THE HONG KONG UNIVERSITY OF
SCIENCE AND TECHNOLOGY

Bridge the Gap between Educators and Students in Online Learning:
A Visualization Approach based on Problem-solving Data

Meng Xia

PhD Thesis Defense

11th August, 2020

Co-supervised by Prof. Huamin Qu and Prof. Xiaojuan Ma

Outline

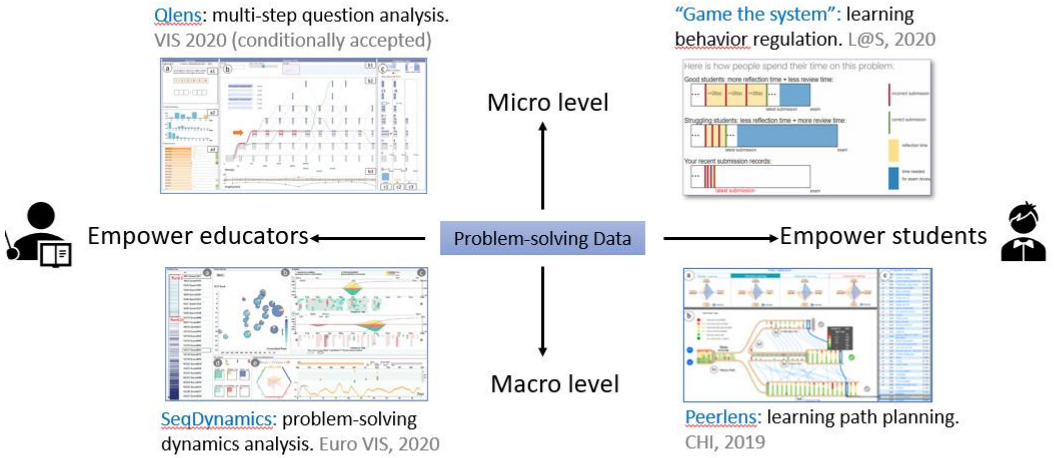
1. Background
2. Visual Analytics for Educators

   2. 1 ***QLens*** for Question Designs (Micro Level)

   2. 2 ***SeqDynamics*** for Evaluating Students (Macro Level)
3. Information visualizations for Students

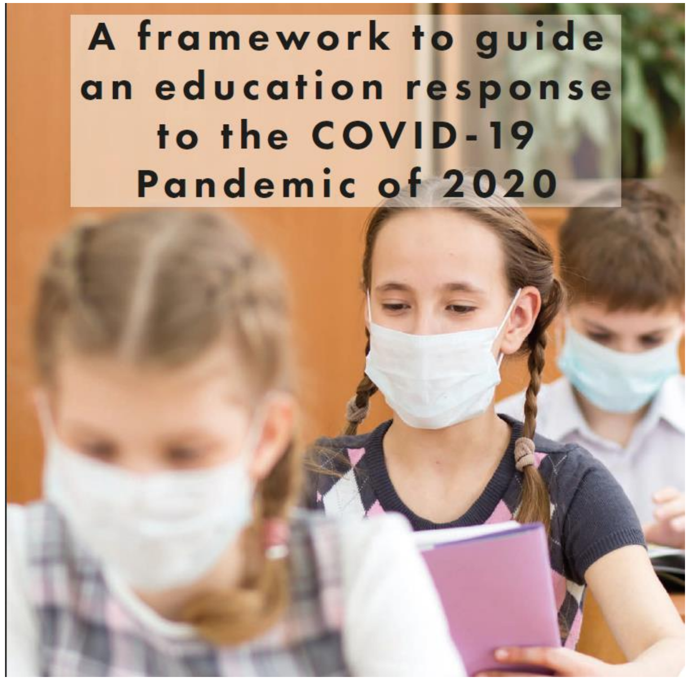
   3. 1 ***Game the system*** for Learning bahavior regulation (Micro Level)

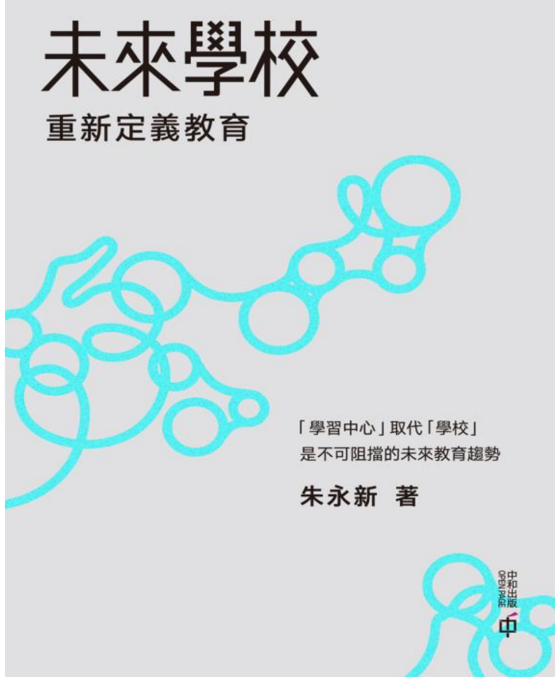
   3. 2 ***PeerLens*** for Learning Path Planning (Macro Level)
4. Conclusion & Future Directions



Online Learning is Important

- 94/98 countries closed the schools in March and most of them encouraged online learning at home *(Organization for Economic Co-operation and Development, 2020)*
- It is an irresistible trend that "learning centre" will replace the "school" in the future



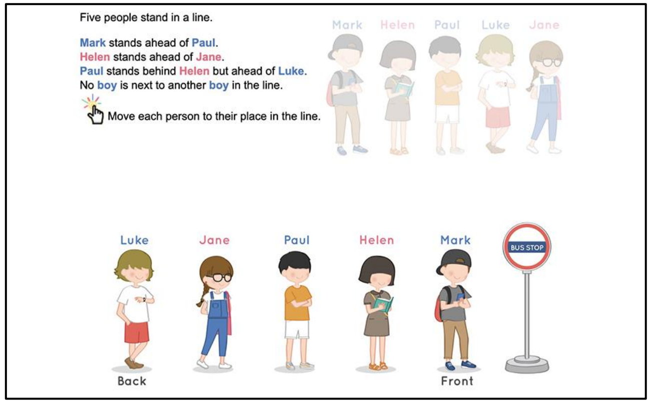


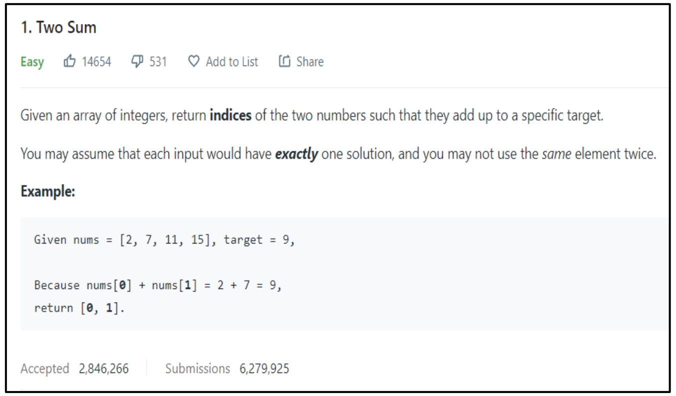
A Framework to Guide and Education Response to the COVID-19 Pandemic by ***OECD (Organization for Economic Co-operation and Development)*** *and the Harvard School of Graduate Education.*

Online Learning Types

Type	Online learning platforms	Examples	Learning Materials
Video-based	Learning Management System	Canvas, Moodle, Coursera, EdX, Udacity	Video/lectures
Question-based	Intelligent tutoring system	Algebra Tutor, SmartTutor	Problems
	Test and quiz systems	LeetCode, Uva	Tests/Quizs
	Learning Objects repositories, wikis, forums, educational games, Q/A systems	StackOverflow	Questions

Question-based Learning Platforms





Math Playground Give your Brain a Workout

MAD

LeetCode

- Become popular increasingly
- Practice **problem-solving skills**

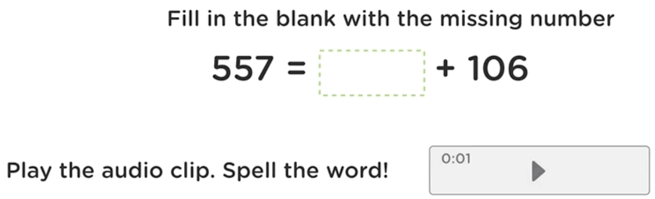
(Vanlehn Kurt., 2006)

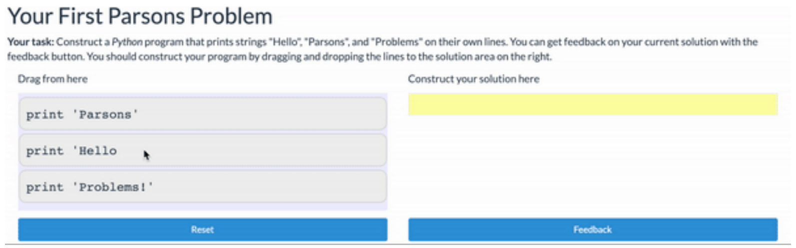
Problem-solving skills

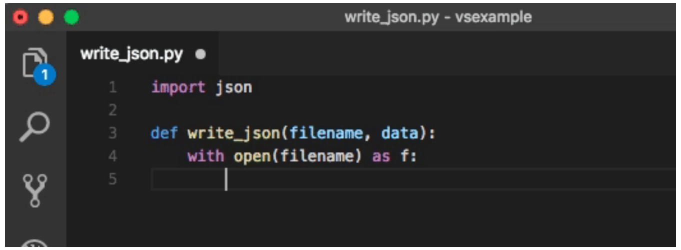
- Cognitive perspective: **ability to engage in cognitive processing** to understand and solve problem situations where a method to solve the problem is not immediately available
- Non-cognitive perspective: **motivation to engage with such situations** in order to “achieve one’s potential as a constructive and reflective citizen” *(Organization for Economic Co-operation and Development, 2014)*
- Problem-solving skills is one important competency that should be fully embraced in the education systems *(Shute et al., 2016)*

Problem-solving processes

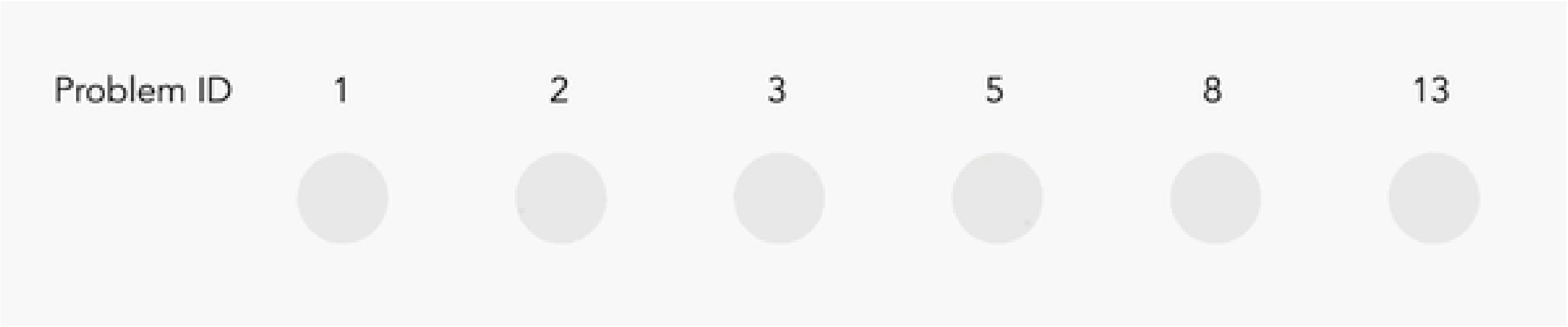
Micro level: students' behaviors **within a question** *(Vanlehn Kurt, 2016)*







Macro level: students' behaviors **among questions** *(Vanlehn Kurt, 2016)*



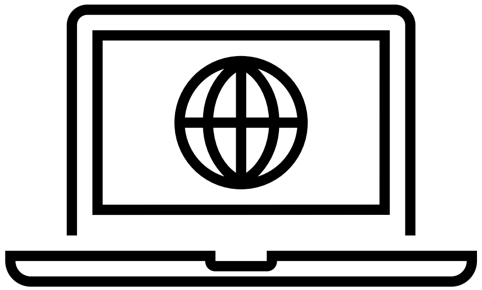
Correct

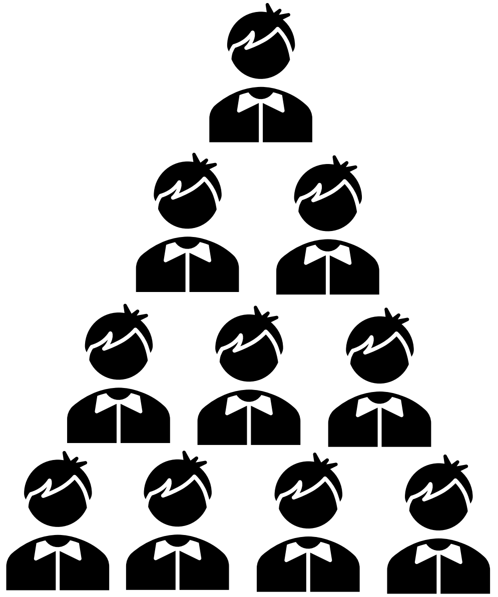
Incorrect

Challenges

- Imbalance in the number of educators and students
- Huge amount of learning resources, i.e., questions

…





customized instructions

personalized learning

Motivation

Empower **educators**: analyze students' problems-solving processes

- Improve the question designs
- Give customized instructions

Empower **students**: improve learning, becoming "educators"

- Self-regulate their learning habits
- Plan the personalized learning paths

(Koedinger et al, 2015)

A visualization approach

- Educators need to explore the patterns based on the real data
- Students need to reflect and plan learning according to their motivations

✗ Automatic algorithm ✓ Keep educator and students in the loop

Data Mining +	Visualization →	Visual Analytics
Clearly defined tasks	High-bandwidth channel	Exploratory analysis
Automated process	External perceptual system	Involve human knowledge
Objective results	Interaction	Deeper understanding

Related Work

Problem-solving Behavior Modelling

Macro level (a series of problems):

- *Liu, R., & Koedinger, K. (2017). Going beyond better data prediction to create explanatory models of educational data. The Handbook of Learning Analytics, 69-76.*
- *Pavlik Jr, P. I., Cen, H., & Koedinger, K. R. (2009). Performance factors analysis - a new alternative to knowledge tracing.*
- *Cen, H., Koedinger, K., & Junker, B. (2006). Learning factors analysis； a general method for cognitive model evaluation and improvement. In International Conference on Intelligent Tutoring Systems, pp. 164-175. Springer.*
- *Corbett, A. T., & Anderson, J. R. (1994). Knowledge tracing: Modeling the acquisition of procedural knowledge. User modeling and user-adapted interaction, 4 (4), 253-278.*

Micro level (one multi-step question):

- *Piech, C., Sahami, M., Koller, D., Cooper, S., & Blikstein, P. (2012). Modeling how students learn to program. In Proceedings of the 43rd ACM technical symposium on Computer Science Education, pp. 153-160.*
- *Vanlehn, K. (2006). The behavior of tutoring systems. International journal of artificial intelligence in education, 16 (3), 227-265.*

Not comprehensive (cognitive & non-cognitive); not well interpreted.

Related Work

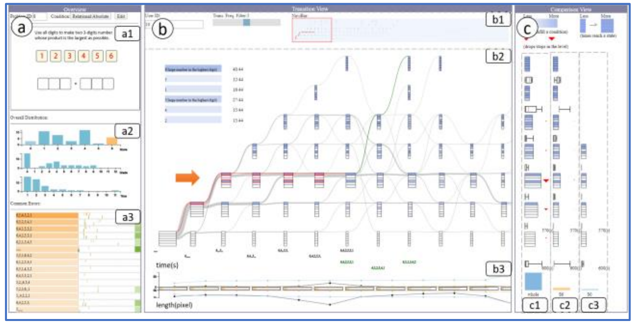
Learning Sequence Visualization (video clickstream/assignments):

- *Chen, Q., Chen, Y., Liu, D., Shi, C., Wu, Y., & Qu, H. (2016). Peakvizor: Visual analytics of peaks in video clickstreams from massive open online courses. IEEE Transactions on Visualization & Computer Graphics, pp. 2315-2330.*
- *Shi, Conglei, et al. "VisMOOC: Visualizing video clickstream data from massive open online courses." 2015 IEEE Pacific visualization symposium (PacificVis). IEEE, 2015.*
- *Chen, Y., Chen, Q., Zhao, M., Boyer, S., Veeramachaneni, K., & Qu, H. (2016). Dropoutseer: Visualizing learning patterns in massive open online courses for dropout reasoning and prediction. In Visual Analytics Science and Technology (VAST), 2016 IEEE Conference on, pp. 111-120. IEEE.*
- *Chen, Q., Yue, X., Plantaz, X., Chen, Y., Shi, C., Pong, T.-C., & Qu, H. (2018). Viseq: Visual analytics of learning sequence in massive open online courses. IEEE transactions on visualization and computer graphics. The Eurographics Association.*
- *Wäschle, Kristin, et al. "Effects of visual feedback on medical students' procrastination within web-based planning and reflection protocols." Computers in Human Behavior 41 (2014): 120-136.*

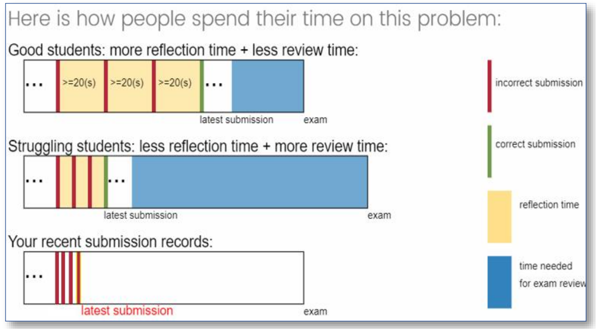
Problem-solving sequences are more detailed and complex, which include the feedback on each step/question.

