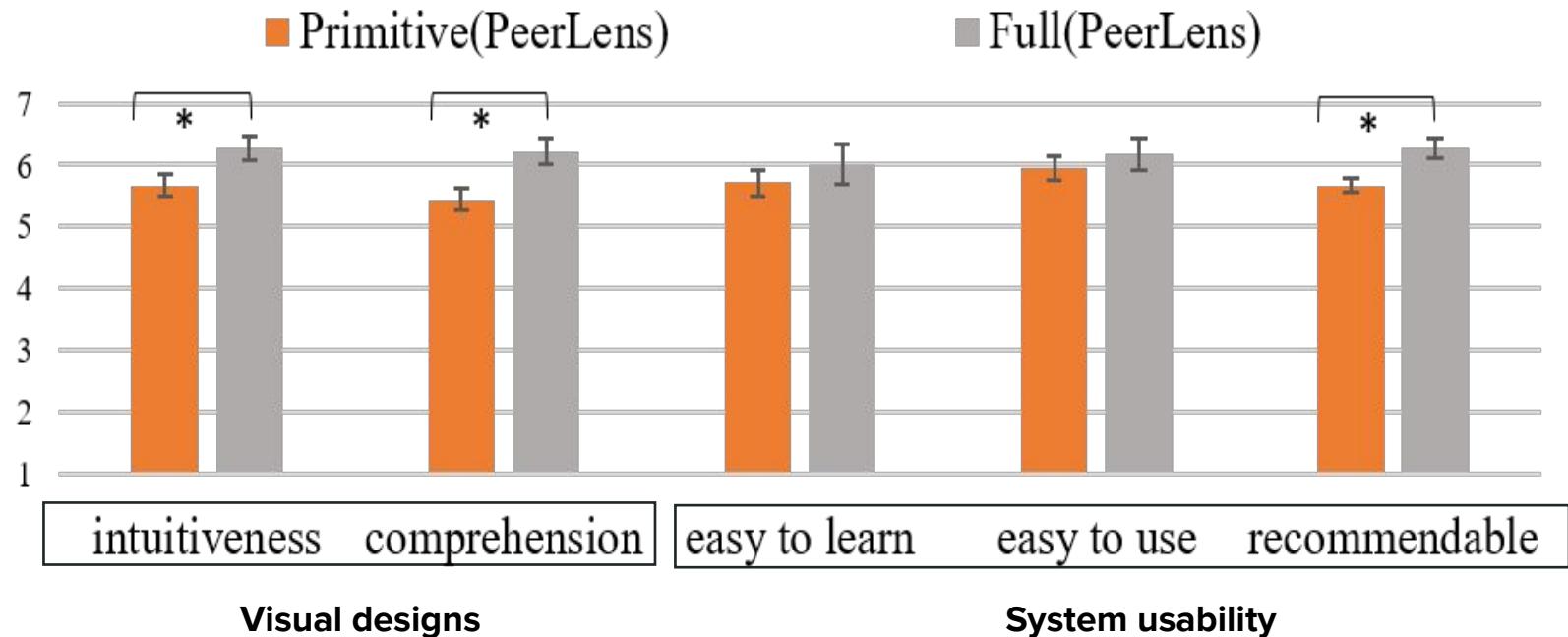
# Results: Using peer data is useful (RQ1)



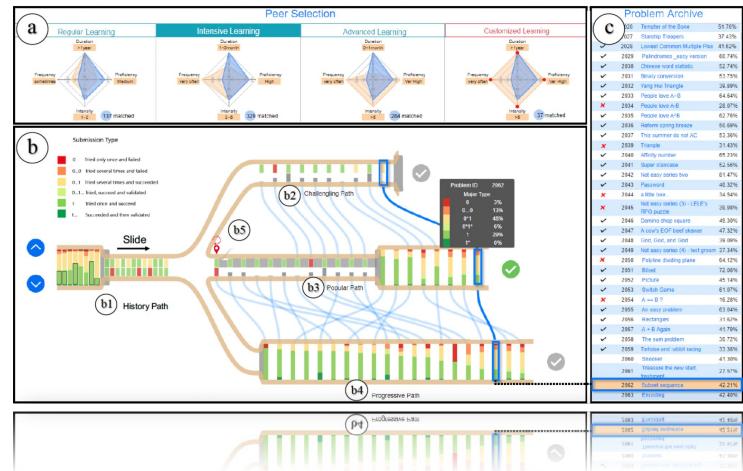
## Results: Visualizing more suggestions is useful (RQ2)



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



With **PeerLens**, we enable students to use **peer data** to plan their own learning path by **suggesting** and **visualizing** multiple paths.



Sequential event-based learning, e.g., other question pools, MOOCs, etc.



Educators (design loop)



Learners (learning loop)

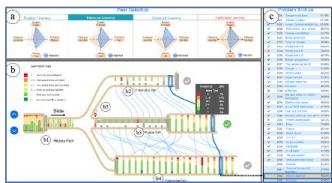
Planning

Performing  
Data

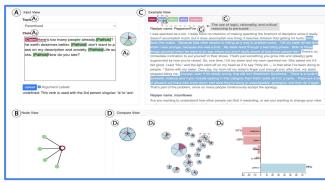
Reflecting

Understanding  
and Analyzing

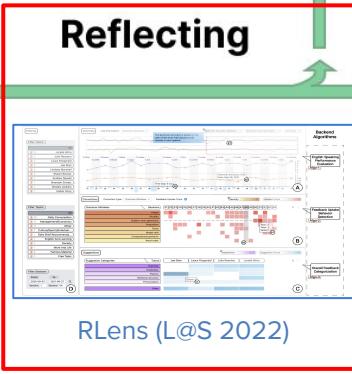
Redesigning



Peerlens (CHI 2019)



Persua (CSCW 2022)



RLens (L@S 2022)

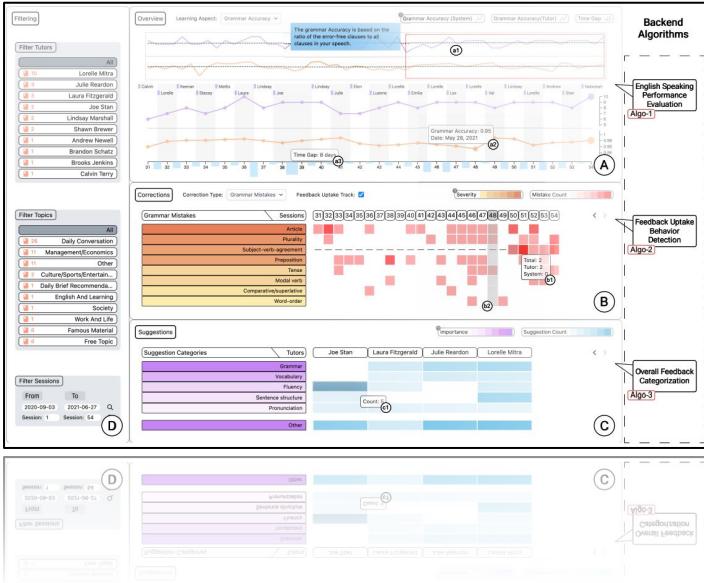


QLens (TVCG 2021)

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

# RLens: A Computer-aided Visualization System for Reflecting Language Learning Progress Under Distributed Tutorship

Meng Xia, Yankun Zhao\*, Jihyeong Hong\*, Mehmet Hamza Erol\*, Taewook Kim, Juho Kim



L@S 2022

# Background

Online language tutoring platforms (e.g., Cambly) are becoming increasingly popular.



SPICUS

당근영어

engoo

PAGODA 토큰

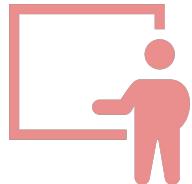


Preply

italki

# Background

These online language tutoring platforms:



Provide temporary jobs for native speakers to work as part-time tutors

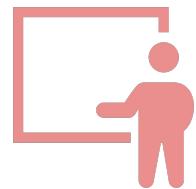


Enable language learners to have 1-1 speaking sessions with native speakers anytime and anywhere

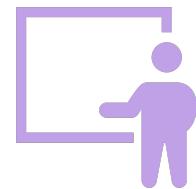
# Distributed Tutorship

My previous work analyzed **15,959** learners' data on one of these platforms and identified that **learners actively distribute their learning time with different tutors during the learning process**, which was defined as **distributed tutorship**.