Our works

Qlens: multi-step question analysis. VIS 2020 (conditionally accepted)



"Game the system": learning behavior regulation. L@S, 2020



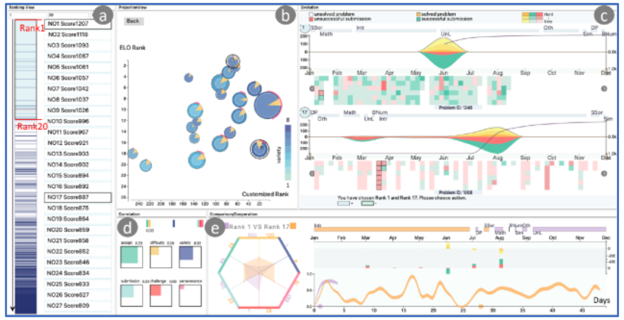
Micro level

Empower educators

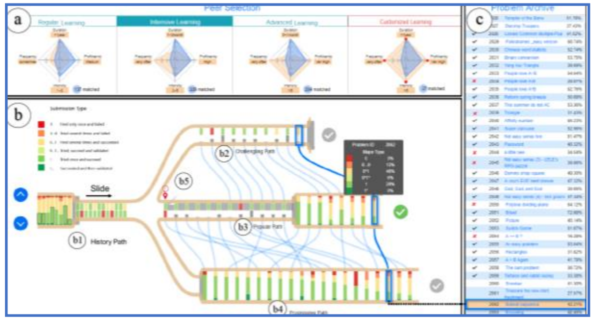
Problem-solving Data

Empower students

Macro level



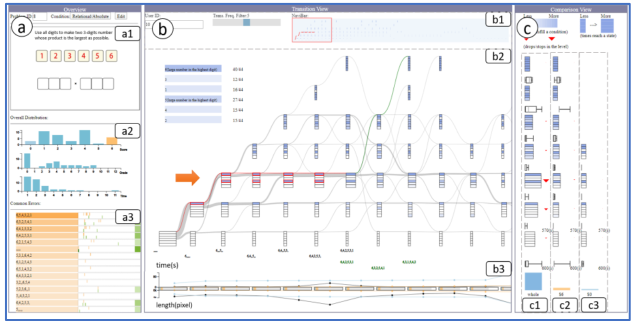
SeqDynamics: problem-solving dynamics analysis. Euro VIS, 2020



Peerlens: learning path planning. CHI, 2019

Our works

Qlens: multi-step question analysis.
VIS 2020 (conditionally accepted)



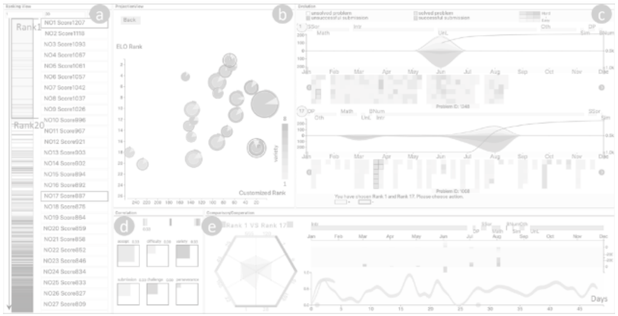
Micro level

"Game the system": learning behavior regulation. L@S, 2020

Empower educators

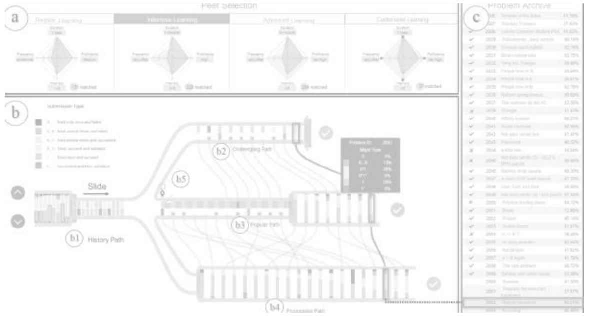
Problem-solving Data

Empower students

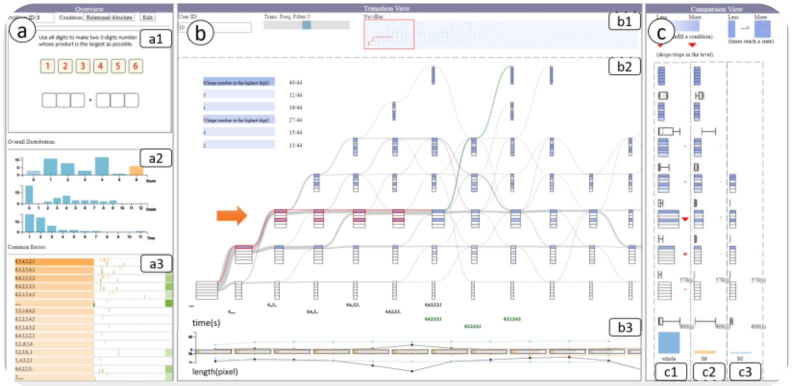


SeqDynamics: problem-solving dynamics analysis. Euro VIS, 2020

Macro level



Peerlens: learning path planning. CHI, 2019



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

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

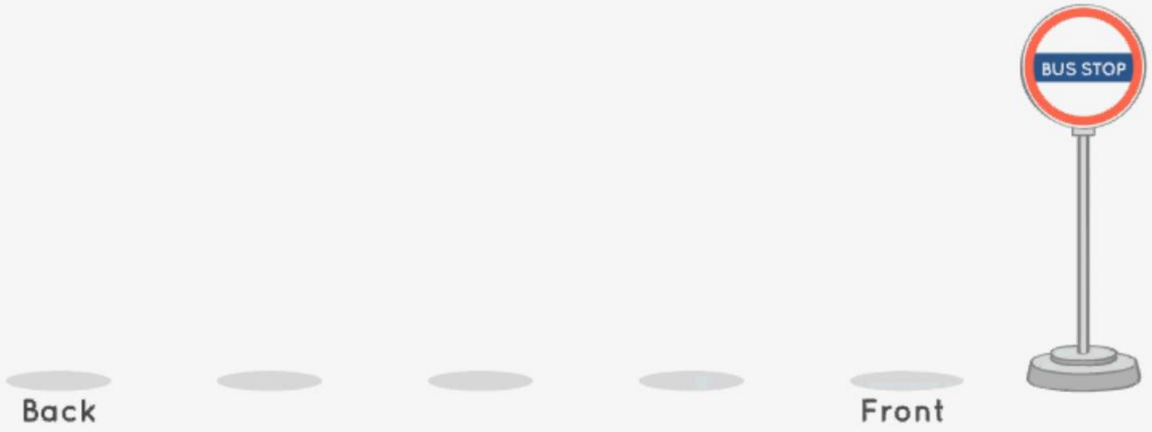
IEEE VIS 2020 (Conditionally accepted)

A Multi-step Question

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.

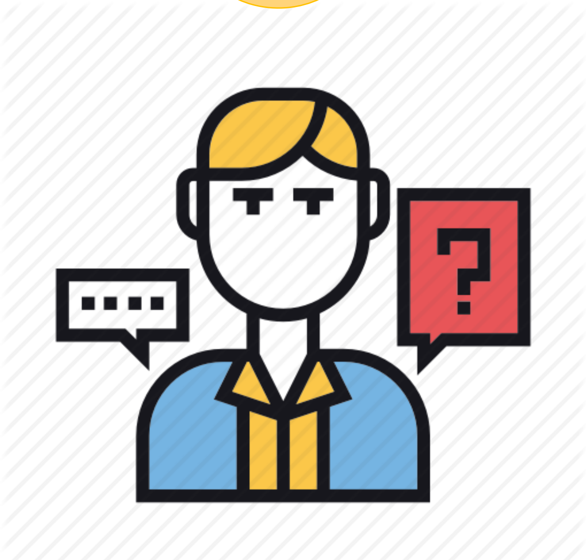


Motivation

Problem-solving logic

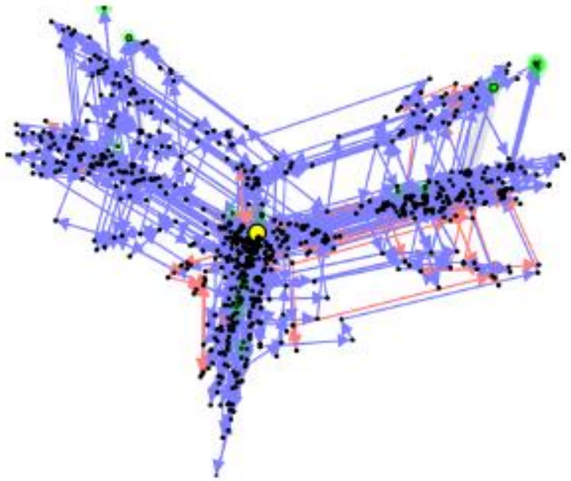
Engagement level

Difficulties

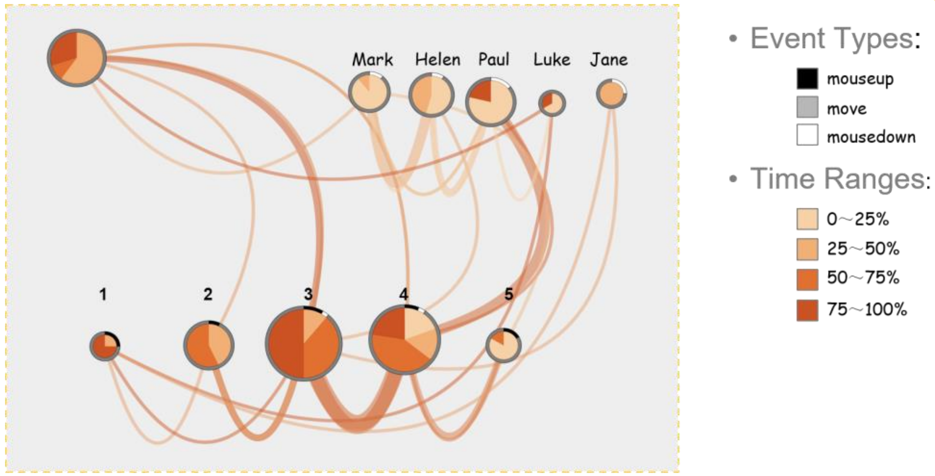


Question Designer

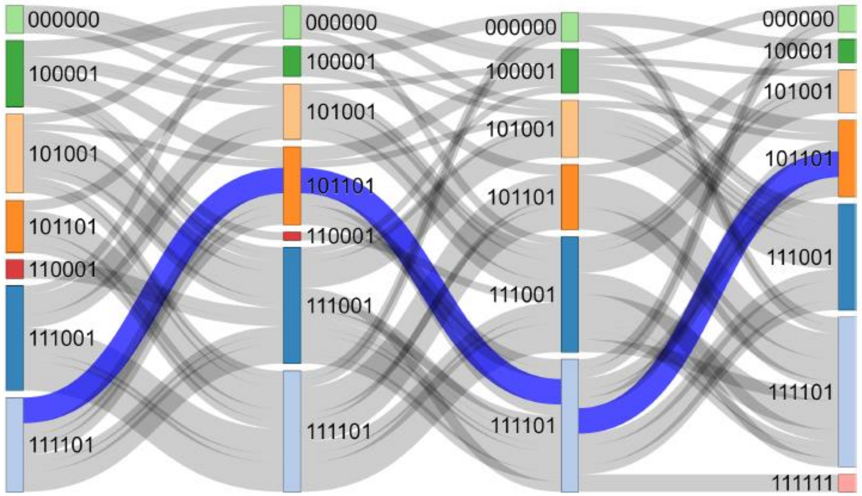
Related work



(Liu et al., 2011)



(Xia et al., 2019)

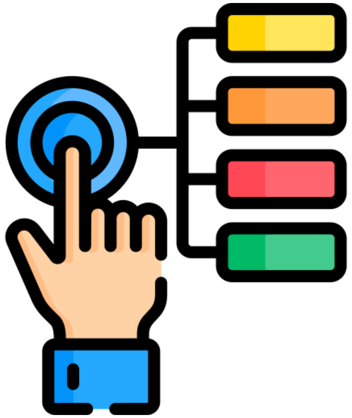


(Wang et al., 2017)

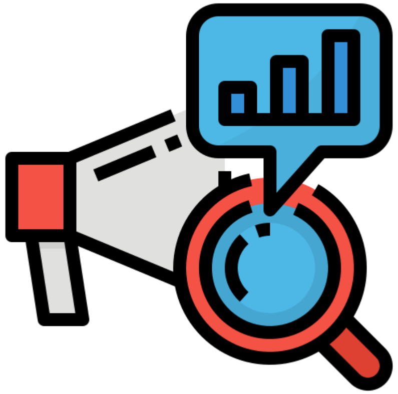
States cannot reflect students' thinking logic

Difficult to support analytical tasks, e.g., comparison

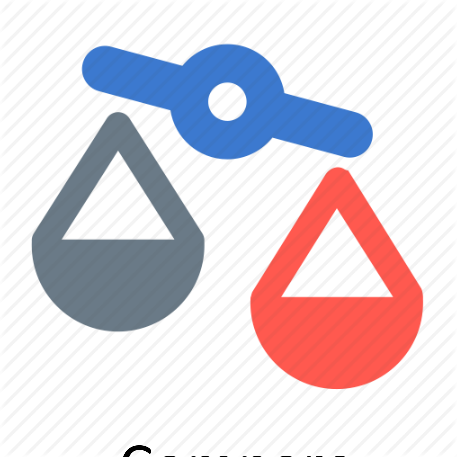
QLens for question designers



Inspect



Analyze



Compare

A user-centered design process

- Four domain experts
  - Question designers (E1, E2)
  - System developer (E3)
  - Project manager (E4)
- Requirements gathering iteratively >= one year

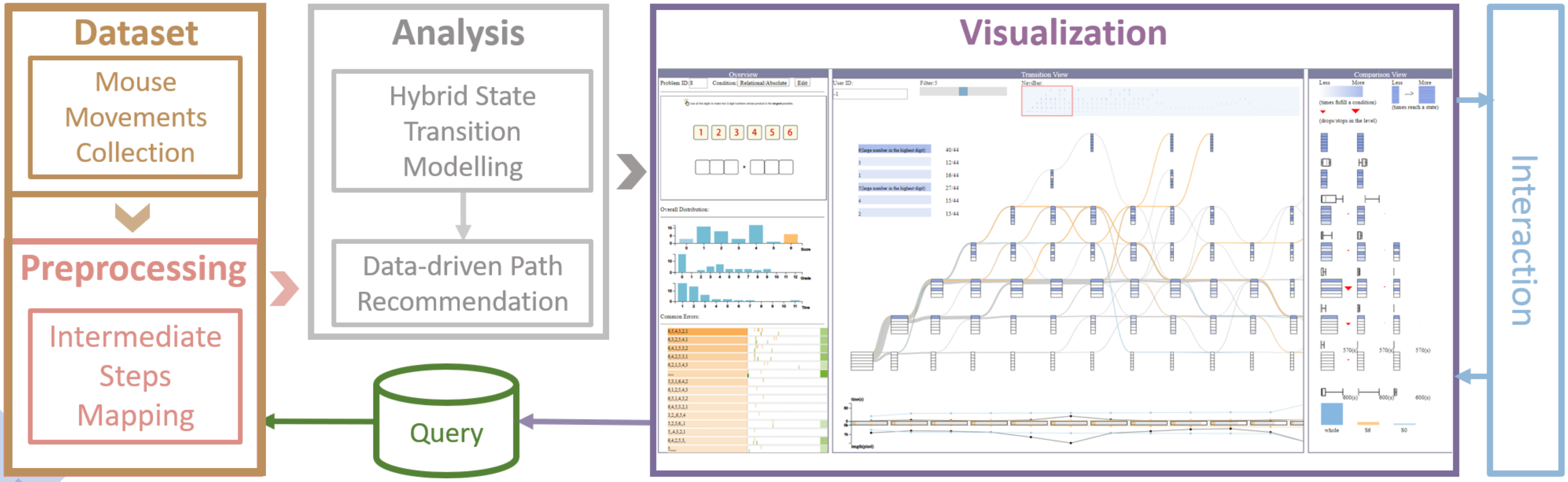
R1: Show students' **overall problem-solving performance**.

R2: **Summarize** and present the multi-step problem-solving behaviors.

R3: **Enable the comparison** of students from different groups.

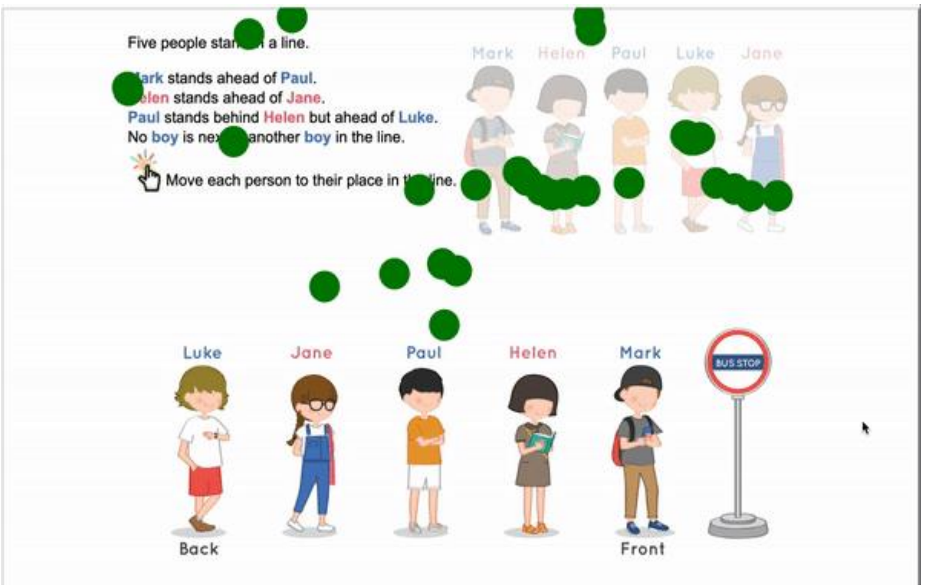
R4: **Evaluate the feasibility** of providing feedback based on existing data.