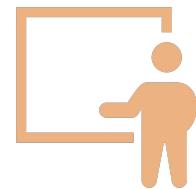
(Xia et al., 2022)



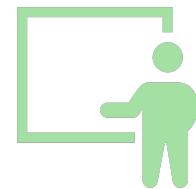
Day 1/tutor 1



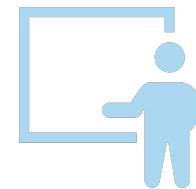
Day 2/tutor 2



Day 3/tutor3



Day 4/tutor 4



Day 5/tutor 5

Day ...



# Distributed Tutorship

There is suggestive evidence that **more distributed tutorship might introduce lower learning improvement.**

(Xia et al., 2022)



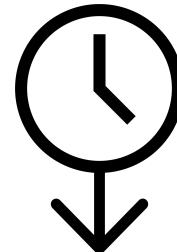
An online English tutoring platform. On Ringle, learners can choose tutors and class time for 1:1 online speaking sessions.

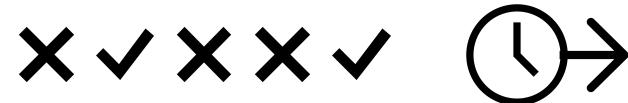


16 learners, who have learnt from more than one tutor.

# Challenge: Feedback Discontinuity

Learners are **unaware of their common language issues** (e.g. tense errors) and they are **not sure whether they have corrected the issues or not**, since previous corrections are not tracked by different tutors.

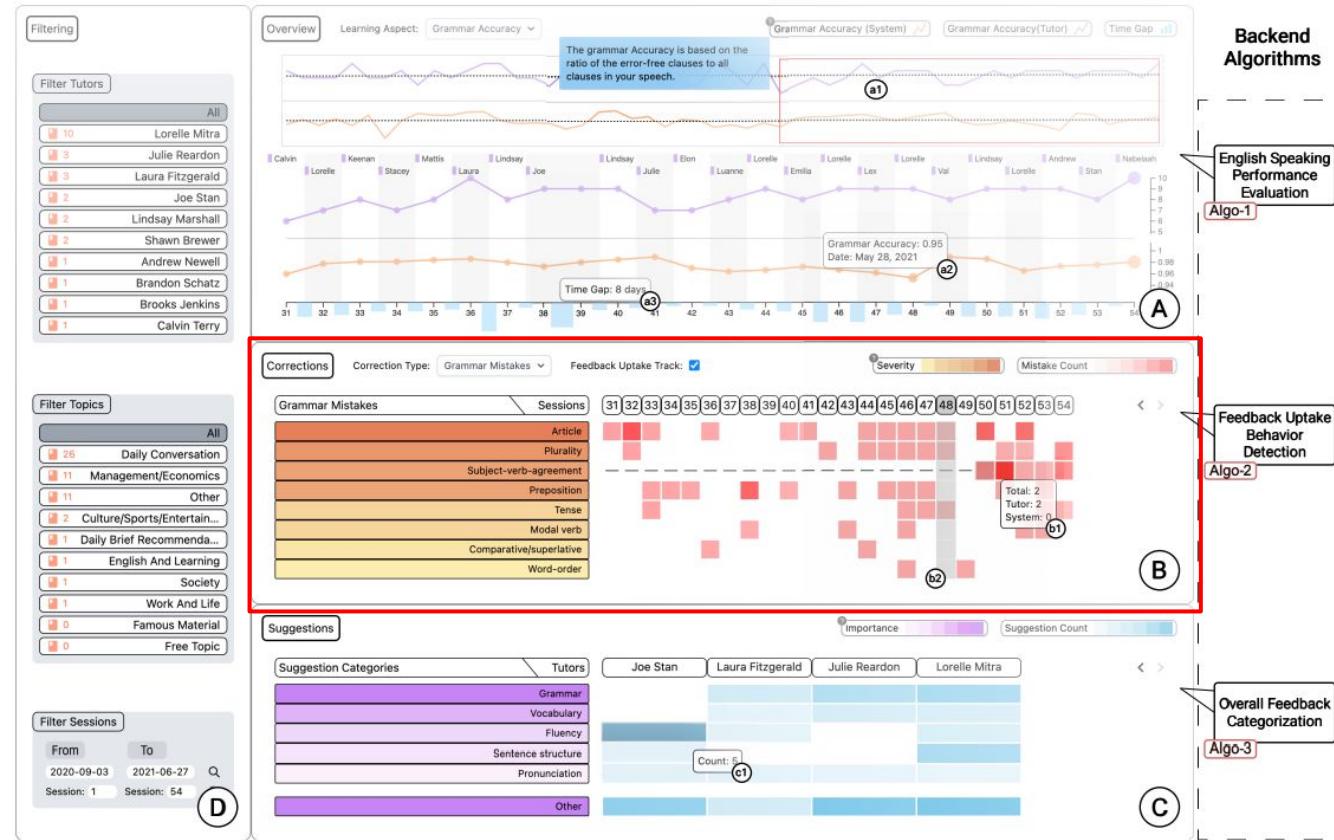




## Learners' corrective actions according to tutors' feedback

- Two apple -> Two apples
- “uh”
- “She always tries to **think positively.**” -> “She is always so **optimistic.**”

# Visualization: Feedback uptake behaviors



**RLens detects feedback uptake behaviors and visualizes the learning progress to keep consistency when learning under distributed tutorship.**



Learning scenarios with subjective feedback from different teachers.



Our collaborator, Ringle, uses some of the algorithms and interface design on their platforms. The company now serves for **100,000+ users** over the world.



**Educators (design loop)**



**Learners (learning loop)**

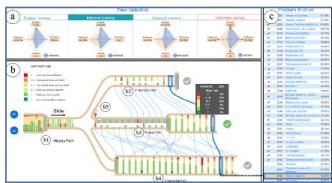
**Planning**

**Performing Data**

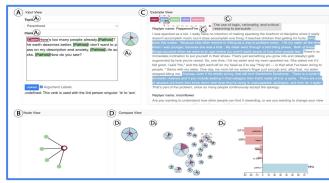
**Reflecting**

**Understanding and Analyzing**

**Redesigning**



Peerlens (CHI 2019)



Persua (CSCW 2022)



RLens (L@S 2022)



QLens (TVCG 2021)

What if the existing learning materials and data online didn't cover different learners' needs?

What if the learners are too young to use the learning analytics?

# Iterative Design Process - Animation

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

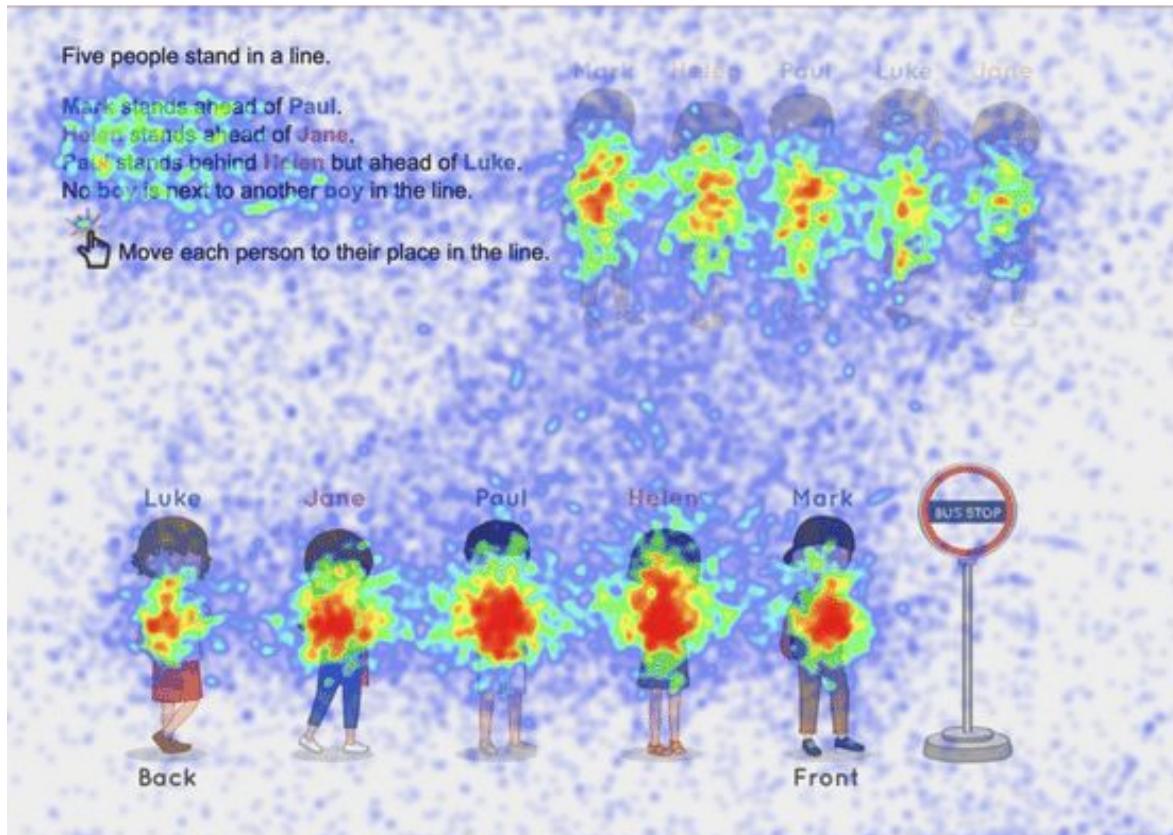
Move each person to their place in the line.

Back

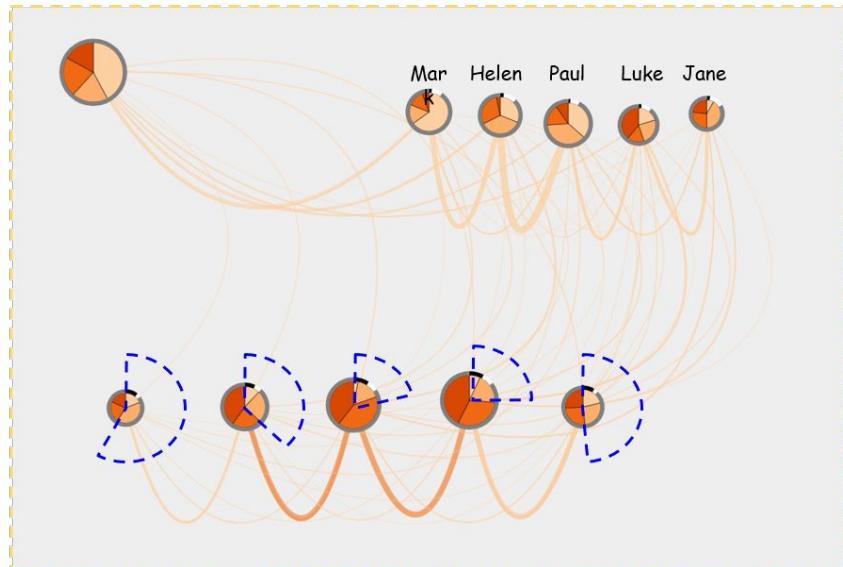
Front

BUS STOP

# Iterative Design Process - Heatmap

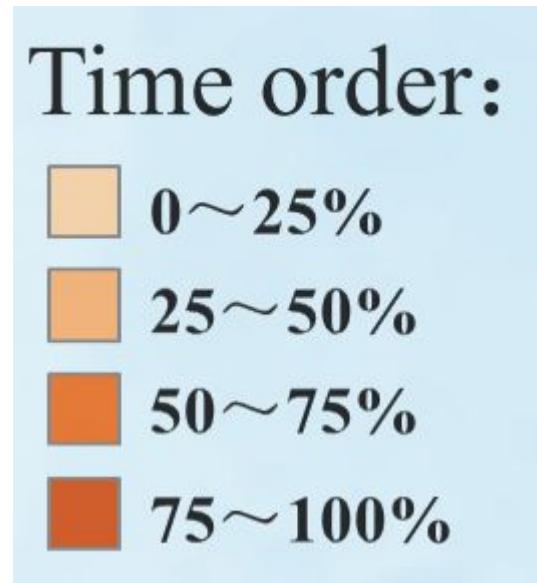


# Iterative Design Process - AOI transition graph

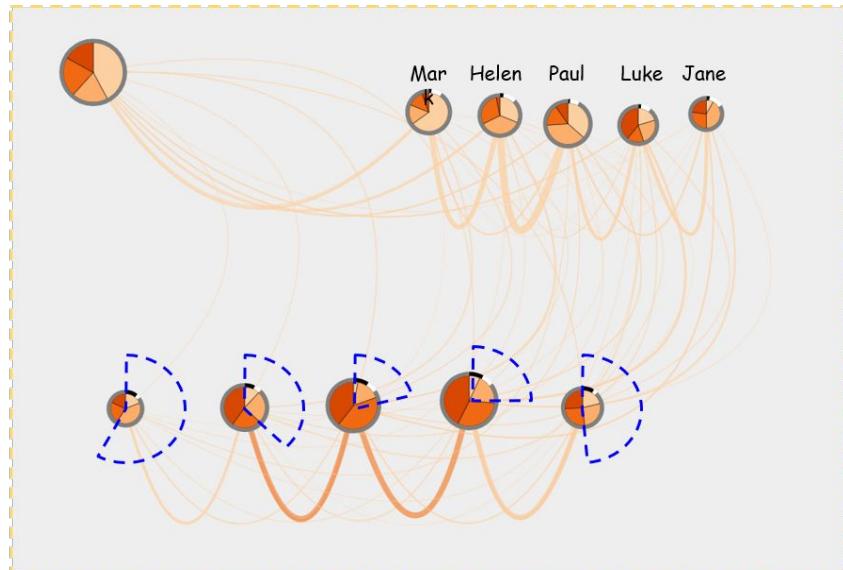


(a)