System overview



1. Data Preprocessing

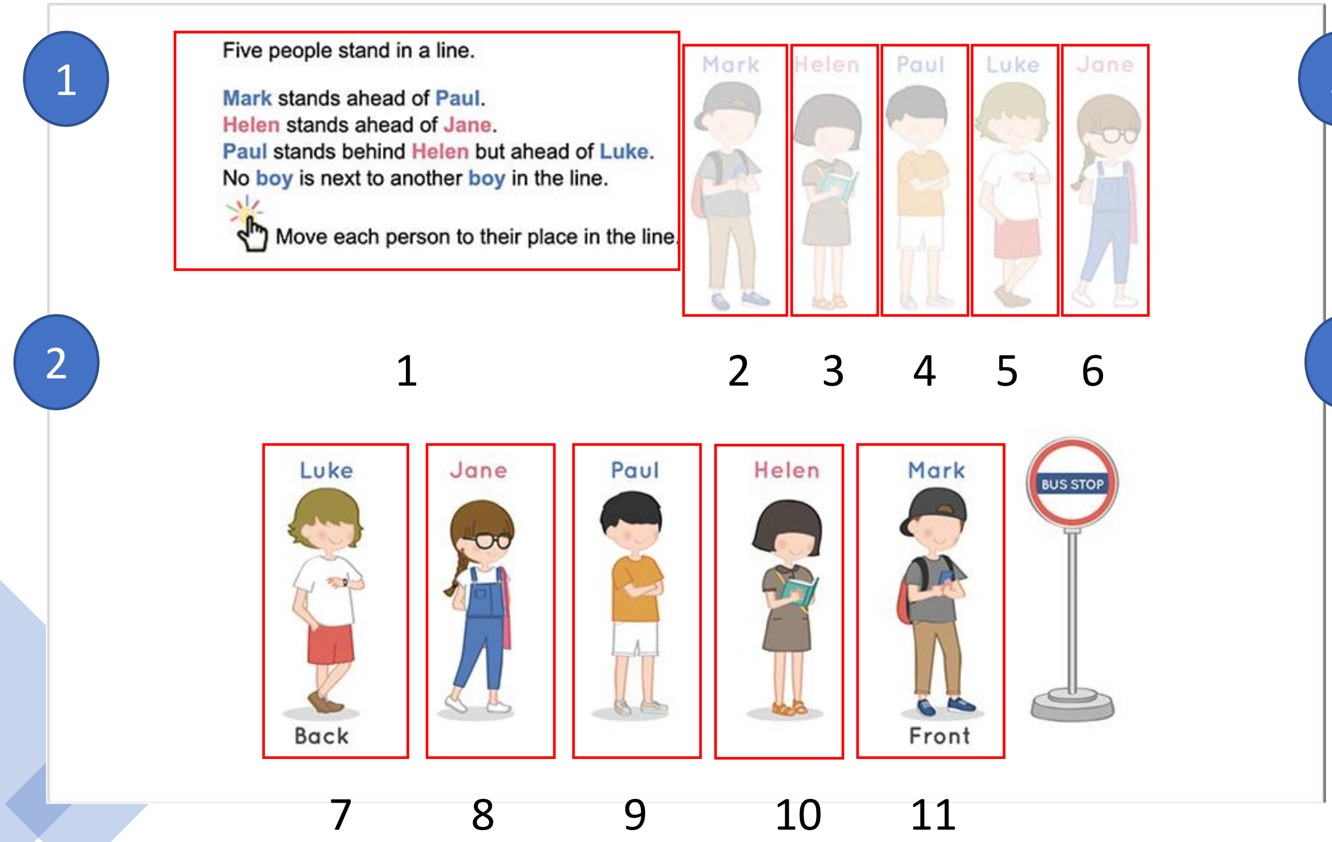
Source URL	http://mad9.learnlex.com/storage/mad/questions/2xbee2fdb4aec4e218/		
Element Path	HTML#.,BODY#.en,DIV#question_content.singlepage,DIV#std_wrapper……		
Question ID	geometry23567	User ID	10001
Time Stamp	20190122T1022	Action Type	click/drag/mousemove
Client Width	1920	Client Height	1080
X	567	Y	432
Touch Screen	True/False	Button	Enter
Platform	Windows/MacOS/iOS	Browser	Chrome/IE/Safari
……			



April 2019 to January 2020,
2,30,644 records from
5,266 students and 1,718 mathematical questions.

1. Data Preprocessing

For each question:



For each student:

3

2 11 4 7 3 8 8 9 …

4

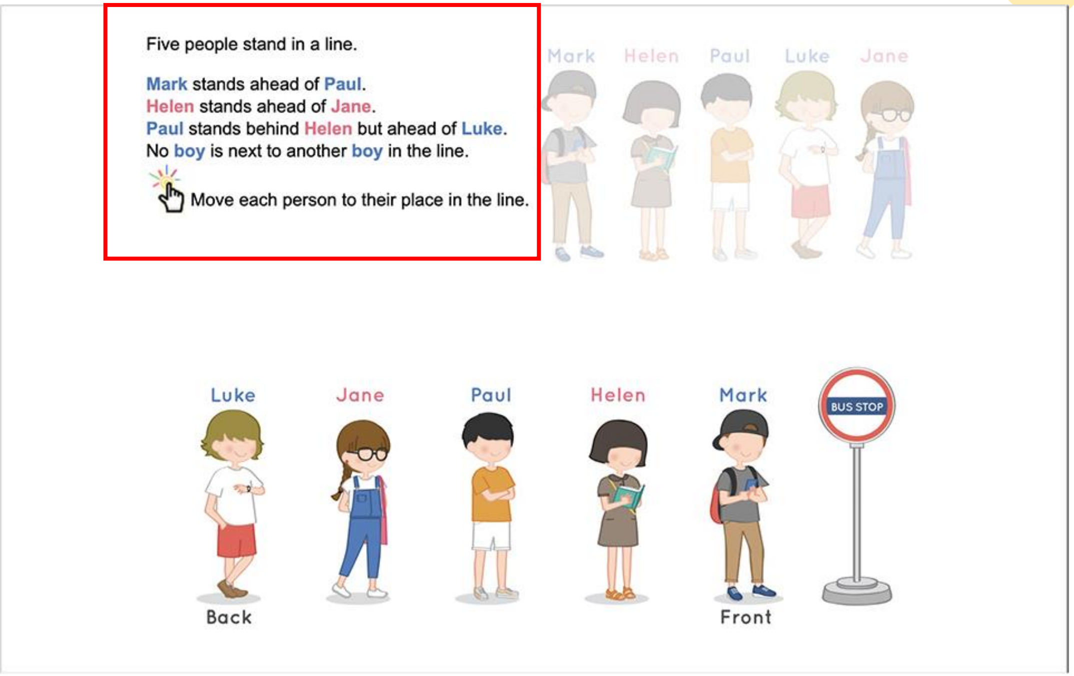
Step1: ,,,,Mark
Step2: Paul,,,,Mark
Step3: Paul,Helen,,,Mark
Step4: Paul,,Helen,,Mark
…

2. Data Analysis - State Transition Model

Step: the smallest user interface interaction that changes the intermediate answers

Stage: the number of conditions the current answer fulfills

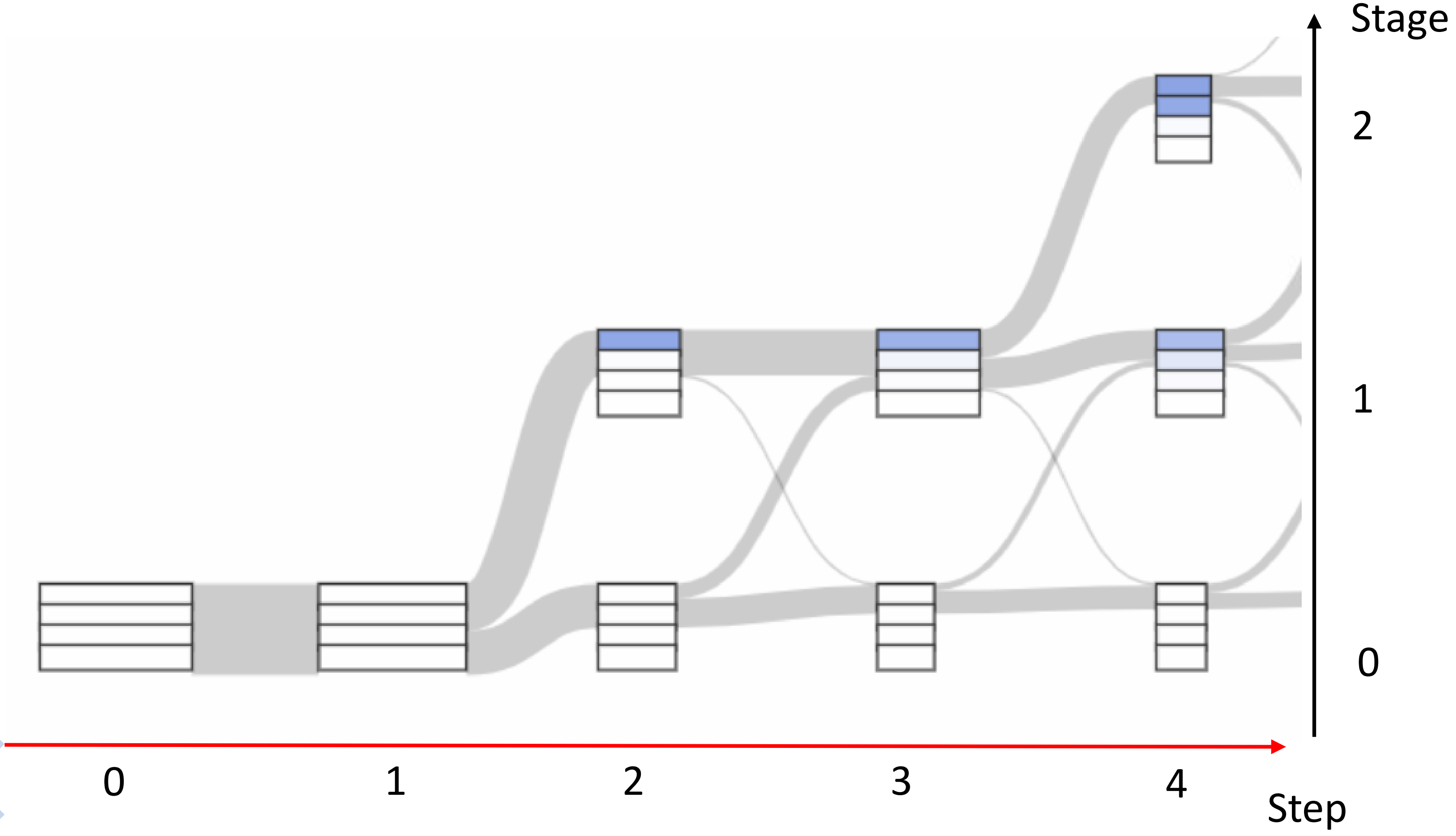
Condition: one criteria that students need to fulfill to get the partial score



Mark > Paul	149/233
Helen > Jane	140/233
Luke > Paul > Helen	78/233
No boys near each other	0/233

Step1: ,,,,Mark	Stage 0
Step2: Paul,,,,Mark	Stage 1
Step3: Paul,Helen,,,Mark	Stage 2
Step4: Paul,,Helen,,Mark	Stage 2
…	

3. Visualization - State Transition Visualization

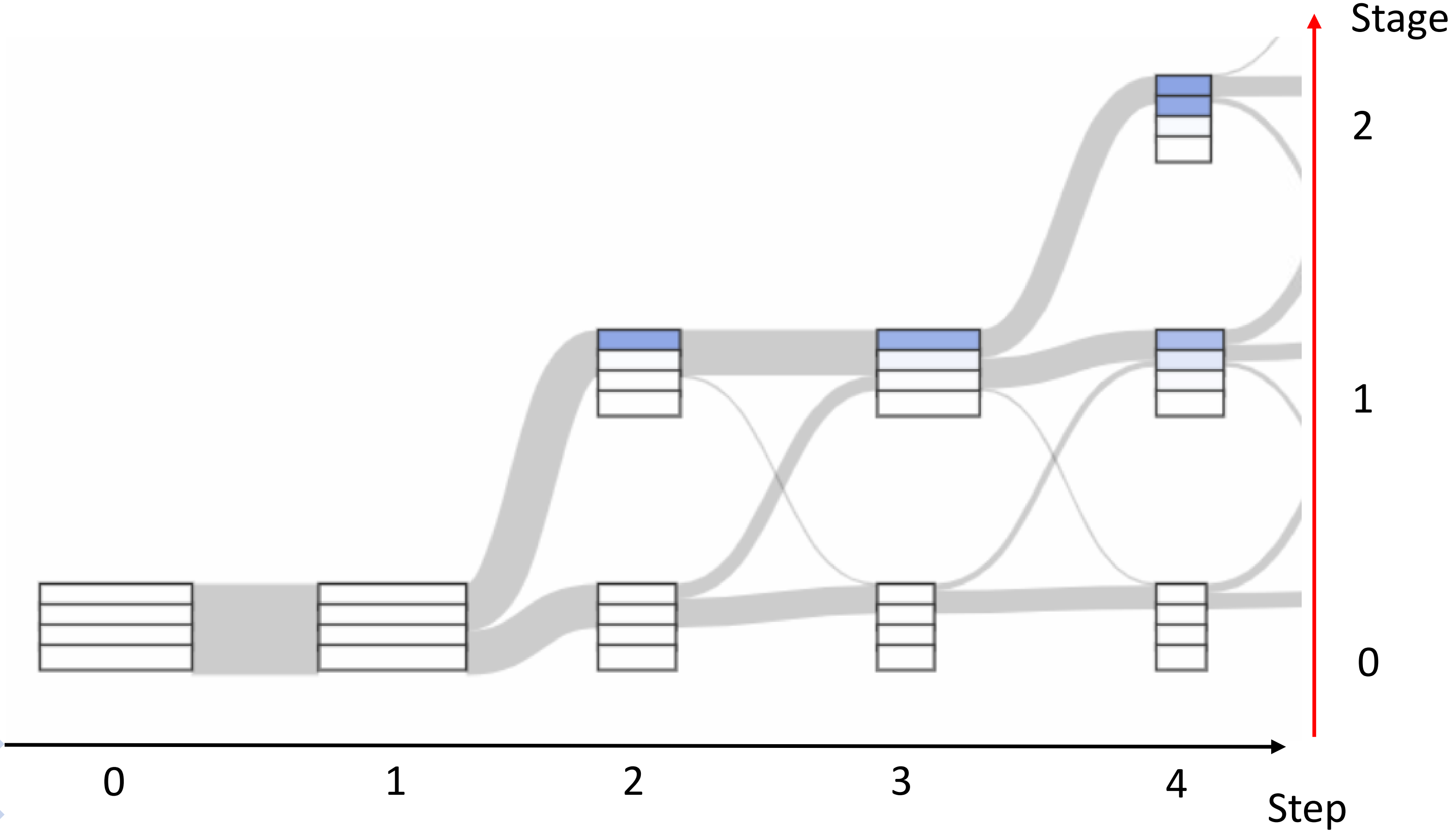


State:

Level1: {Step, Stage} + {Condition array, Time elapse, Trajectory length}

Level2: {Intermediate answer}

3. Visualization - State Transition Visualization

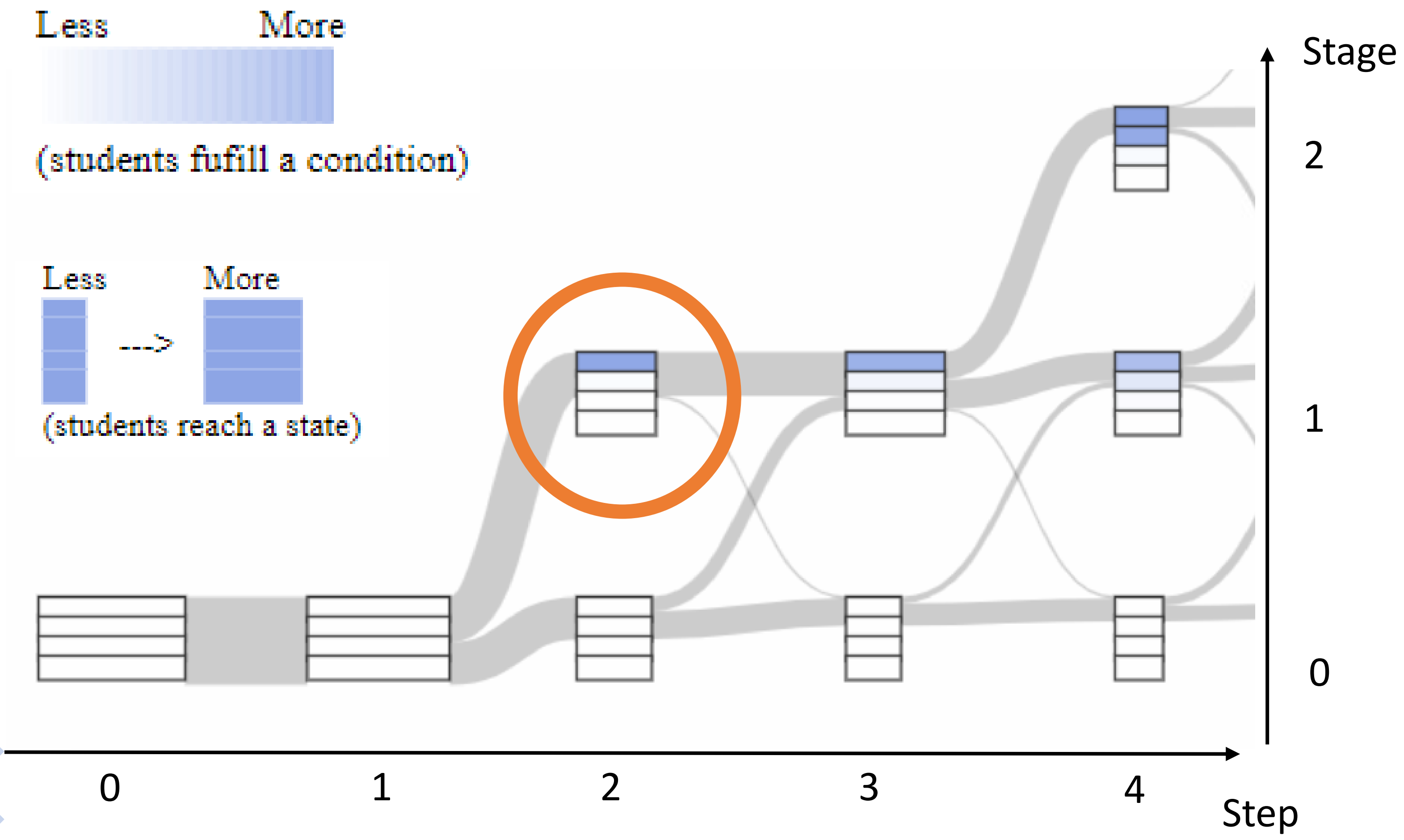


State:

Level1: {Step, Stage} + {Condition array, Time elapse, Trajectory length}

Level2: {Intermediate answer}

3. Visualization - State Transition Visualization

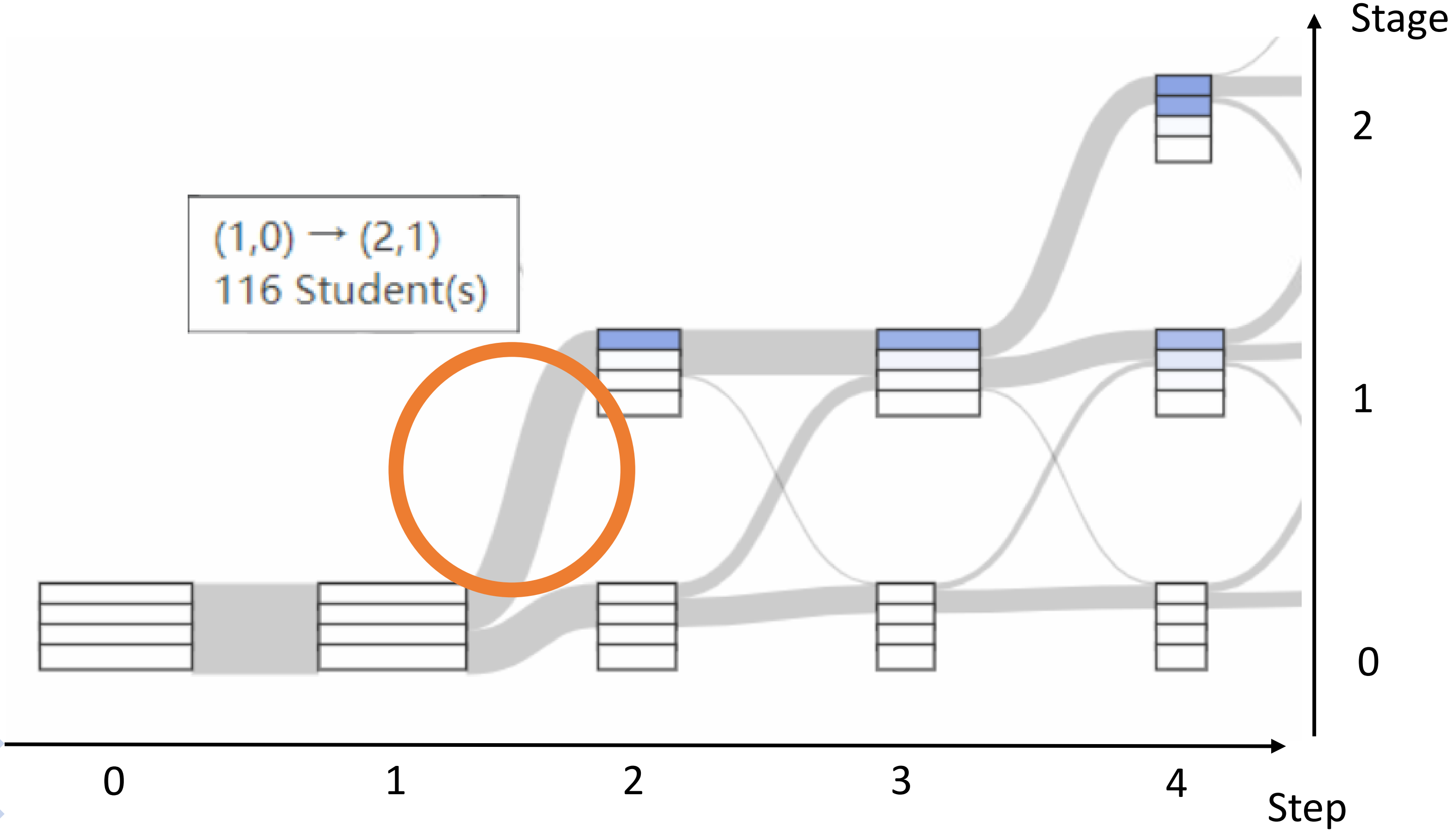


State:

Level1: {Step, Stage} + {Condition array, Time elapse, Trajectory length}

Level2: {Intermediate answer}

3. Visualization - State Transition Visualization

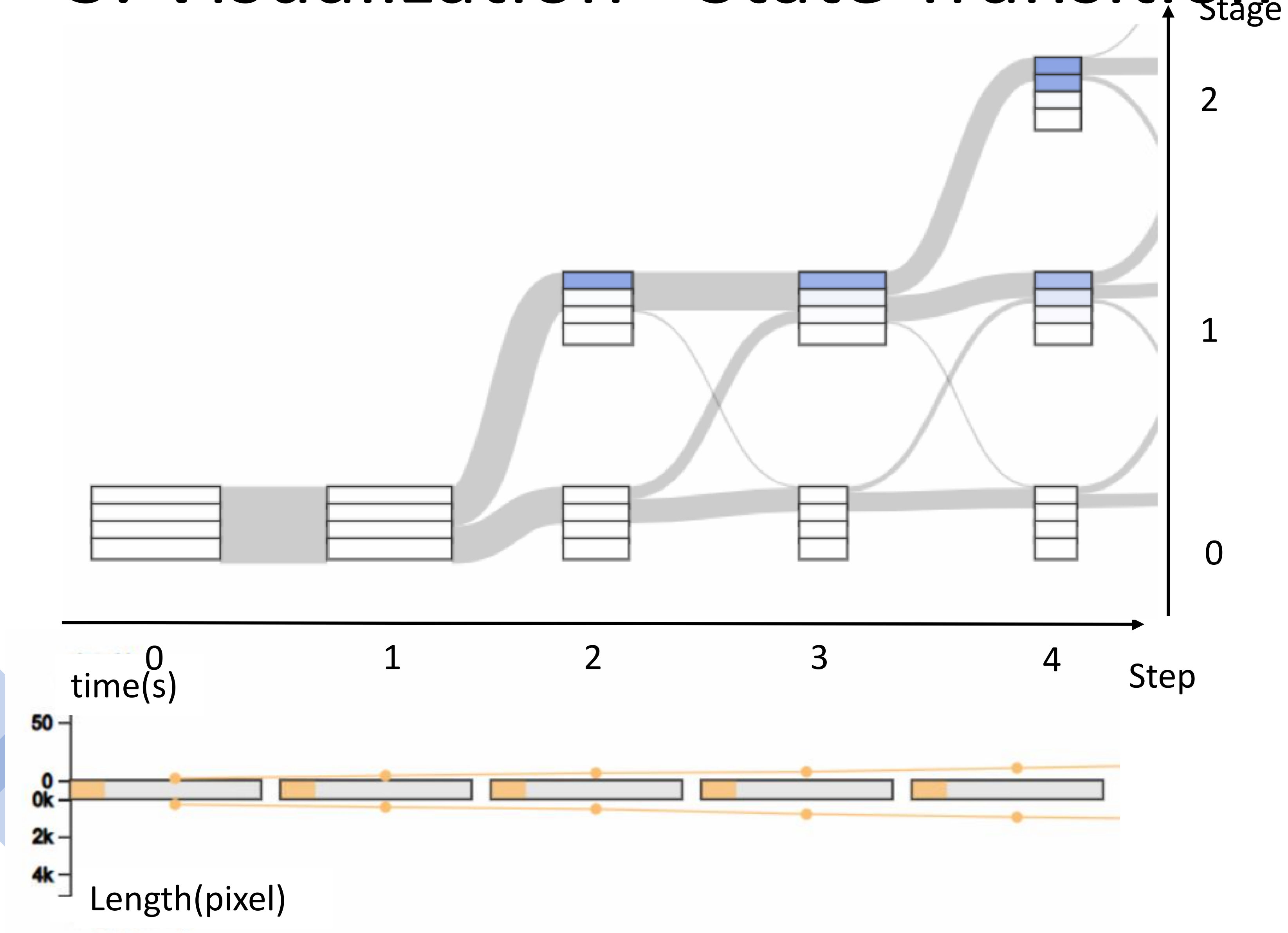


State:

Level1: {Step, Stage} + {Condition array, Time elapse, Trajectory length}

Level2: {Intermediate answer}

3. Visualization - State Transition Visualization

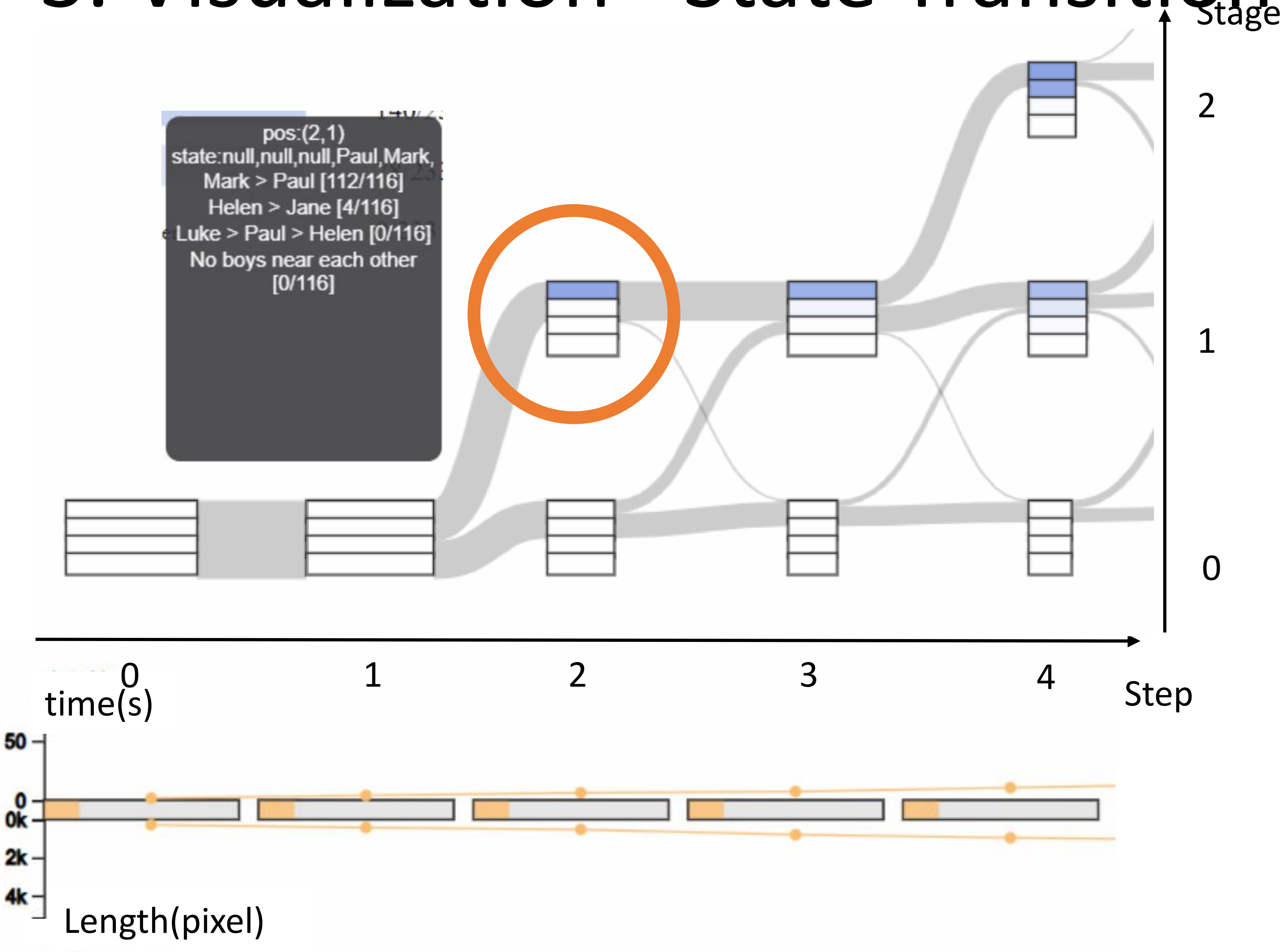


State:

Level1: {Step, Stage} + {Condition array, Time elapse, Trajectory length}

Level2: {Intermediate answer}

3. Visualization - State Transition Visualization

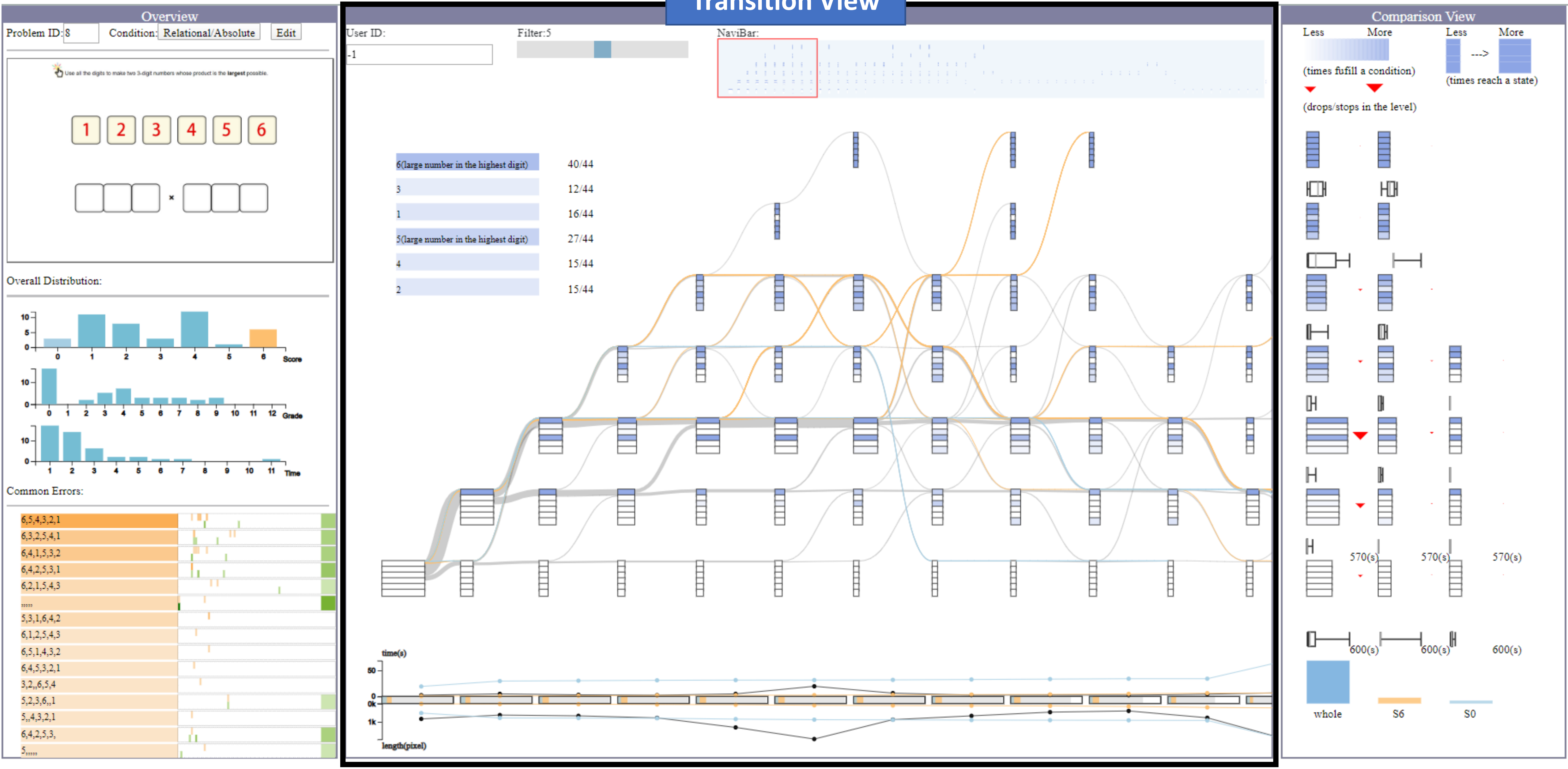


State:

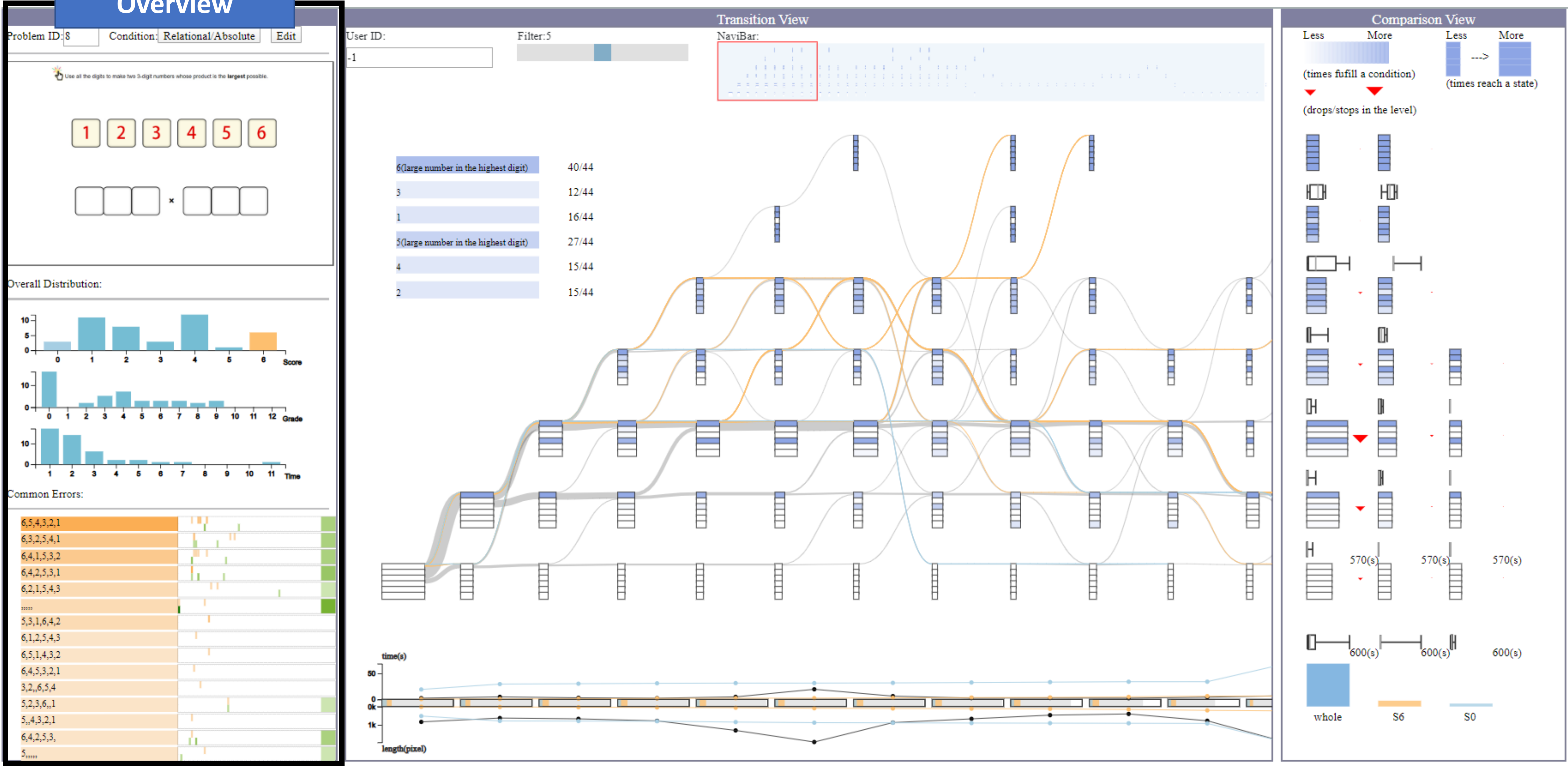
Level1: {Step, Stage} + {Condition array, Time elapse, Trajectory length}

Level2: {Intermediate answer}

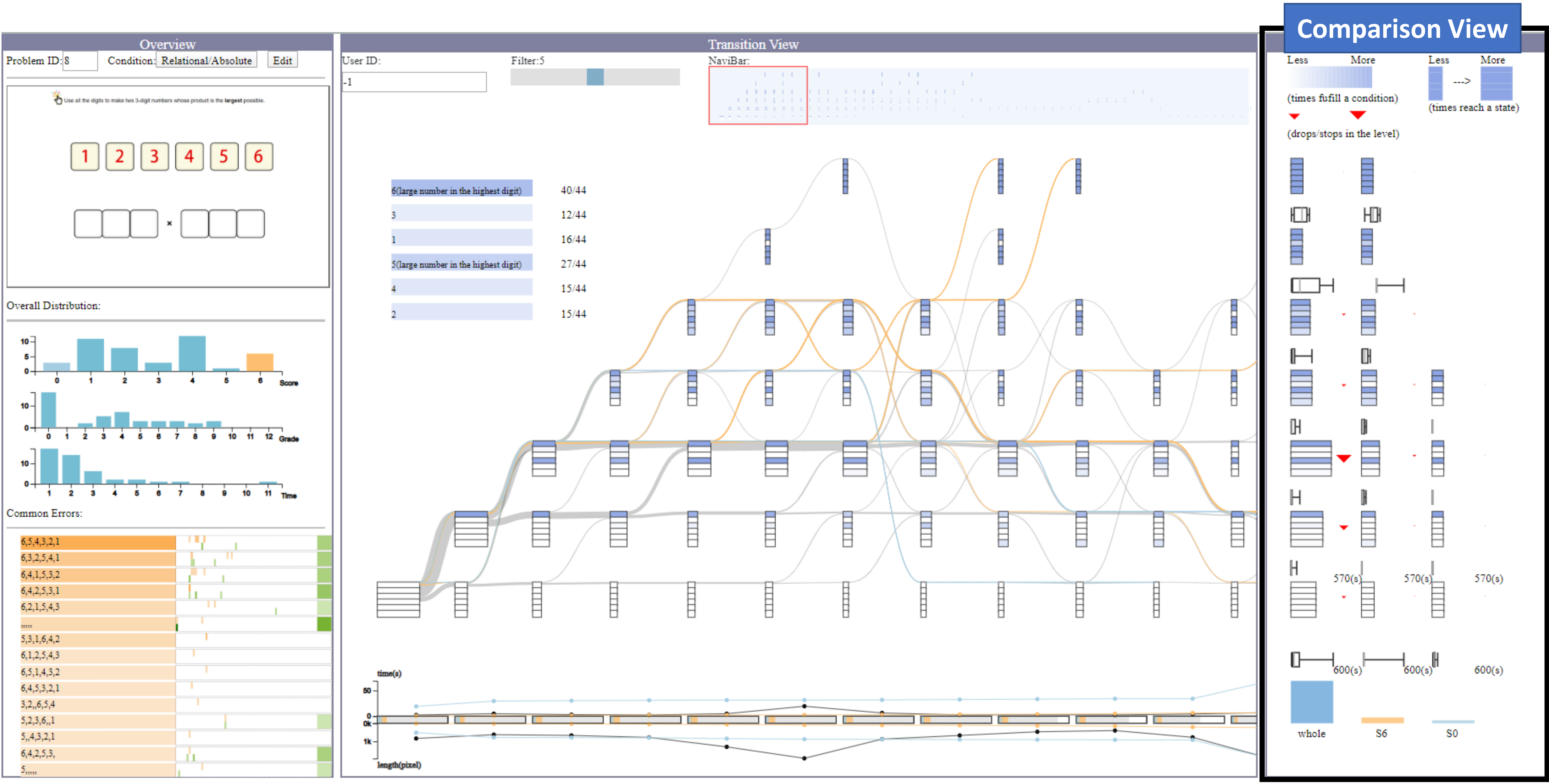
Transition View

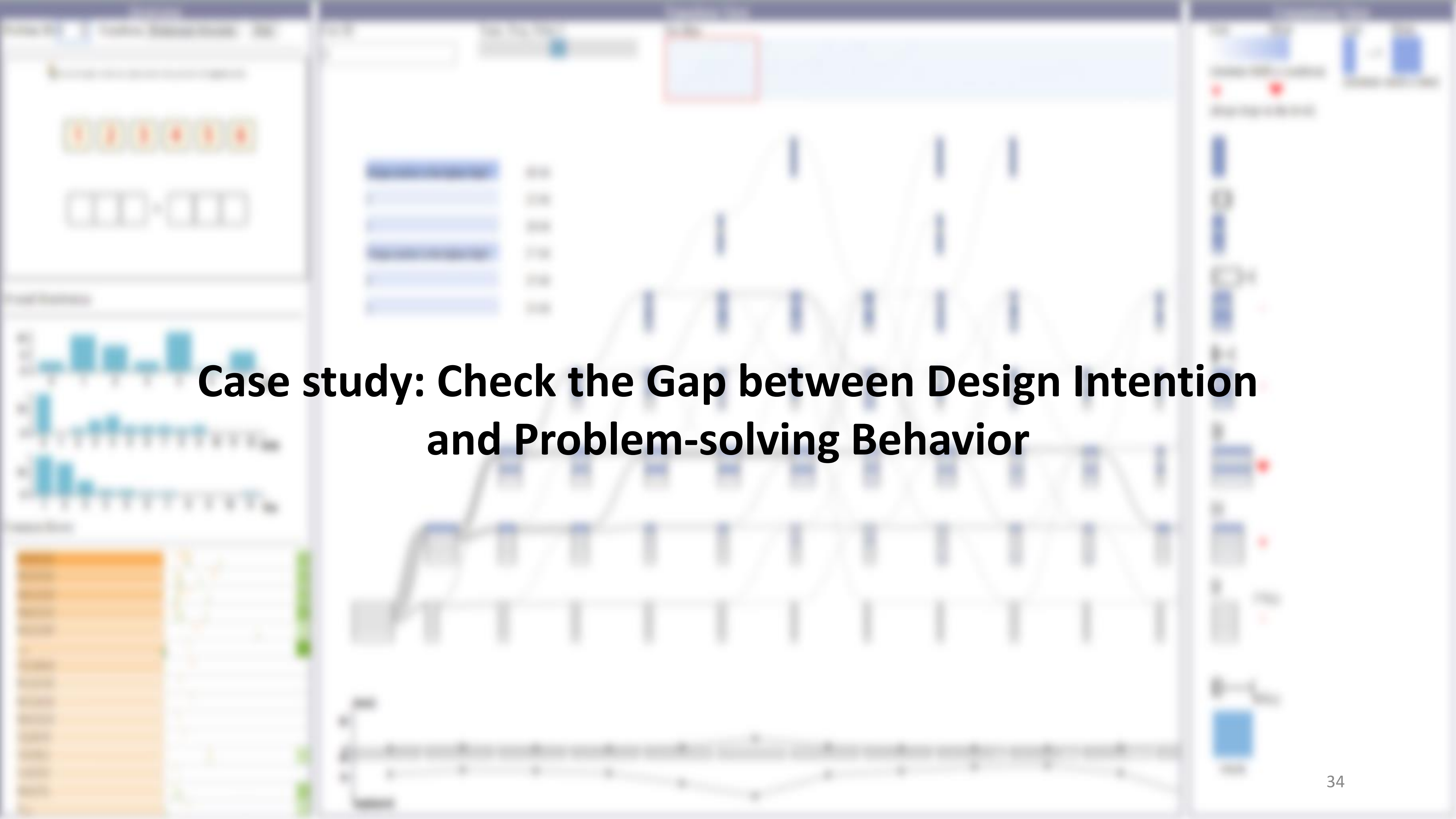


Overview



Problem ID: 8
Condition: Relational/Absolute
Edit
Overall Distribution:
Score
Grade
Time
Common Errors:
Transition View
User ID:
Filter:5
NaviBar:
6(large number in the highest digit) 40/44
3 12/44
1 16/44
5(large number in the highest digit) 27/44
4 15/44
2 15/44
time(s)
length(pixel)
Comparison View
Less
More
(times fufill a condition)
(times reach a state)
(drops/stops in the level)
570(s)
600(s)
whole
S6
S0


Comparison View
Overview
Problem ID: 8
Condition: Relational/Absolute
Edit
Transition View
User ID:
-1
Filter:5
NaviBar:
6(large number in the highest digit) 40/44
3 12/44
1 16/44
5(large number in the highest digit) 27/44
4 15/44
2 15/44
Overall Distribution:
Score
Grade
Time
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
6,5,1,4,3,2
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,,,,,
time(s)
length(pixel)
Less
More
(times fufill a condition)
(drops/stops in the level)
(times reach a state)
570(s)
600(s)
whole
S6
S0



Case study: Check the Gap between Design Intention and Problem-solving Behavior

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.

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

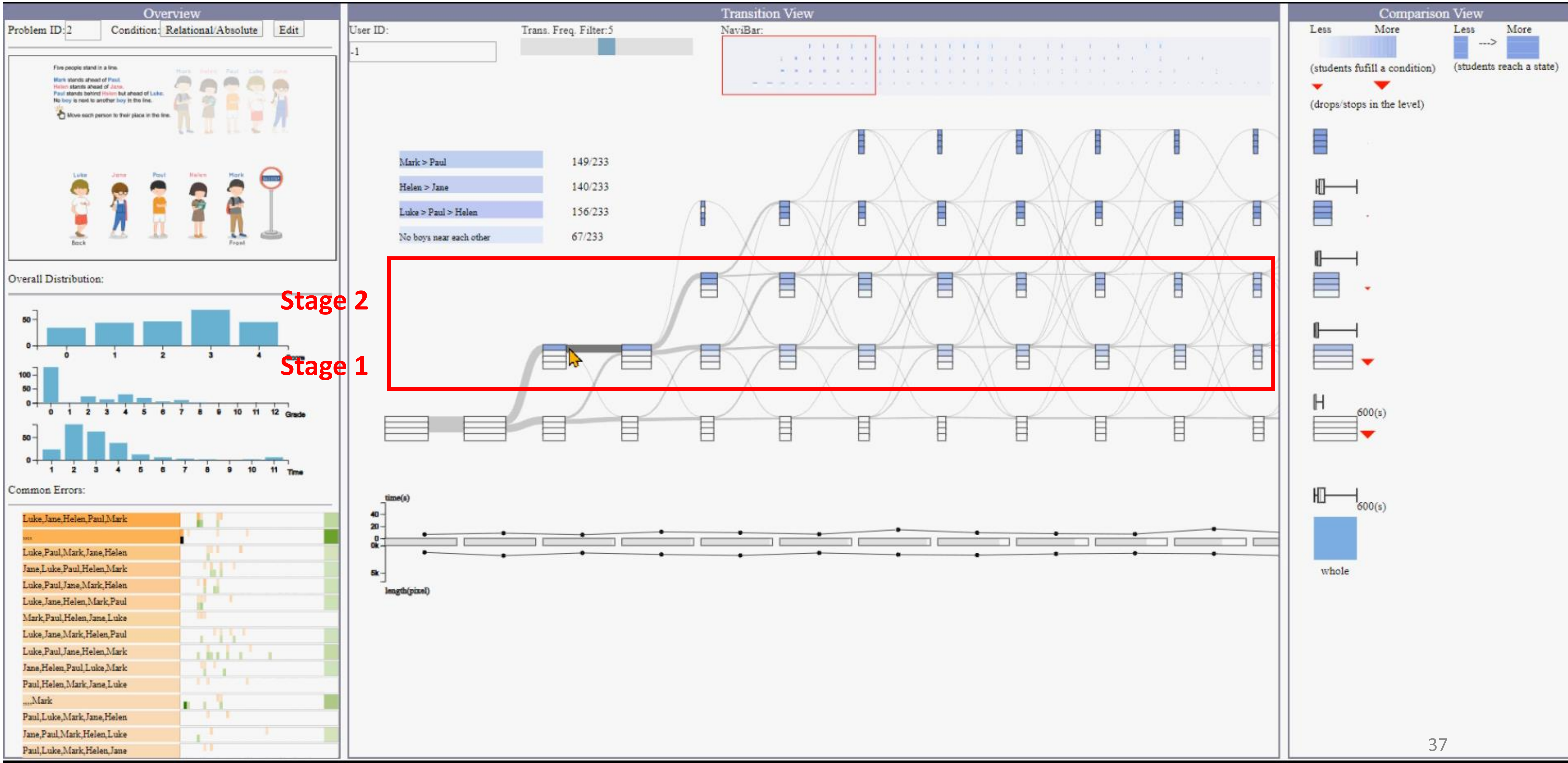
Back Boy Girl Boy Girl Boy Front

“Mark stands ahead of Paul”, “Paul stands ahead of Luke”. Therefore,

Back Luke Girl Paul Girl Mark Front

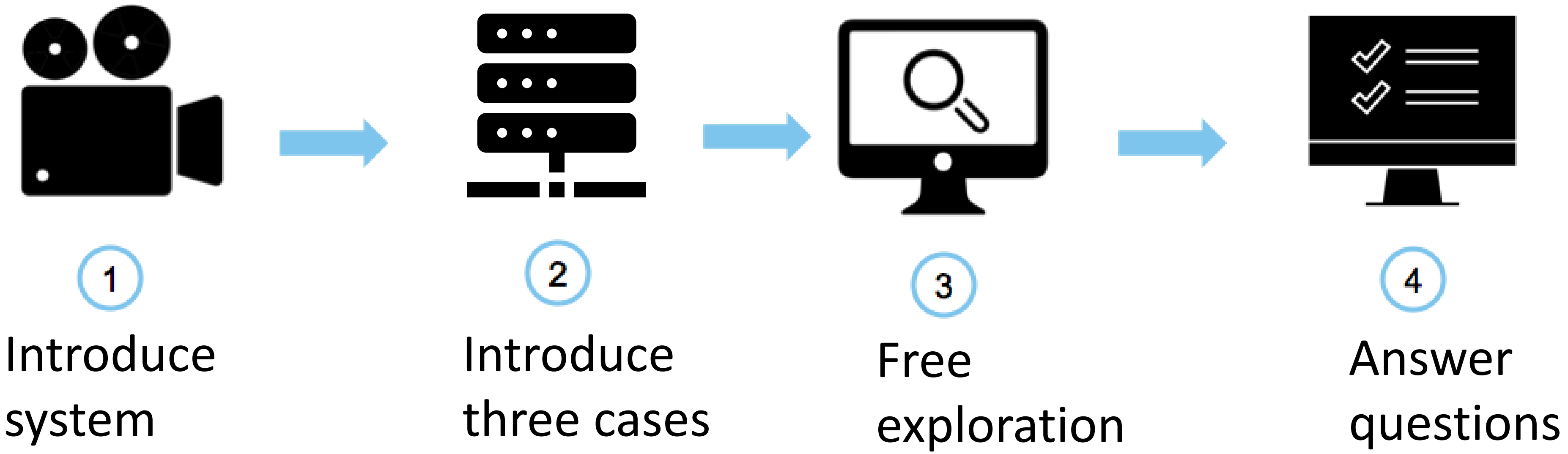
“Helen stands ahead of Jane”. Therefore,

Back Luke Jane Paul Helen Mark Front


Overview
Problem ID: 2
Condition: Relational/Absolute
Edit
Overall Distribution:
Common Errors:
Transition View
User ID:
-1
Trans. Freq. Filter: 5
NaviBar:
Mark > Paul 149/233
Helen > Jane 140/233
Luke > Paul > Helen 156/233
No boys near each other 67/233
Stage 2
Stage 1
Comparison View
Less
More
(students fufill a condition)
(students reach a state)
(drops/stops in the level)
600(s)
whole

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



Evaluation

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

System usefulness

"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

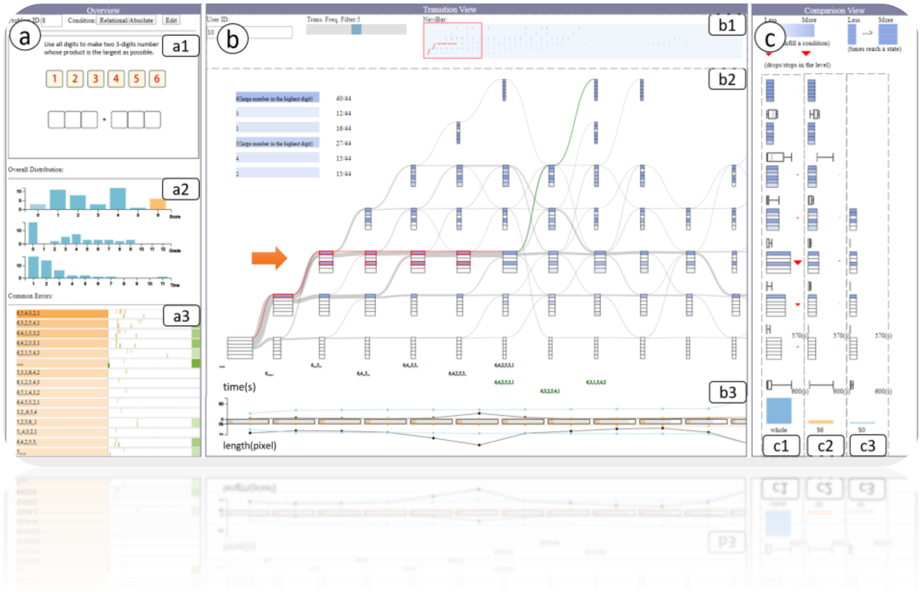
Positive

Neutral

Negative

Conclusion

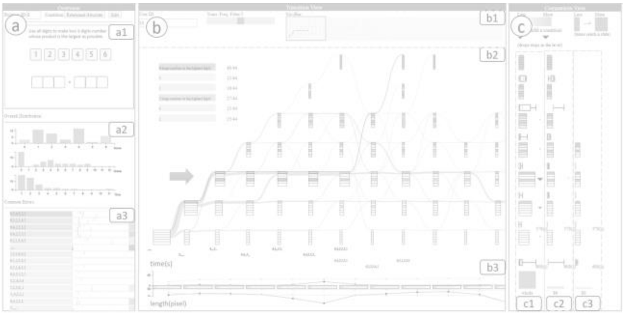
- An interactive visual analytics system on multi-step question design
- A novel glyph-embedded Sankey diagram
- Three case studies and interviews with domain experts



How can we analyze students' behaviors on macro level (multiple questions)?