students with incorrect answers

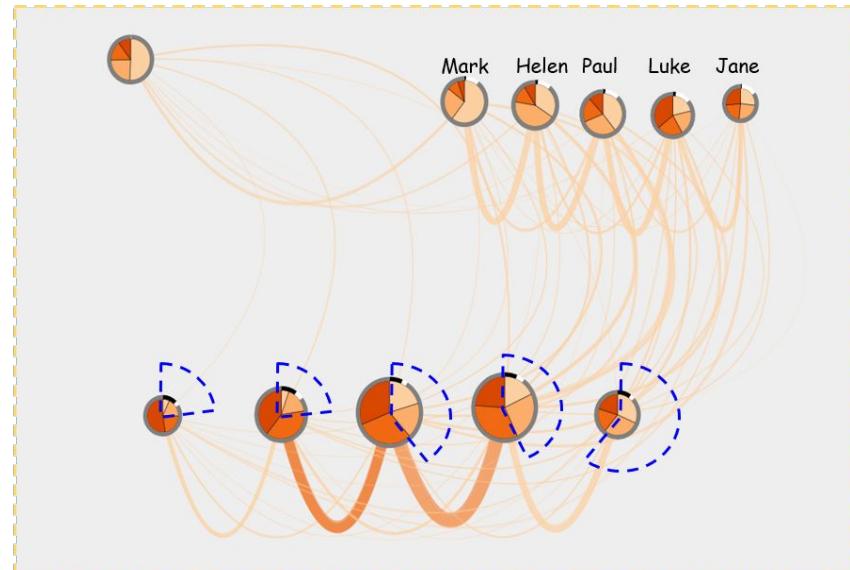


# Iterative Design Process - AOI transition graph



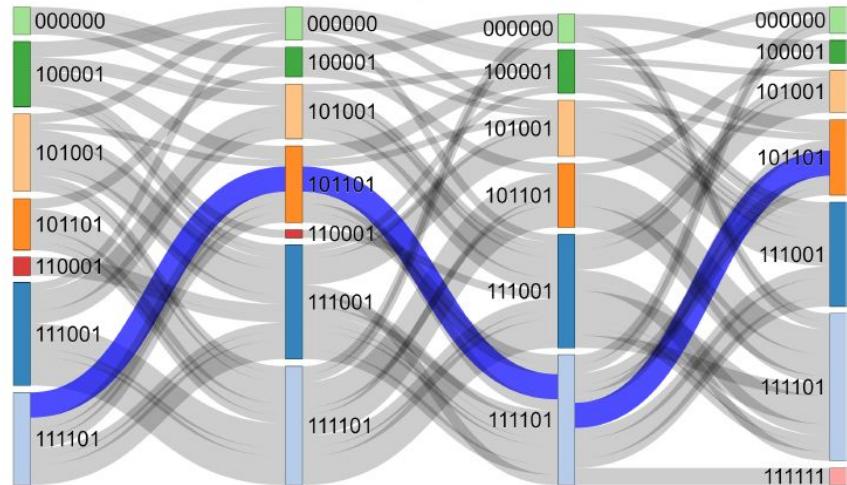
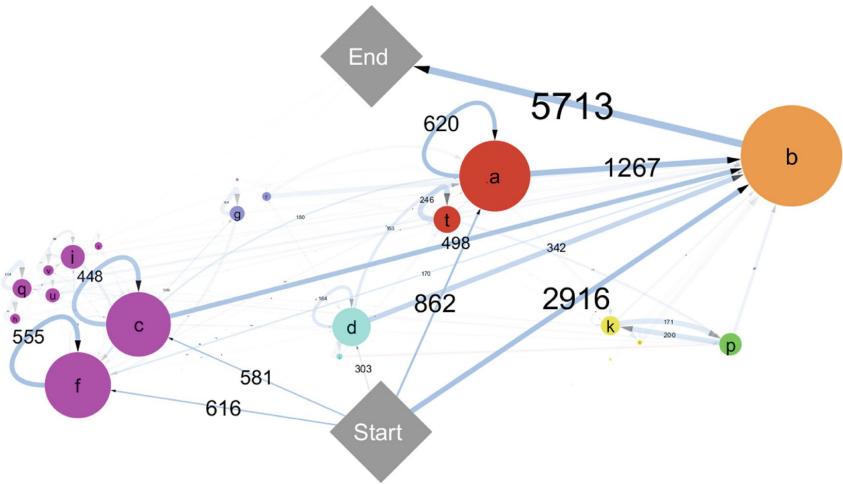
(a)

students with incorrect answers



(b)

students with correct answers

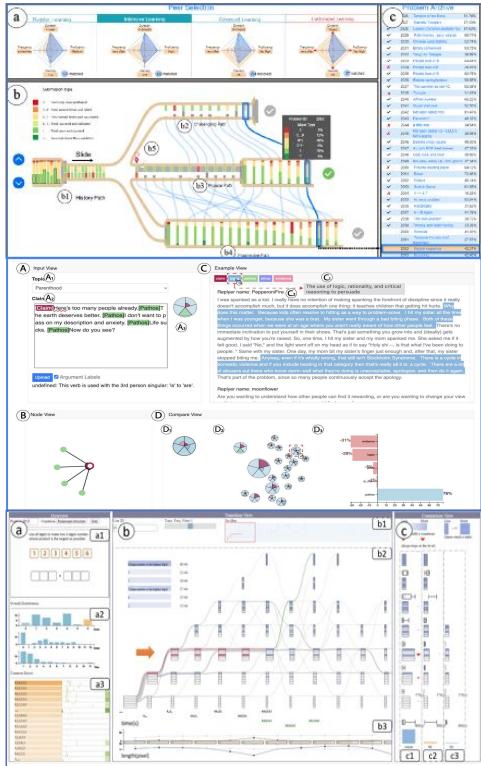


Not scalable with a very large states.

McBroom, Jessica, et al. "A data-driven method for helping teachers improve feedback in computer programming automated tutors." *International Conference on Artificial Intelligence in Education*. Springer, Cham, 2018.

Wang, Yiting, Walker M. White, and Erik Andersen. "Pathviewer: Visualizing pathways through student data." *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 2017.

# Conclusion



Domain situation: formative studies to understand target users' requirements: educators and students

## Data/task abstraction:

Data: event sequence data

Tasks: representation, summarization, comparison

## Learning behavior modelling:

Learning materials: difficulty level, test knowledge

Students: cognitive skills, non-cognitive variables

**Visual encoding:** justify alternative designs; address interaction; show the data step by step

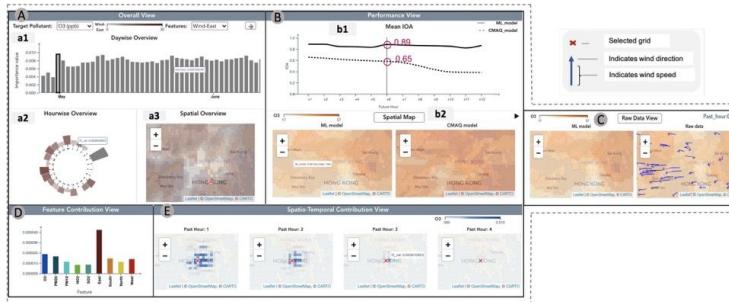
Iterative design with educators and students

Lab study, deployment, and post-study interviews

# More Broad - Enhance Personalization in Other Domains

How about other scenarios like personal health data analysis, investment data analysis, searching engine analysis?

The interface consists of two main sections. On the left, a sidebar lists three hotels: 'Hackfuns Hotel' (4 stars), 'Central City Road Hotel' (4 stars), and 'Chelton Guest House' (3 stars). Below each hotel is a small thumbnail image and a 'View Details' button. On the right, a larger panel titled 'About London Hotel' shows a bar chart of 'Helpful votes (1)'. The chart has two bars: one for 'Aspect' (101) and one for 'Helpfulness (Score/review)' (45). A legend indicates that blue bars represent 'Aspect' and orange bars represent 'Helpfulness (Score/review)'. Below the chart is a text box: 'All Reviews Show all All the reviews of this hotel' followed by a link 'View Details'. At the bottom, there's a section for 'Reported Aspects (15)' with a bar chart and a legend.



Bias-Aware Design for Informed Decisions  
(Zhu, et al., CSCW 2022)

Explaining Air Quality Forecast for Verifying Domain Knowledge using Feature Importance Visualization  
(Palaniyappan, et al., IUI 2022)



## Advisors



## Collaborators



## Mentees



# Overview

Problem ID: 8 Condition: Relational/Absolute | Edit

User ID: -1 Filter: 5

Use all the digits to make two 3-digit numbers whose product is the largest possible.

**1 2 3 4 5 6**

**□ □ □ × □ □ □**

Overall Distribution:

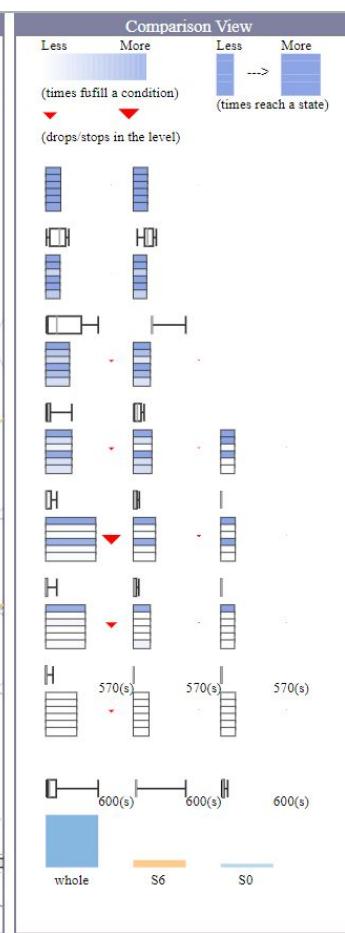
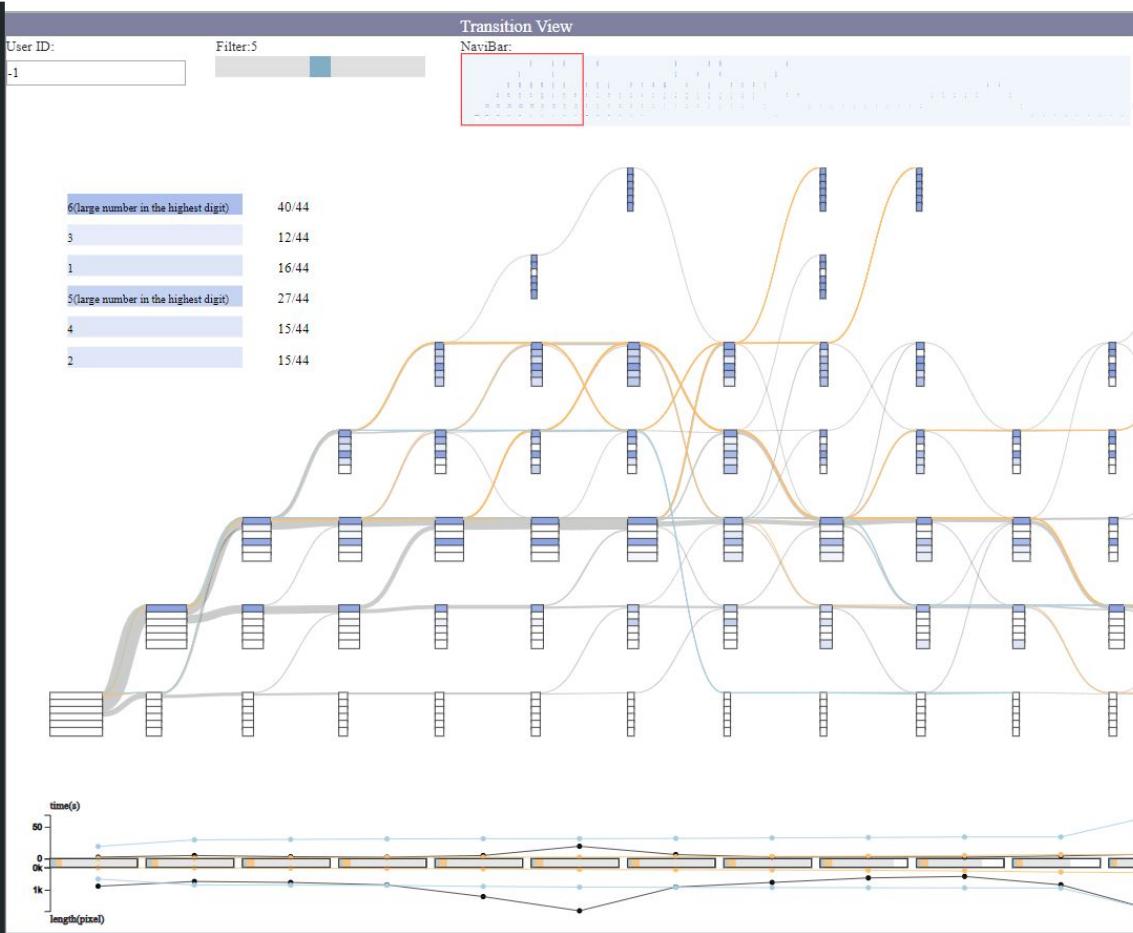
Grade	Score	Count
0	1	10
1	1	10
2	1	10
3	1	10
4	1	10
5	1	10
6	1	10
7	1	10
8	1	10
9	1	10
10	1	10
11	1	10
12	1	10