Our works

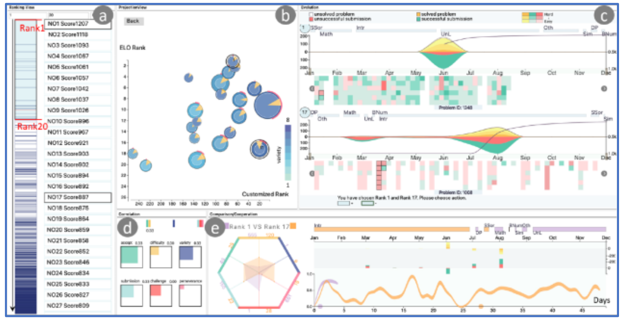
Qlens: multi-step question analysis. VIS 2020 (conditionally accepted)



"Game the system": learning behavior regulatin. L@S, 2020

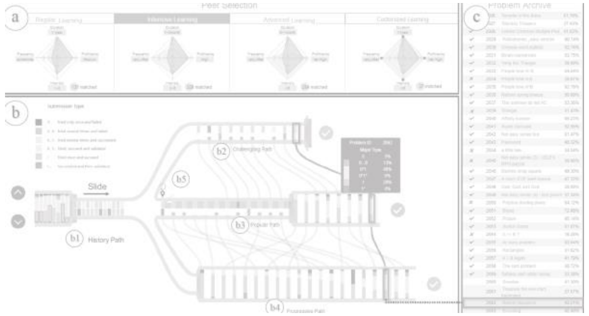
Micro level

Empower educators ← Problem-solving Data → Empower students

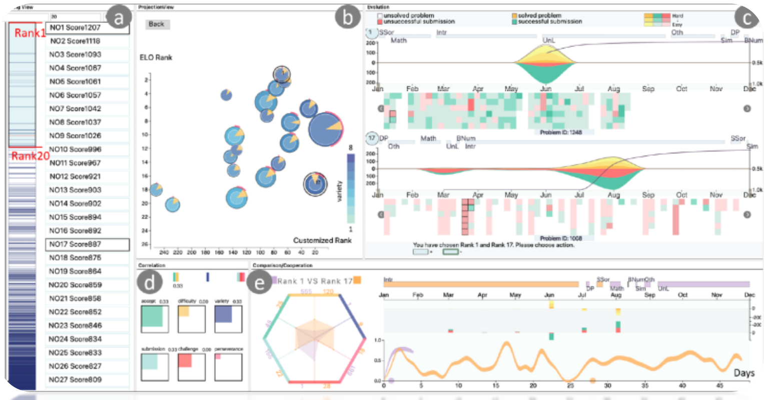


SeqDynamics: problem-solving dynamics analysis. Euro VIS, 2020

Macro level



Peerlens: learning path planning. CHI, 2019



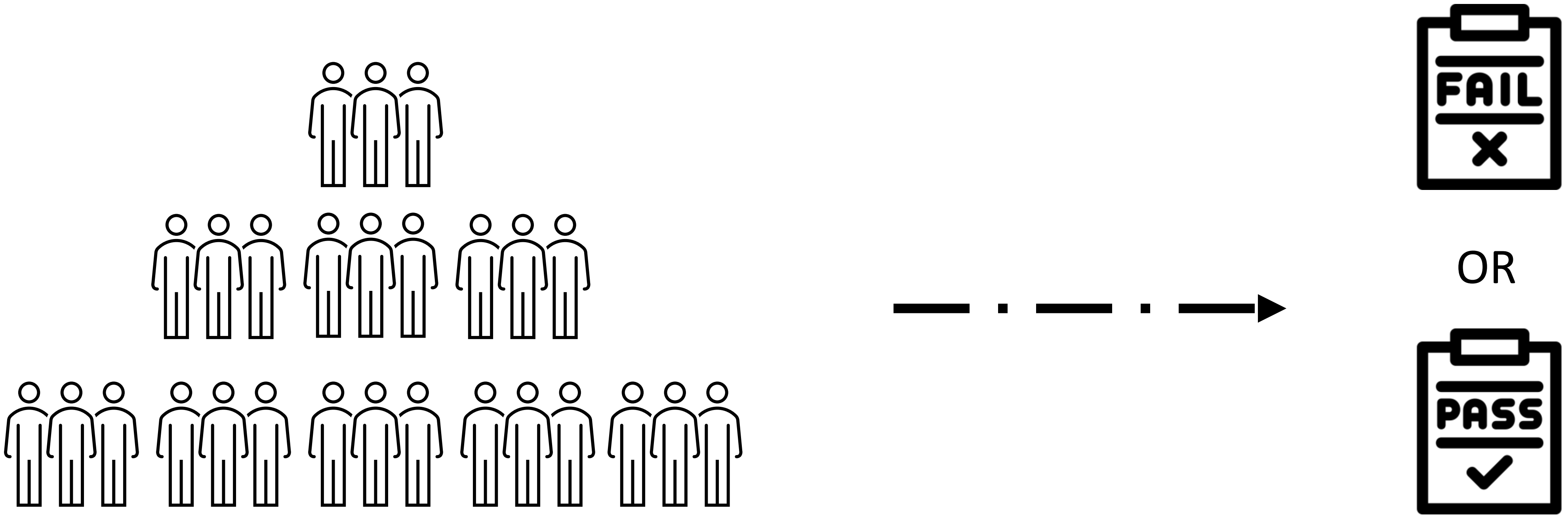
SeqDynamics: Visual Analytics for Evaluating Online Problem-solving Dynamics

Meng Xia, Min Xu, Chuan-en Lin, Ta Ying Cheng, Huamin Qu, Xiaojuan Ma

EuroVIS 2020

Elite Selection in University

Interview in IT Company

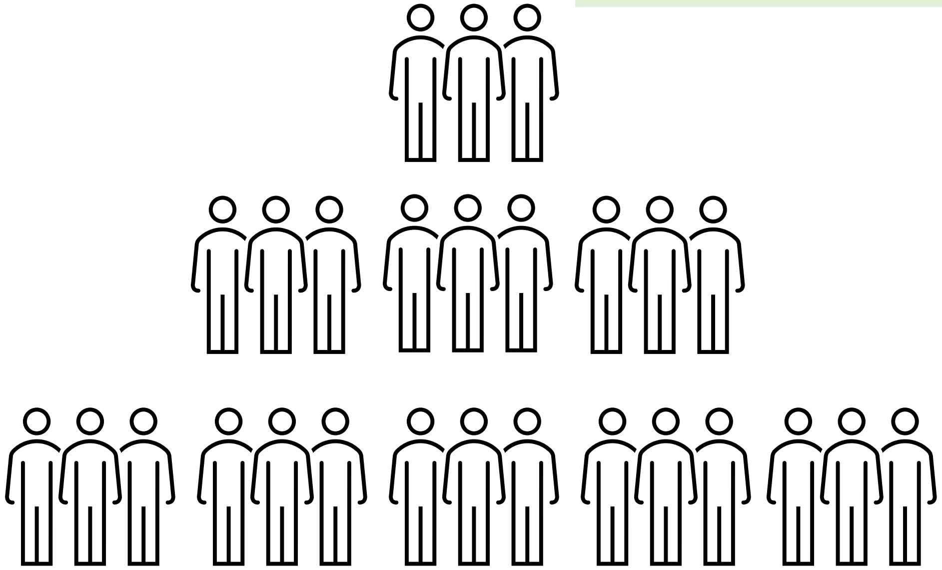


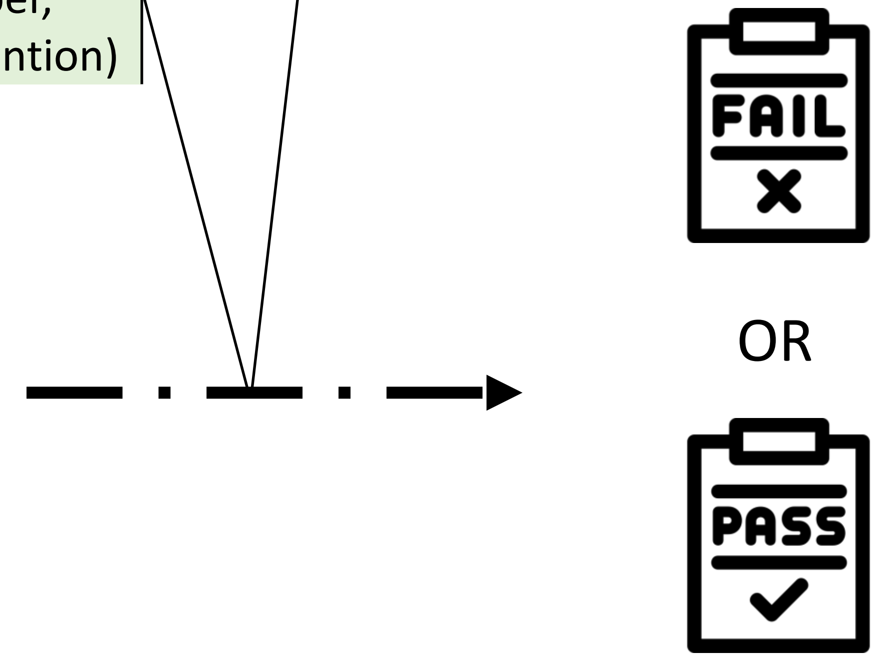
Elite Selection in University

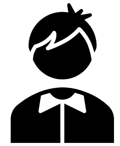
Interview in IT Company

Cognitive skills (think, read, learn, remember, reason, and pay attention)

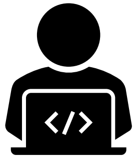
Noncognitive traits (motivation, conscientiousness, perseverance, self-regulation, and collaboration)



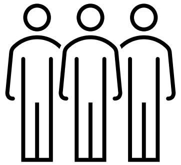




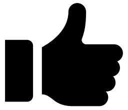
Elite Selection in University



Interview in IT Company



Cognitive skills (think, read, **learn**, remember, reason, and pay attention)



Noncognitive traits (motivation, conscientiousness, perseverance, **self-regulation**, and collaboration)

OR

Exams/Technical interviews

Performance and behavior on a long period.

Run ID	Submit Time	Judge Status	Pro.ID	Exe.Time	Exe.Memory	Code Len.	Language	Author
23412857	2017-12-28 00:03:33	Accepted	2046	0MS	1700K	310B	G++	xiameng552180
23412041	2017-12-27 22:24:35	Accepted	2045	0MS	1696K	309B	G++	xiameng552180
23411734	2017-12-27 21:52:45	Wrong Answer	2045	0MS	1700K	388B	G++	xiameng552180
23411669	2017-12-27 21:45:25	Wrong Answer	2045	0MS	1696K	382B	G++	xiameng552180
23411286	2017-12-27 21:10:04	Accepted	2044	15MS	2052K	410B	G++	xiameng552180
23411278	2017-12-27 21:09:05	Wrong Answer	2044	0MS	2048K	404B	G++	xiameng552180
23410918	2017-12-27 20:38:17	Wrong Answer	2044	0MS	2052K	404B	G++	xiameng552180
23408905	2017-12-27 17:39:49	Accepted	2043	0MS	1700K	899B	G++	xiameng552180
23408506	2017-12-27 16:52:47	Accepted	2042	0MS	1696K	254B	G++	xiameng552180
23405316	2017-12-27 01:33:38	Accepted	2041	15MS	1708K	360B	G++	xiameng552180
23405296	2017-12-27 01:21:02	Accepted	2040	78MS	1688K	433B	G++	xiameng552180
23405284	2017-12-27 01:11:27	Accepted	2039	0MS	1740K	280B	G++	xiameng552180
23405283	2017-12-27 01:10:20	Wrong Answer	2039	0MS	1744K	283B	G++	xiameng552180
23405282	2017-12-27 01:09:41	Wrong Answer	2039	15MS	1692K	280B	G++	xiameng552180
23405277	2017-12-27 01:05:09	Accepted	2037	15MS	1708K	729B	G++	xiameng552180

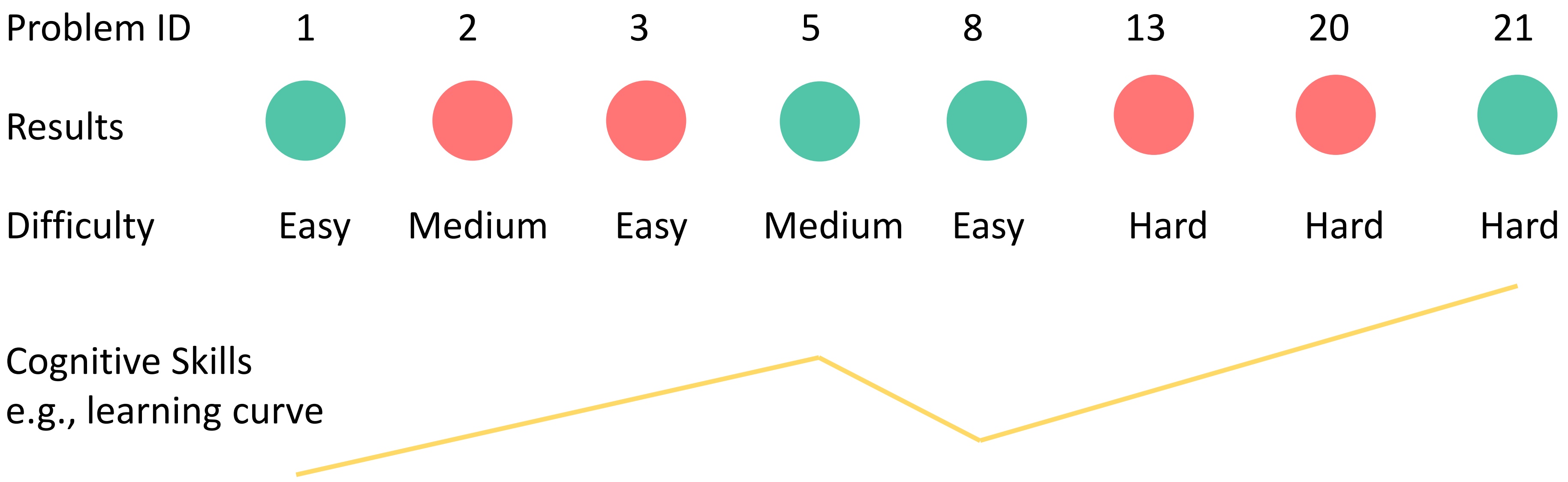
Problem-solving Dynamics

The process and progress of solving a series of problems over time.

Problem ID	1	2	3	5	8	13	20	21
Results								
Difficulty	Easy	Medium	Easy	Medium	Easy	Hard	Hard	Hard

Problem-solving Dynamics

The process and progress of solving a series of problems over time.

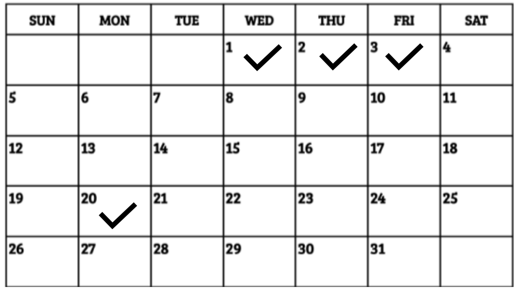


Problem-solving Dynamics

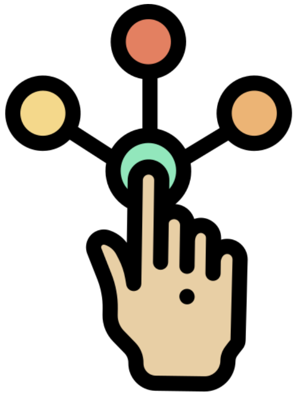
The process and progress of solving a series of problems over time.

Problem ID	1	2	3	5	8	13	20	21
Results								
Difficulty	Easy	Medium	Easy	Medium	Easy	Hard	Hard	Medium
Timestamp	Jan. 1	Jan. 1	Jan. 2	Jan. 3	Jan. 3	Jan. 20	Jan. 20	Jan. 20

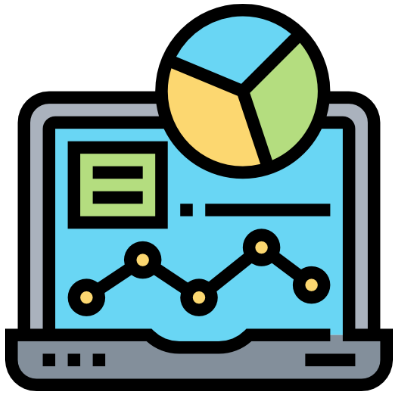
Non-cognitive Trait
e.g., self-regulation



SeqDynamics



Interactive



Multi-dimensional

Time-series

A user-centered design process

Four domain experts

- Recruiters from the competitive programming team (E1, E2)
- Student coaches (E3, E4)

Requirements gathering iteratively for three months

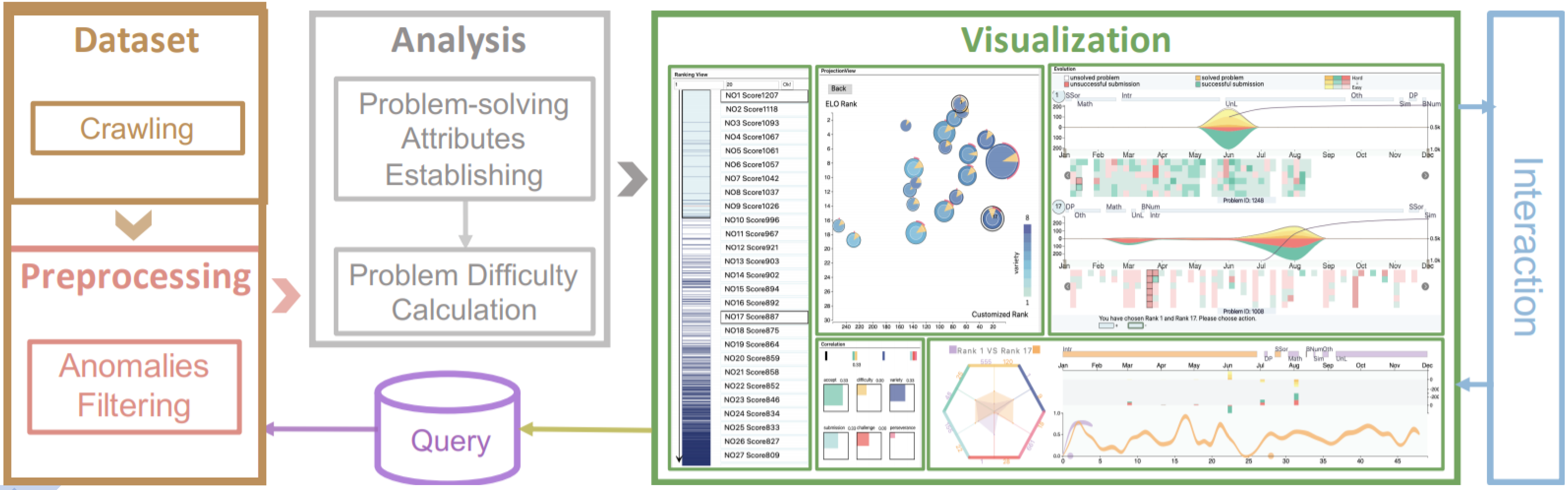
R1: Show a clear overview of overall students' problem-solving performance.