Time

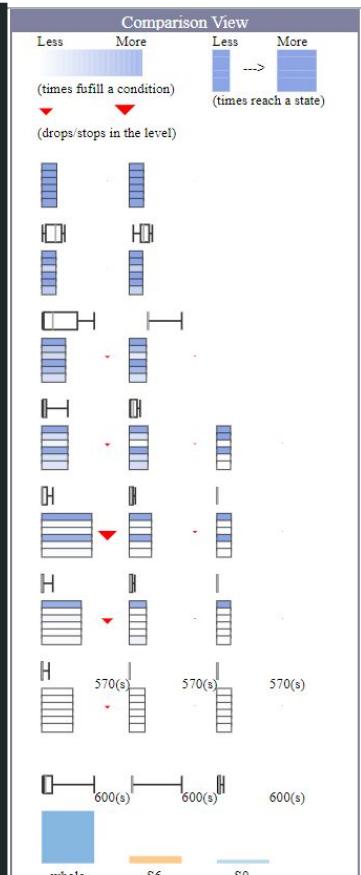
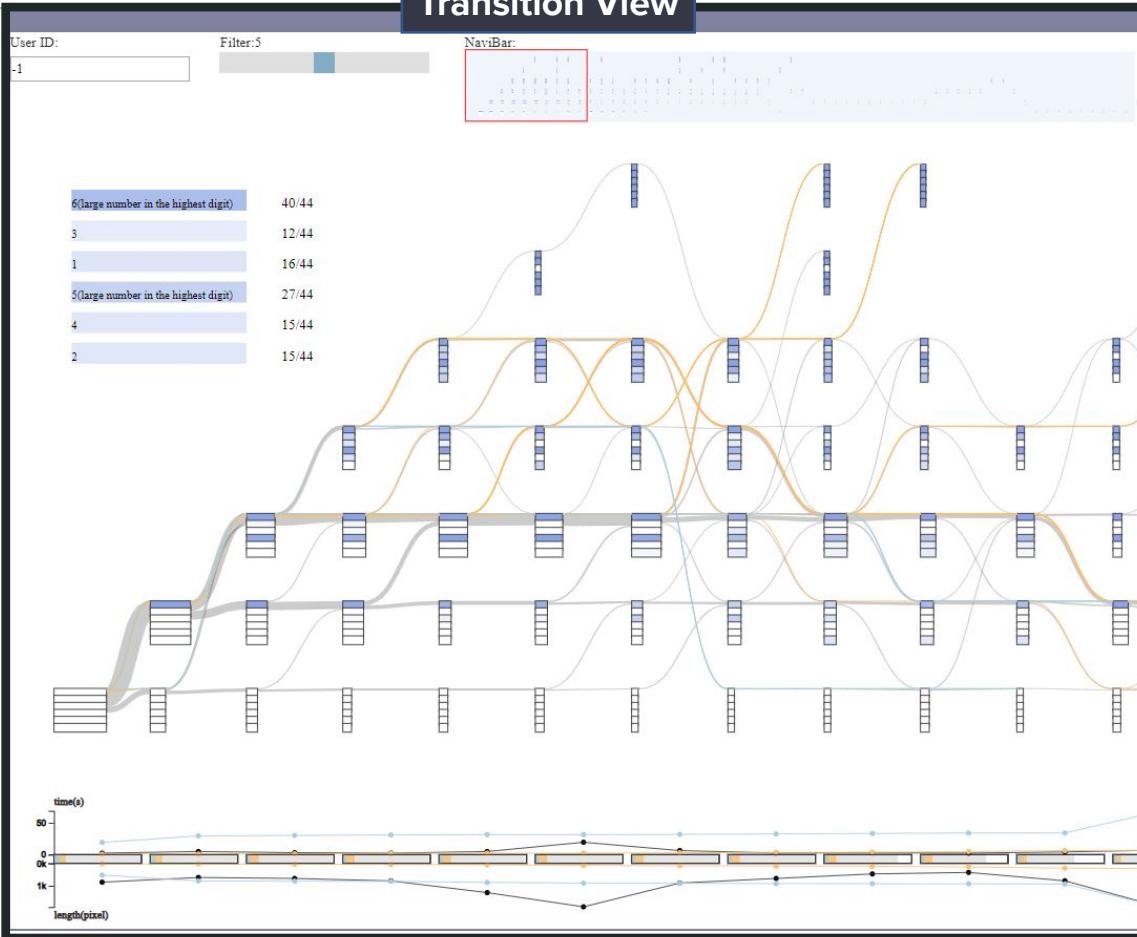
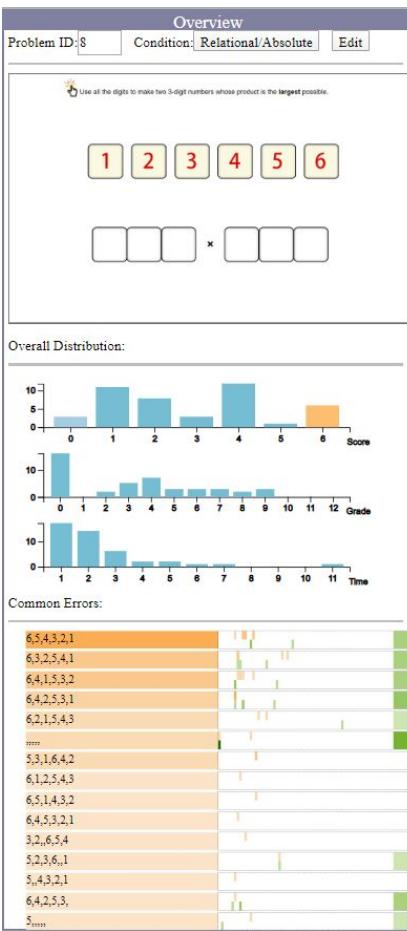
Grade	Time	Count
1	1	10
2	1	10
3	1	10
4	1	10
5	1	10
6	1	10
7	1	10
8	1	10
9	1	10
10	1	10
11	1	10

Common Errors:

- 6,5,4,3,2,1
- 6,3,2,5,4,1
- 6,4,1,5,3,2
- 6,4,2,5,3,1
- 6,2,1,5,4,3
- ...
- 5,3,1,6,4,2
- 6,1,2,5,4,3
- 6,5,14,3,2
- 6,4,5,3,2,1
- 3,2,6,5,4
- 5,2,3,6,1,1
- 5,4,3,2,1
- 6,4,2,5,3,
- 5,...