R2: Understand problem-solving dynamics from different perspectives over time. (i.e., cognitive and non-cognitive).

R3: Compare/Combine the problem-solving performance at different scales.

R4: Support an interactive and customized exploration of the evaluation.

System overview



Problem-solving Feature Extraction

Changes of these features below over time:

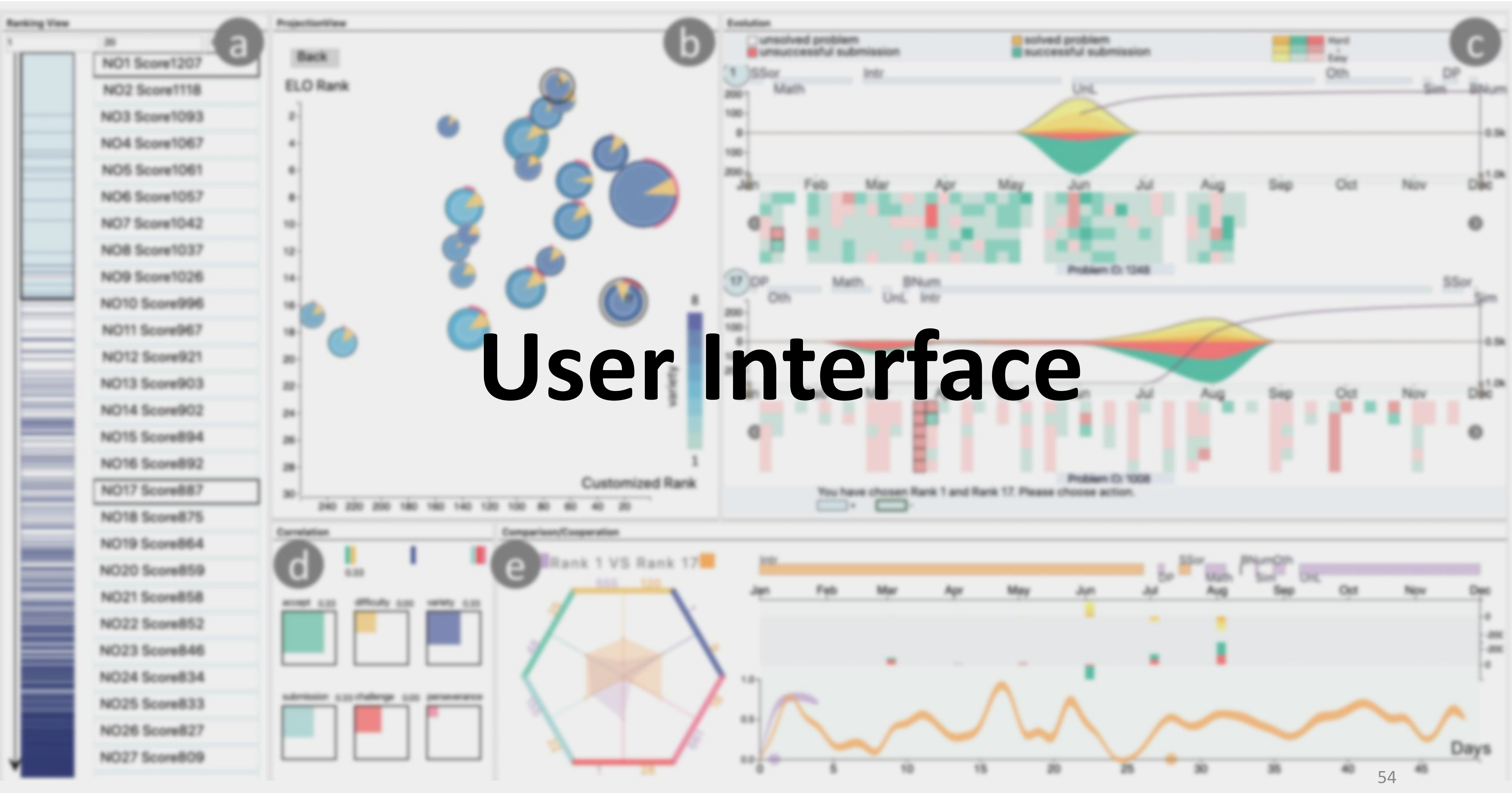
Cognitive ability *(Ausubel et al., 1968)*

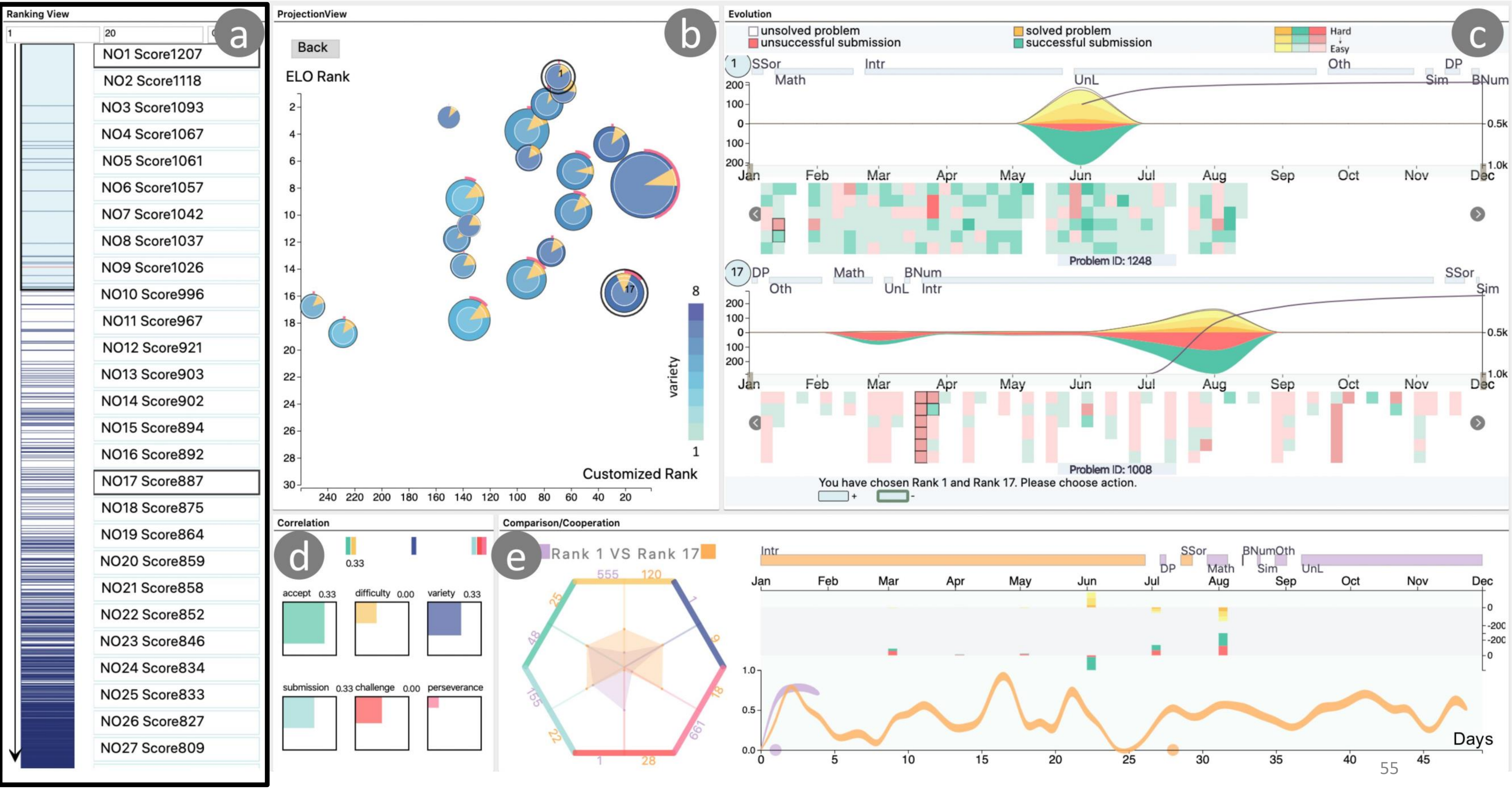
- L1: number of problems solved
- L2: ratio of hard problems solved
- L3: diversity of problems solved

Non-cognitive traits *(Farkas, 2003)*

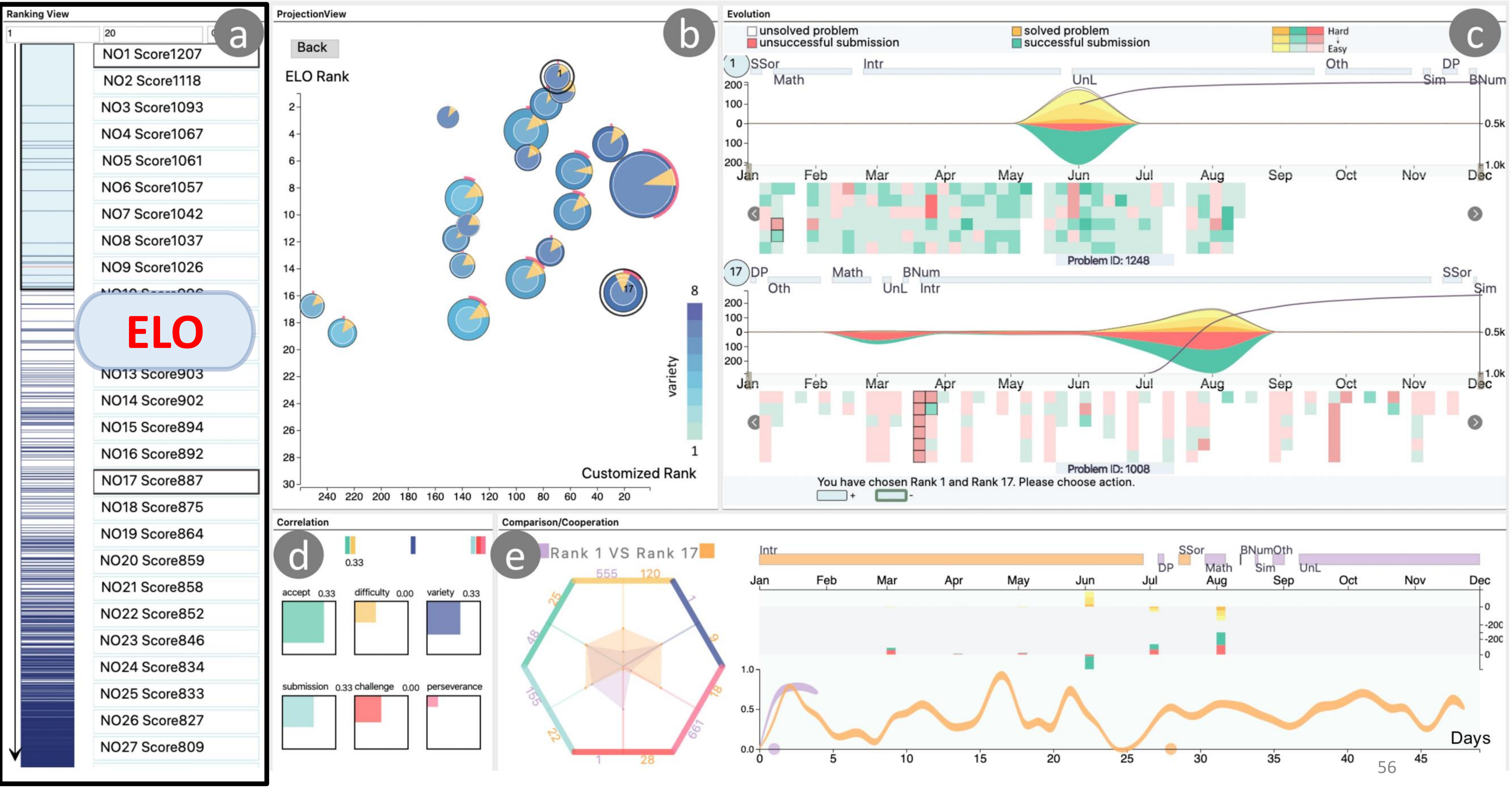
- L4: number of submissions (diligence level)
- L5: time starting to trying hard problems (willingness to take challenge)
- L6: ratio of active days (perseverance)