# Transition View



## Comparison View

**Overview**

Problem ID: 8 Condition: Relational/Absolute Edit

Use all the digits to make two 3-digit numbers whose product is the largest possible.

1 2 3 4 5 6

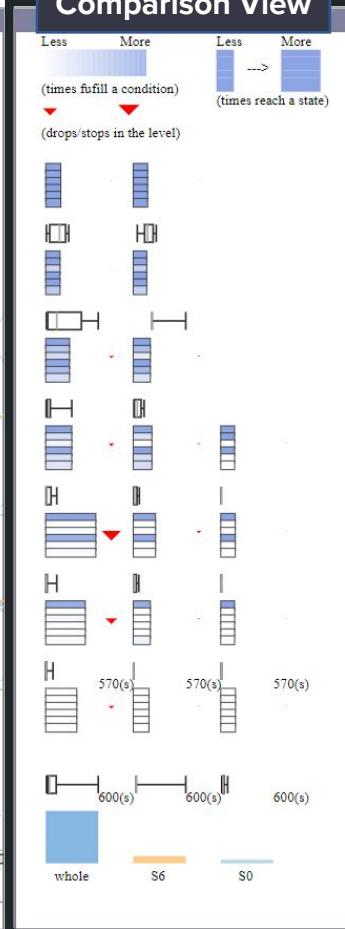
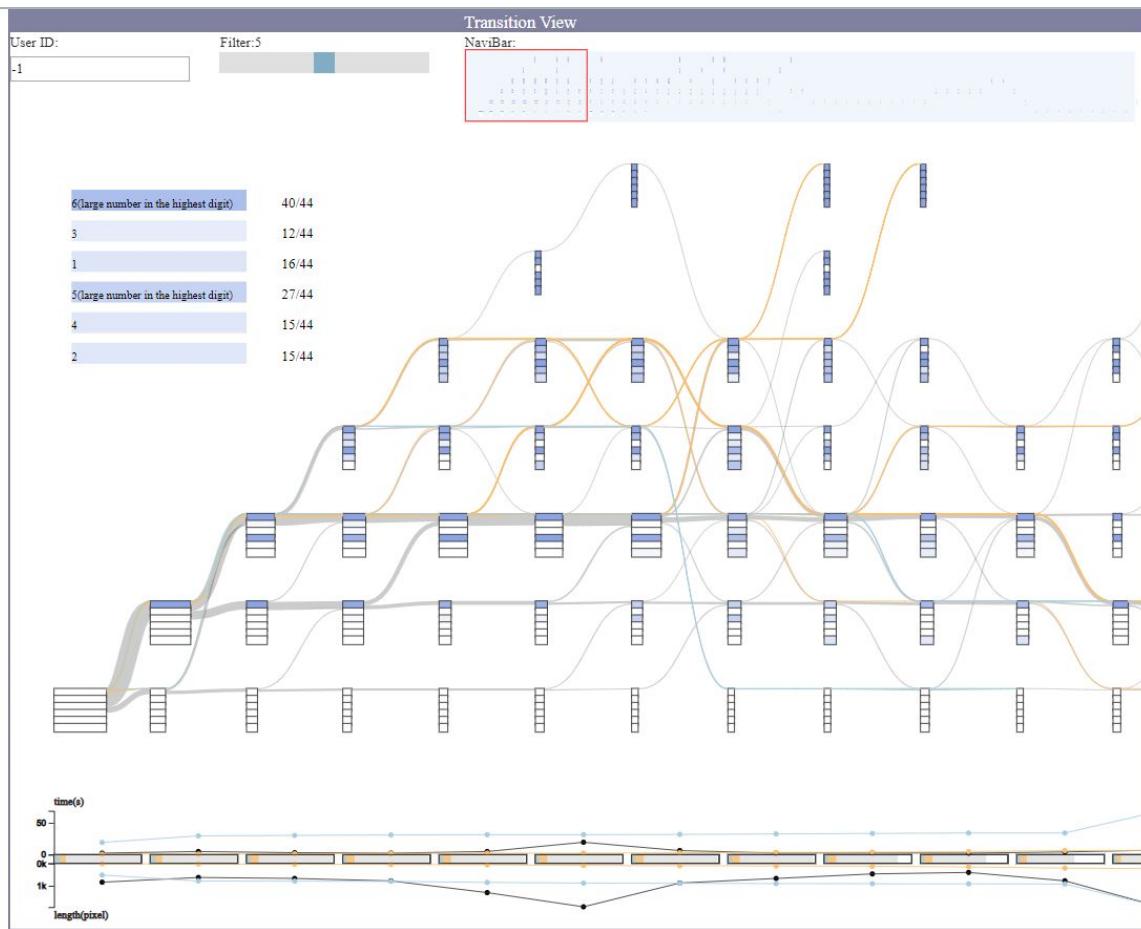
$\boxed{\phantom{000}} \times \boxed{\phantom{000}}$

Overall Distribution:

Score: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Common Errors:

- 6,5,4,3,2,1
- 6,3,2,5,4,1
- 6,4,1,5,3,2
- 6,4,2,5,3,1
- 6,2,1,5,4,3
- ...
- 5,3,1,6,4,2
- 6,1,2,5,4,3
- 6,5,14,3,2
- 6,4,5,3,2,1
- 3,2,6,5,4
- 5,2,3,6,1
- 5,4,3,2,1
- 6,4,2,5,3,
- 5,...



# Motivation

Problem-solving logic

Engagement level

Difficulties



Question Designer

- Four domain experts
  - Question designers (E1, E2)
  - System developer (E3)
  - Project manager (E4)

# 1. Data preprocessing: Recover the Steps

For each question:

1

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.

2

3

4

For each student:

2 11 4 7 3 8 8 9 ...

Step1: „,,Mark  
Step2: Paul„,,Mark  
Step3: Paul,Helen„,,Mark  
Step4: Paul,,Helen,,Mark  
...  
126

## 2. Data Analysis - State Transition Model

Step: one drag-and-drop

**Stage:** number of  
correct conditions

Step1: ,,,Mark

Step2: Paul,,,Mark

Step3: Paul,Helen,,,Mark

Step4: Paul,,Helen,,Mark

...

- Condition 1 **Mark** stands ahead of **Paul**.
- Condition 2 **Helen** stands ahead of **Jane**.
- Condition 3 **Paul** stands behind **Helen** but ahead of **Luke**.
- Condition 4 **No boy** is next to another **boy** in the line.



Stage 0

Stage 1

Stage 2

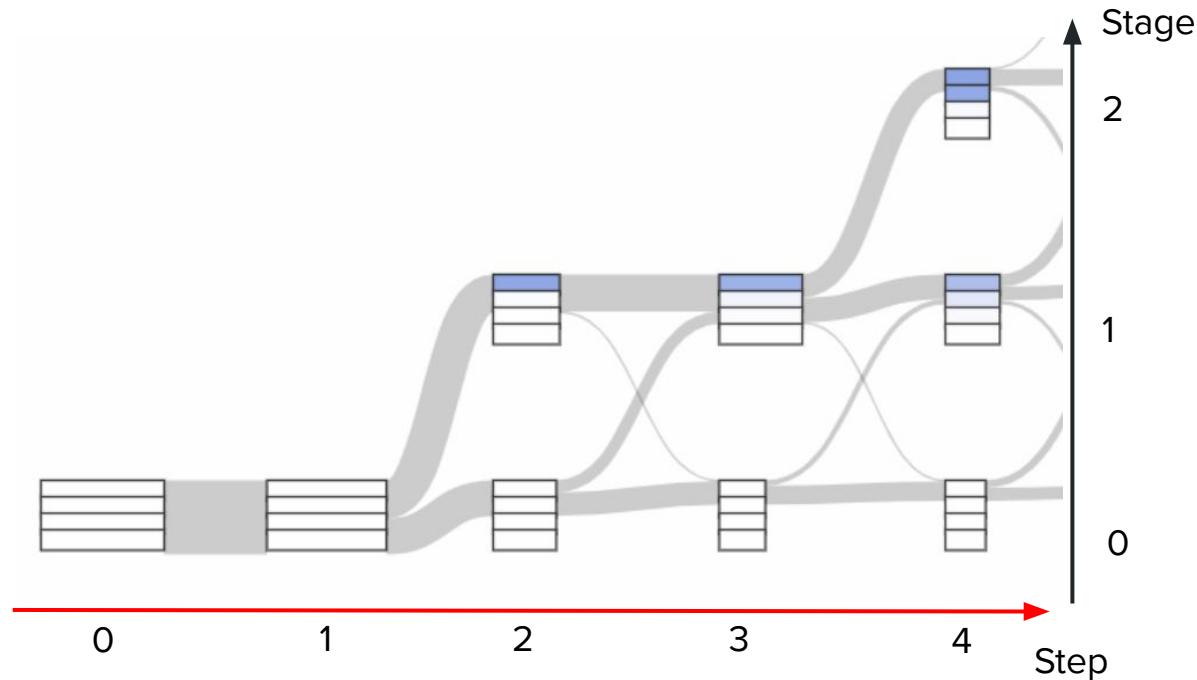
Stage 2

Five people stand in a line.

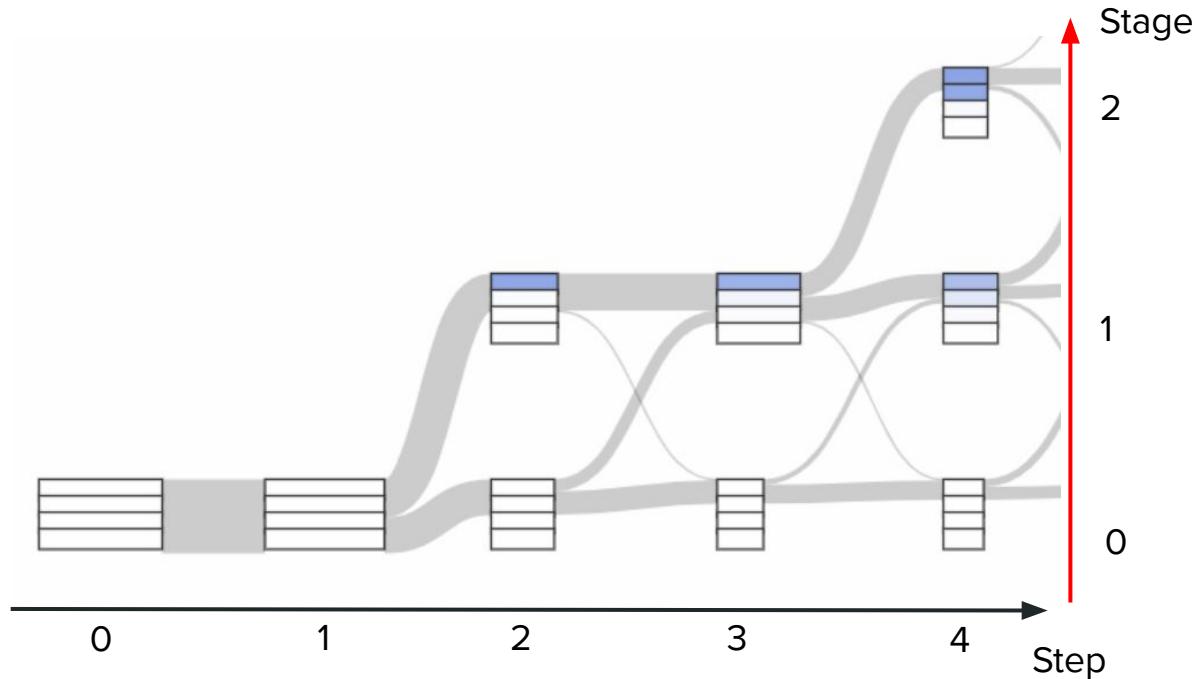


Move each person to their place in the line.

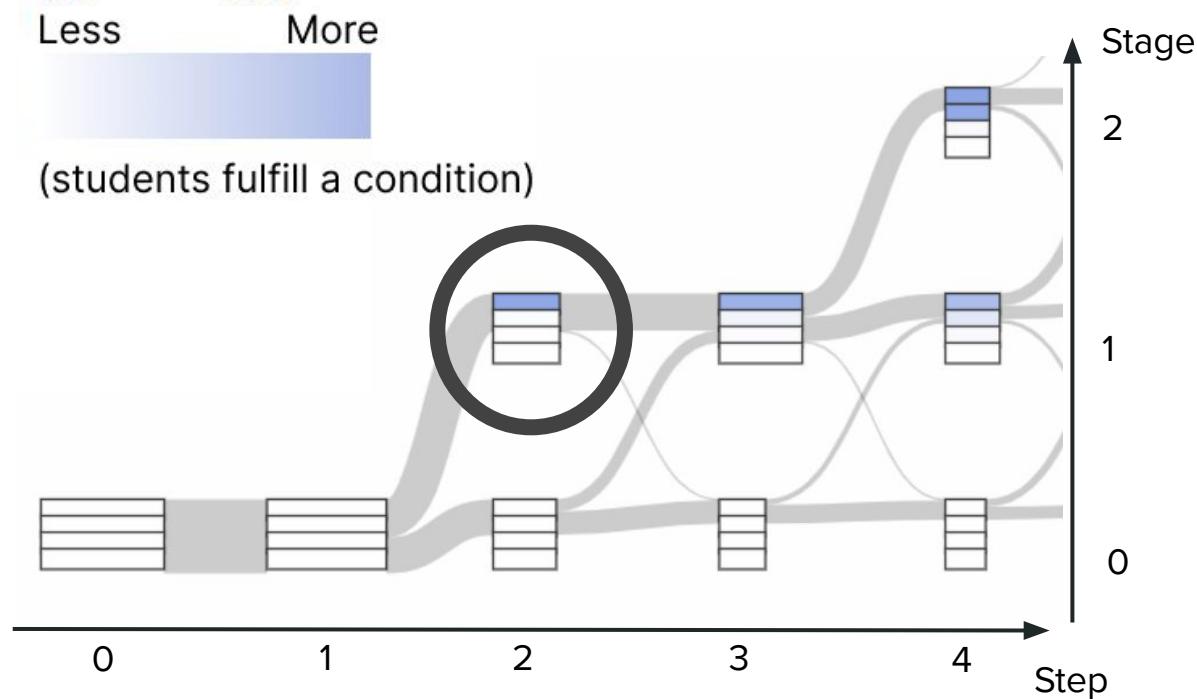
### 3. Visualization - State Transition Visualization



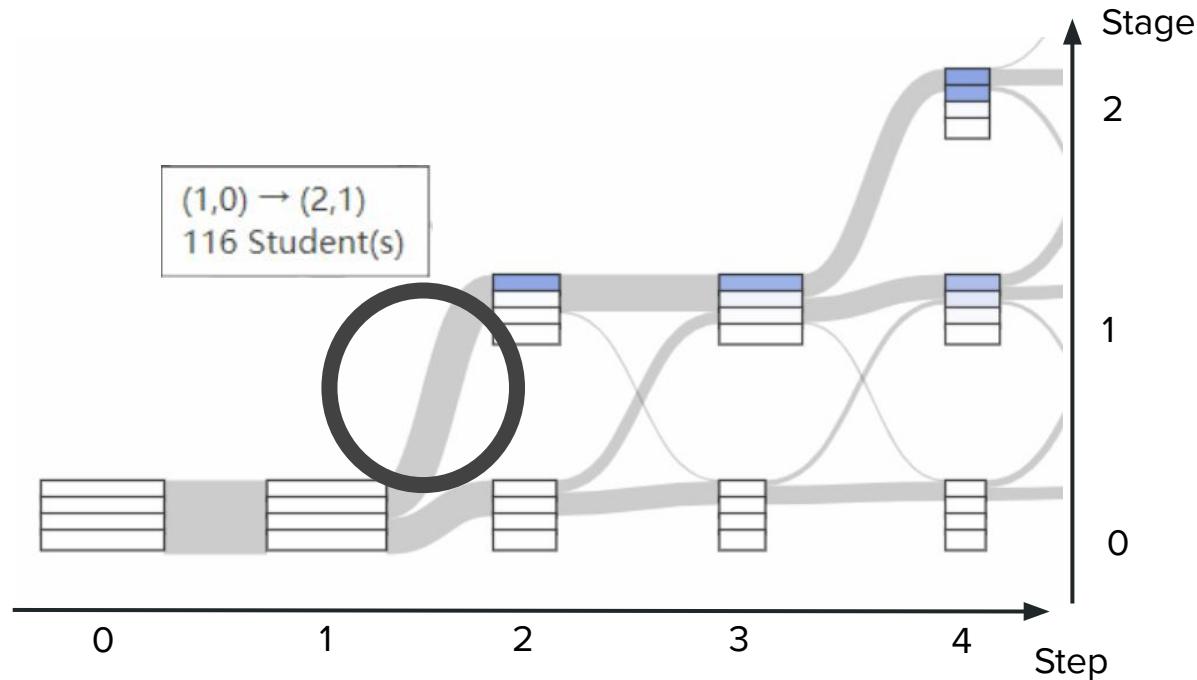
### 3. Visualization - State Transition Visualization



### 3. Visualization - State Transition Visualization



### 3. Visualization - State Transition Visualization



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.



Back

Front

**Mark** stands ahead of **Paul**.

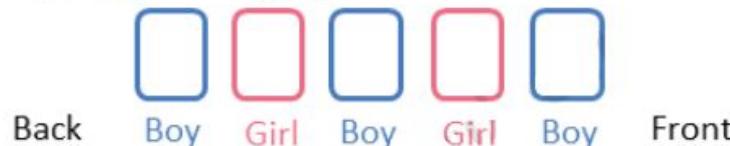
**Helen** stands ahead of **Jane**.

**Paul** stands behind **Helen** but ahead of **Luke**.

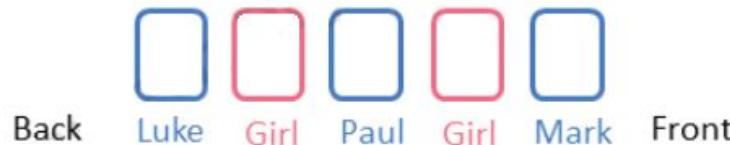
No **boy** is next to another **boy** in the line.

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,



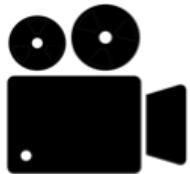
"Helen stands ahead of Jane". Therefore,



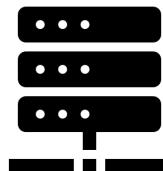
# Evaluation



- **Cases studies** with four domain experts during the development
- **Semi-structured interviews** with another three domain experts (two questions designers form a different education company, one senior manager); each interview lasts about 1.5 hours



1  
Introduce system



2  
Introduce three cases



3  
Free exploration



4  
Answer questions

# Evaluation

## System usefulness

Overall, all experts confirmed the **usefulness** and the **intuitiveness** of the system.

“The insights from Transition View will be very useful for the question designer (for example to decide which question is more suitable for which grade students) and the system developer.”

--- E6

“As more and more learning activities conducted are online, it was also very useful to compare students from different schools (e.g., international and local ones) or regions.”

--- E5

“The on-the-fly guidance is what we expected but needs more considerations.”

--- E5

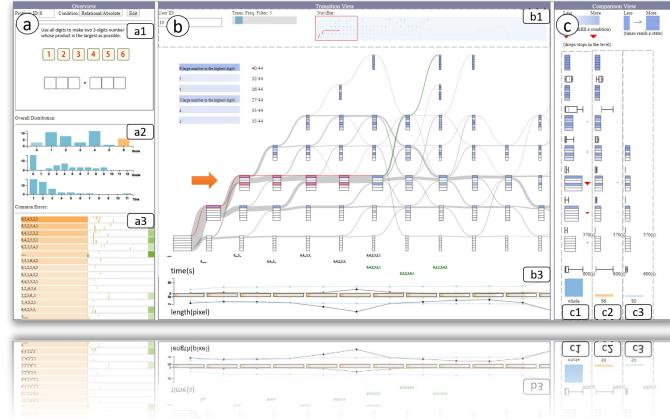
## Visual design & interactions

“It is so clear to view the problem-solving process using the visualization like this (Transition View).”

--- E7

- █ Positive
- █ Neutral
- █ Negative

# QLens visualizes learners' multi-step problem-solving processes to help educators improve learning materials.



Multiple-step problem solving, e.g., how different test cases/rules are satisfied in coding exercises.

# Conclusion

How data can be used for learners and educators  
in achieving personalized online 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**)

**A** Input View

Topic **A<sub>1</sub>**  
Parenthood

Claim **A<sub>2</sub>**  
[Claim] Here's too many people already. [Pathos] The earth deserves better. [Pathos] I don't want to pass on my description 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'.

**C** Example View

claim logos pathos ethos evidence

The use of logic, rationality, and critical reasoning to persuade

Replyer name: PepperoniFire **C<sub>1</sub>**  
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.

Replyer 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

**D<sub>1</sub>** **D<sub>2</sub>** **D<sub>3</sub>**

Argument Type	Percentage
evidence	-31%
logos	-29%
ethos	-5%
is_claim	1%
pathos	76%

## A Input View

Topic A1

Parenthood

Claim A2

[Claim] Here's too many people already. [Pathos] T  
he earth deserves better. [Pathos] I don't want to p  
ass on my description and anxiety. [Pathos] Life su  
cks. [Pathos] Now do you see?



A3

Upload  Argument Labels

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

## C Example View

claim logos pathos ethos evidence

Replyer 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.

Replyer name: moonflower

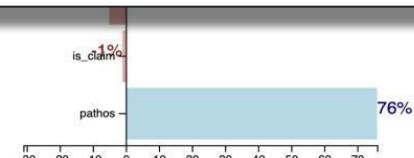
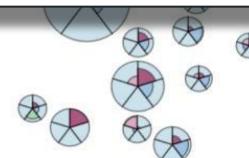
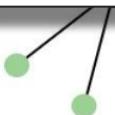
Are you wanting to understand how other people can find it rewarding, or are you wanting to change your view

C1

# 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



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

Meng Xia et al., CSCW 2022

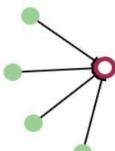
**A Input View**

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 description 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'.

**B Node View**



**C Example View**

claim logos pathos ethos evidence

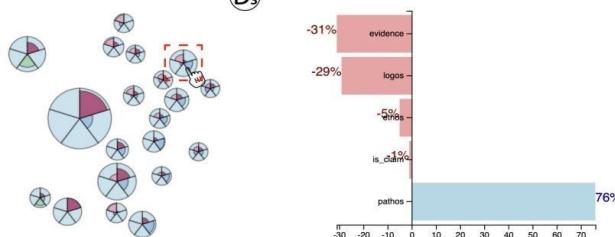
Replier name: PepperoniFire **C2**  
The use of logic, rationality, and critical reasoning to persuade

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 shit --, 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

**D Compare View**

**D1** **D2** **D3**



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



Educators (design loop)



Learners (learning loop)

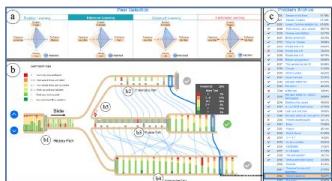
Planning

Performing  
Data

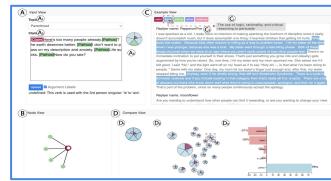
Reflecting

Understanding  
and Analyzing

Redesigning



Peerlens (CHI 2019)



Persua (CSCW 2022)



RLens (L@S 2022)



QLens (TVCG 2021)



SolutionVis (AIED 2023)

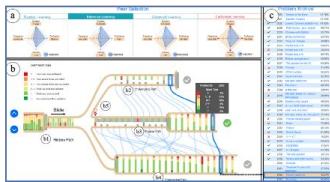
How data can be used for learners to plan, perform, and reflect on their learning?

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



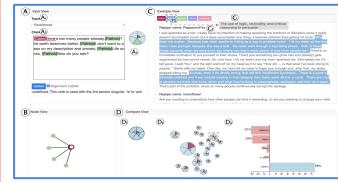
## Learners (learning loop)

### Planning



Peerlens (CHI 2019)

### Performing Data



Persua (CSCW 2022)

### Reflecting



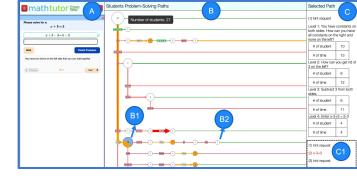
RLens (L@S 2022)

### Understanding and Analyzing



QLens (TVCG 2021)

### Redesigning



SolutionVis (AIED 2023)

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