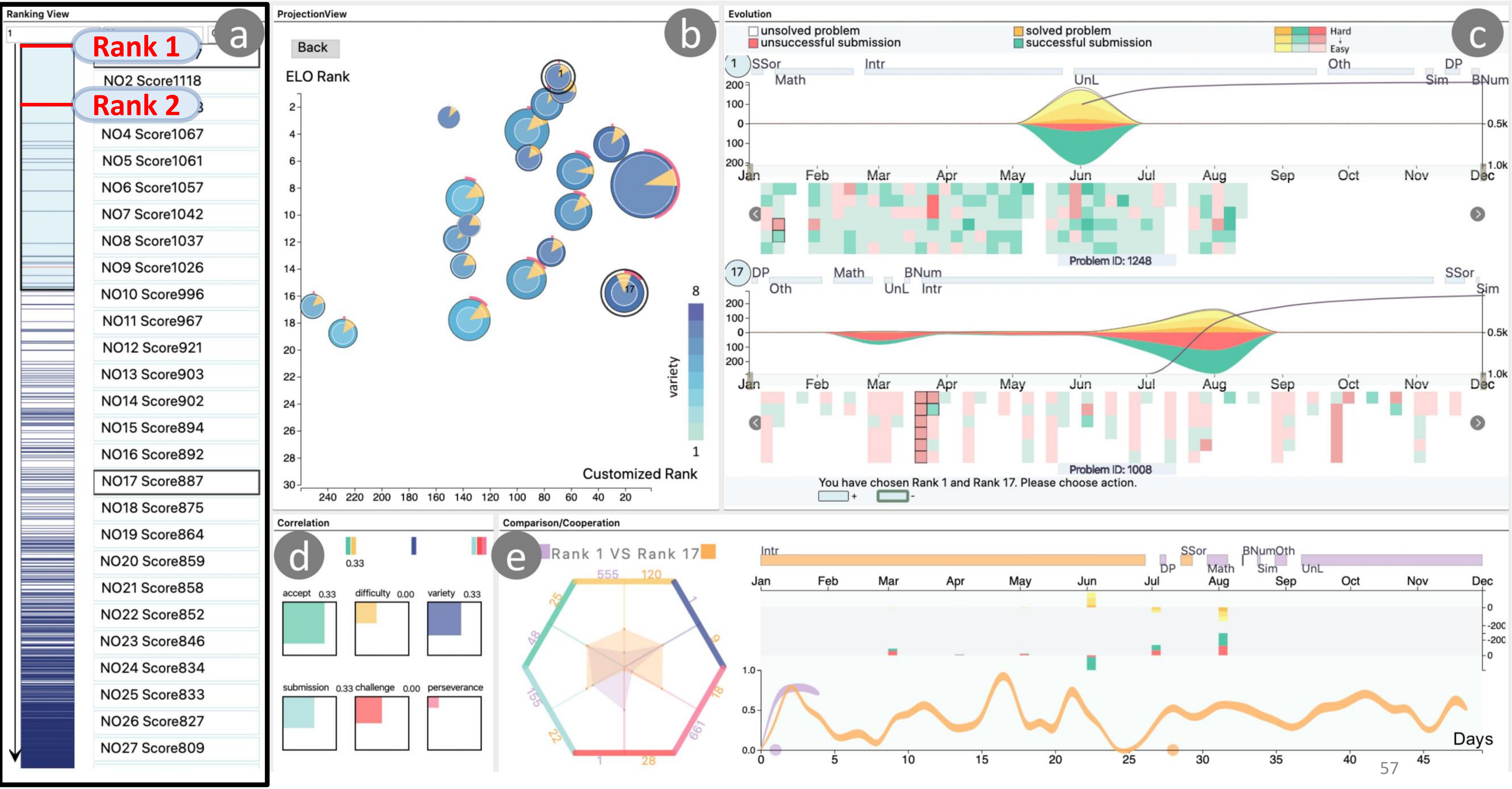
User Interface



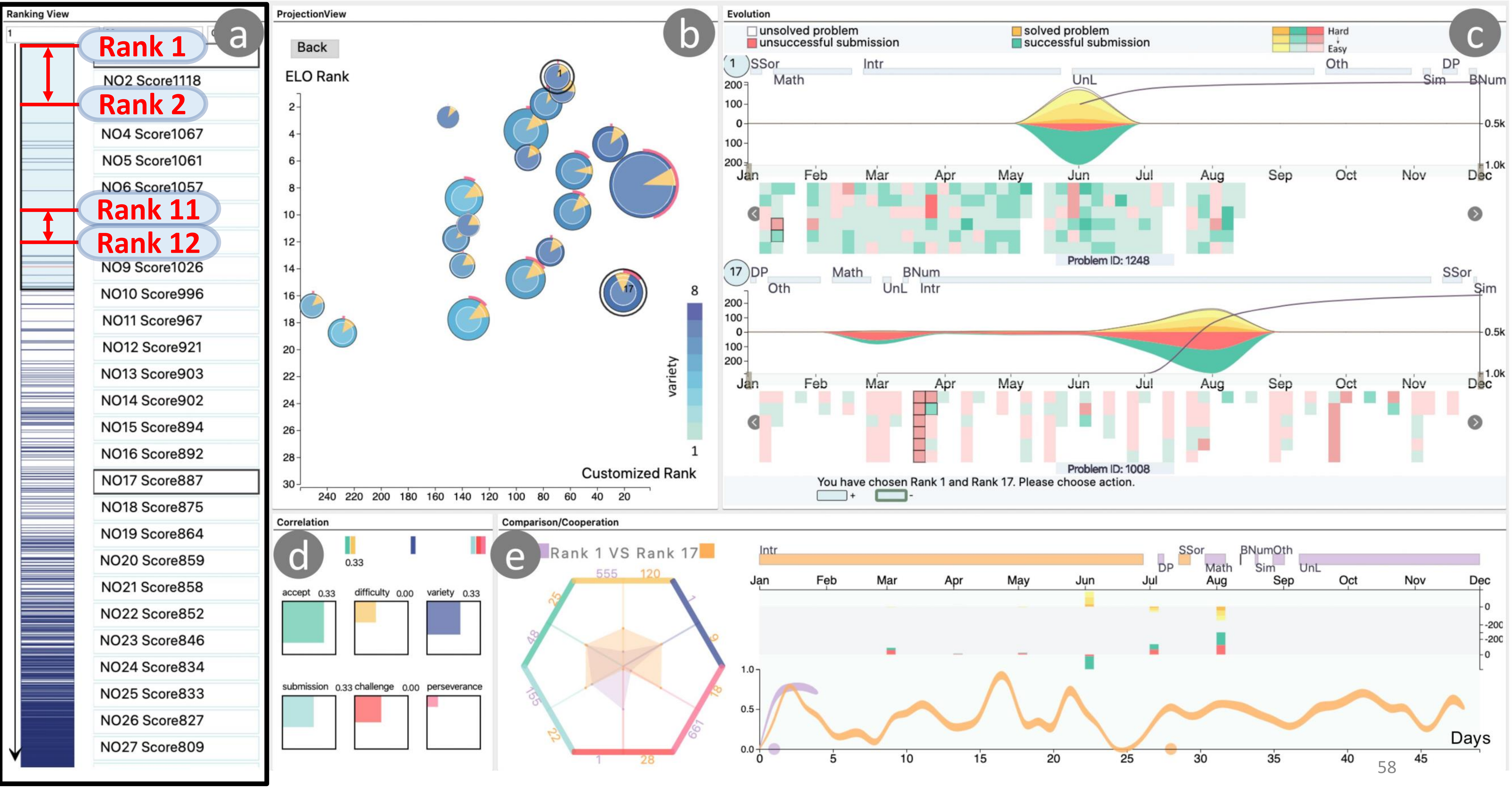


Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
variety
Customized Rank
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days

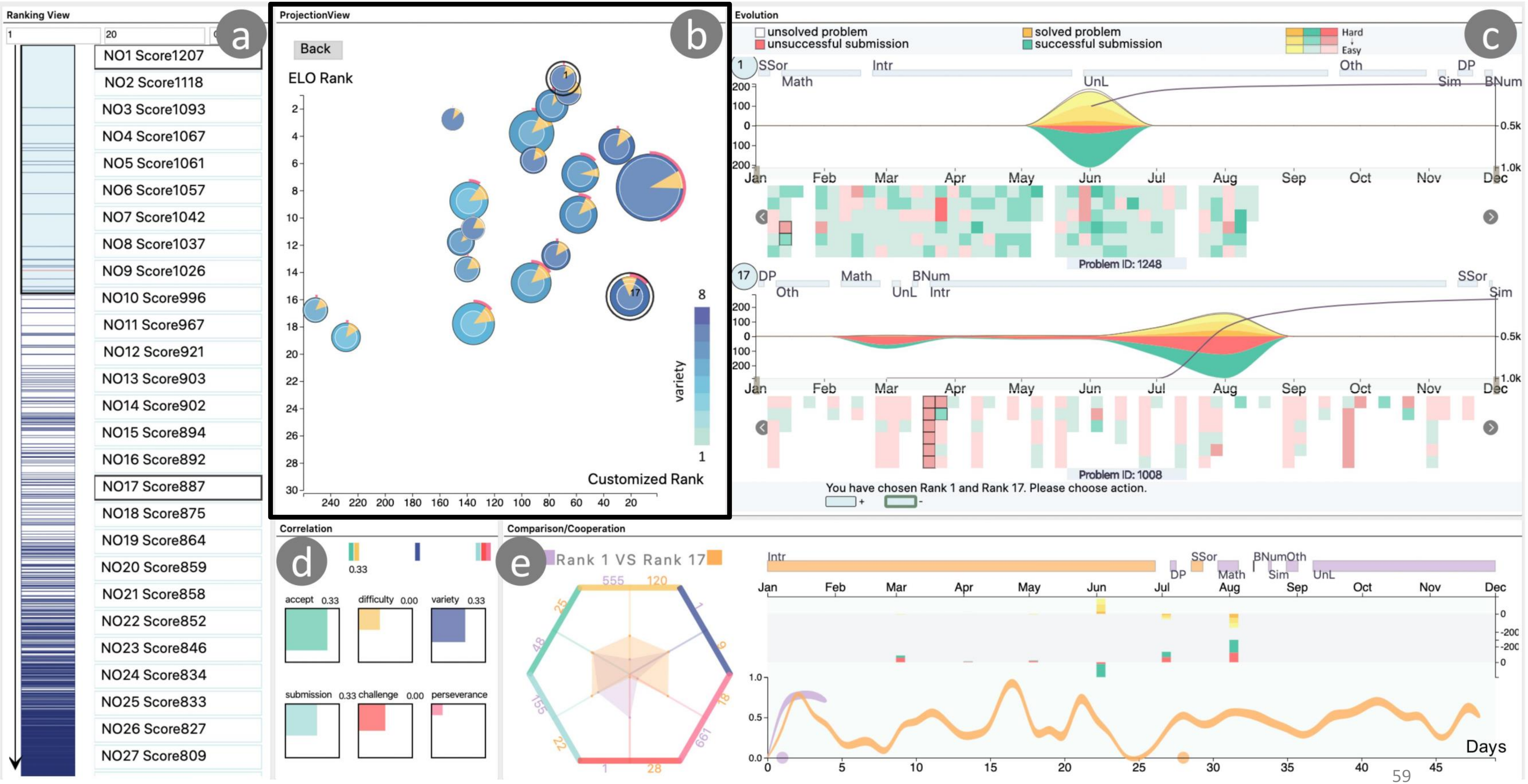

Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
ELO
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
Customized Rank
variety
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days



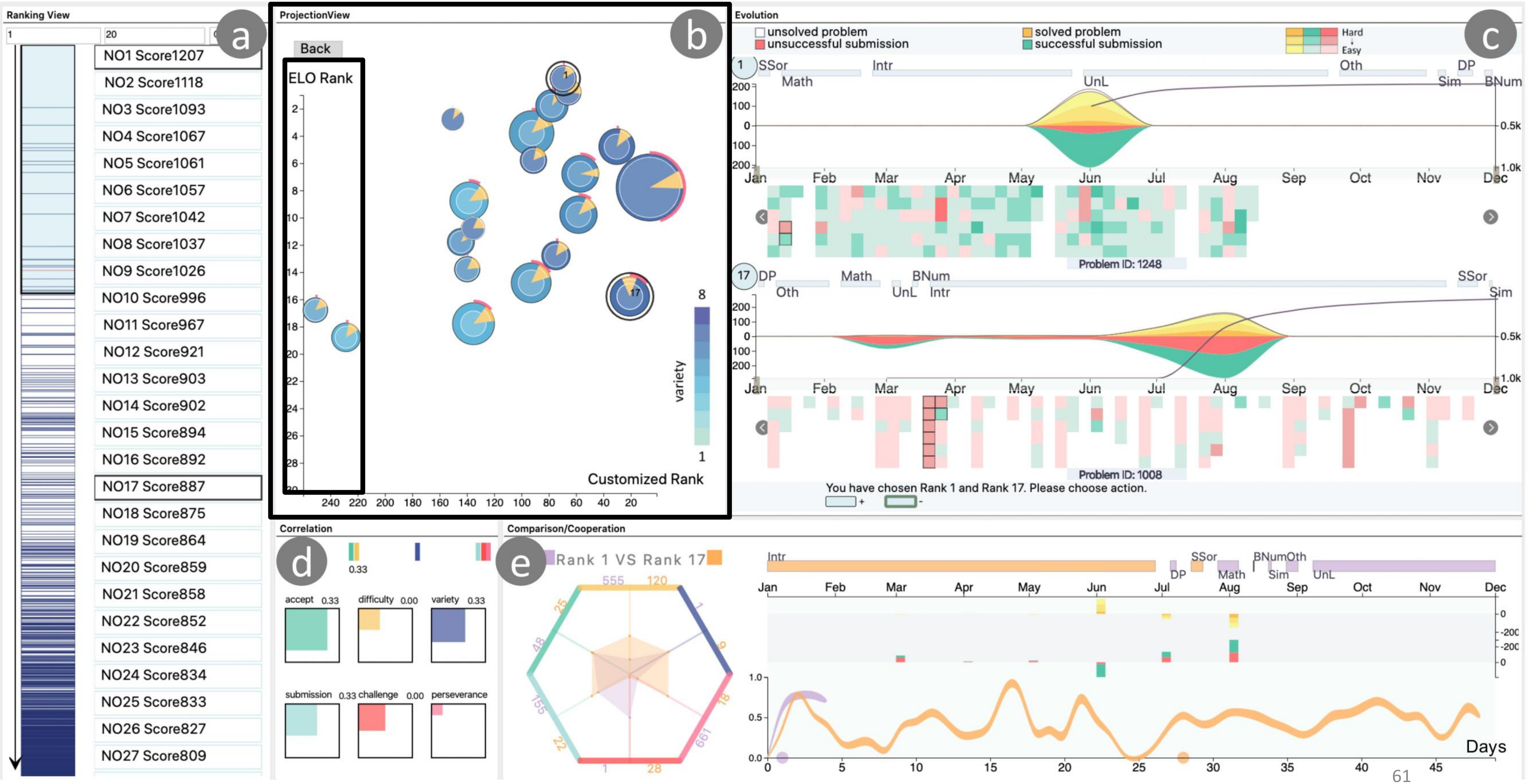
Ranking View
Rank 1
Rank 2
a
NO2 Score1118
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
variety
Customized Rank
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days

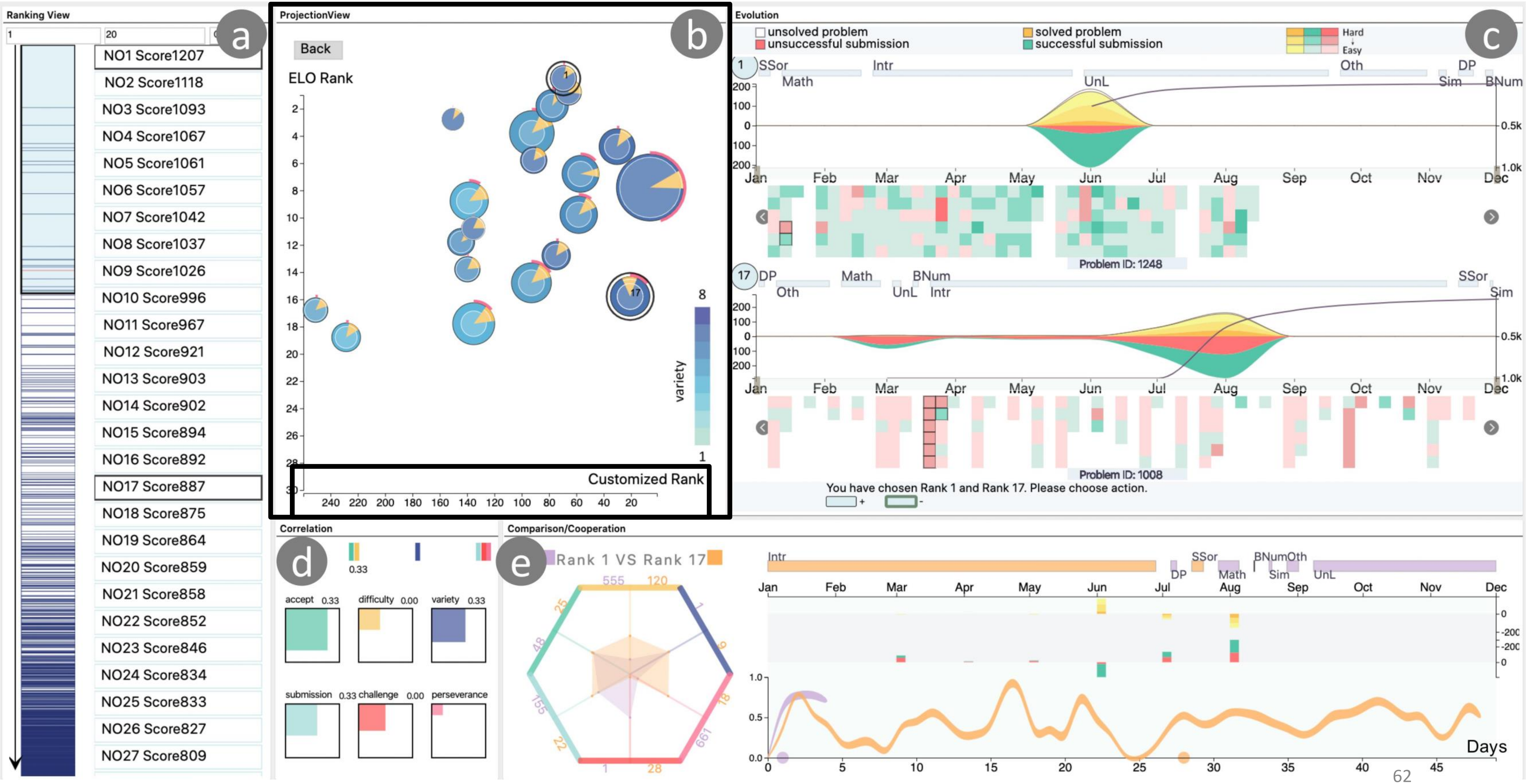


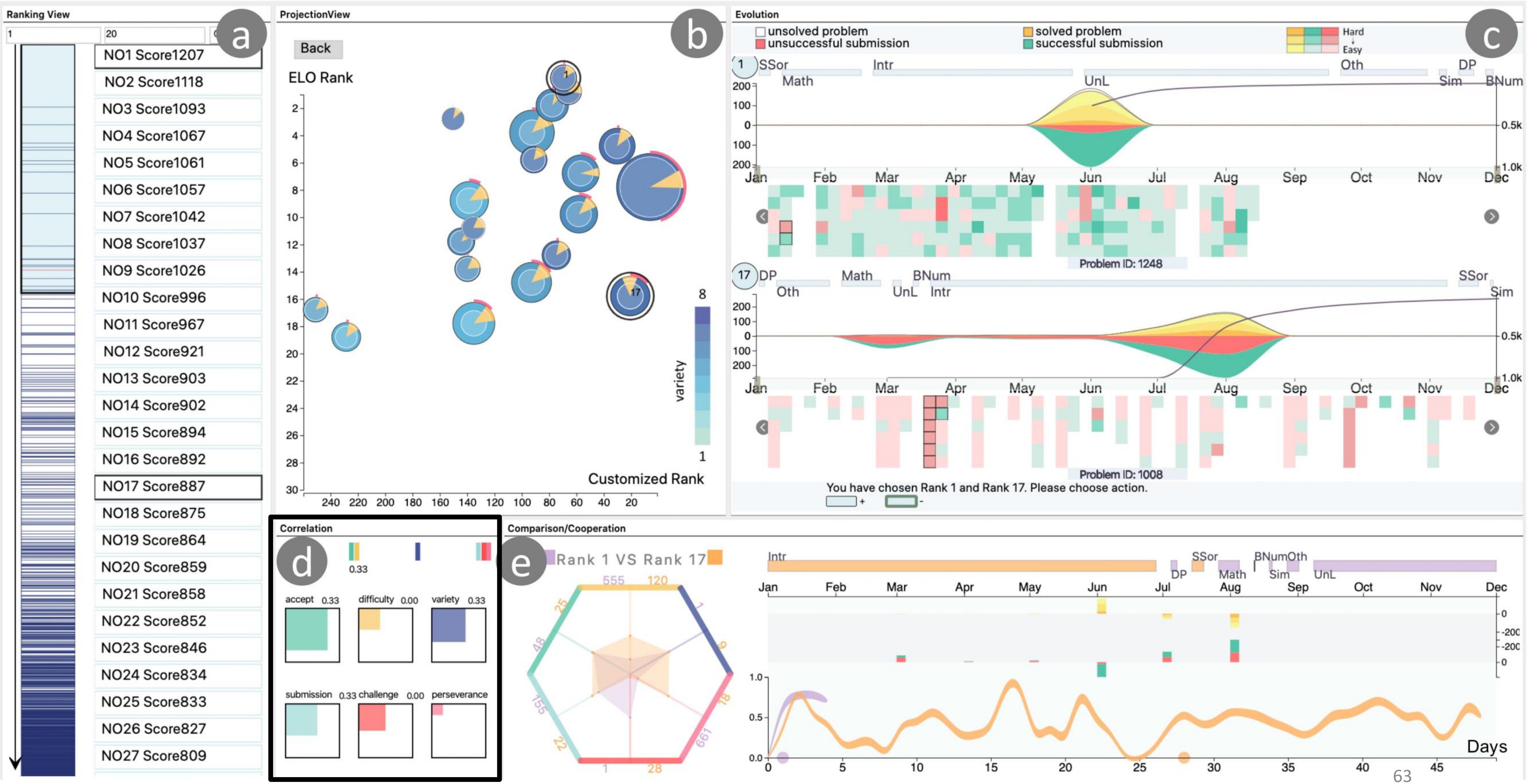
Ranking View
Rank 1
Rank 2
Rank 11
Rank 12
NO2 Score1118
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
a
ProjectionView
Back
ELO Rank
Customized Rank
variety
b
Evolution
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
c
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days

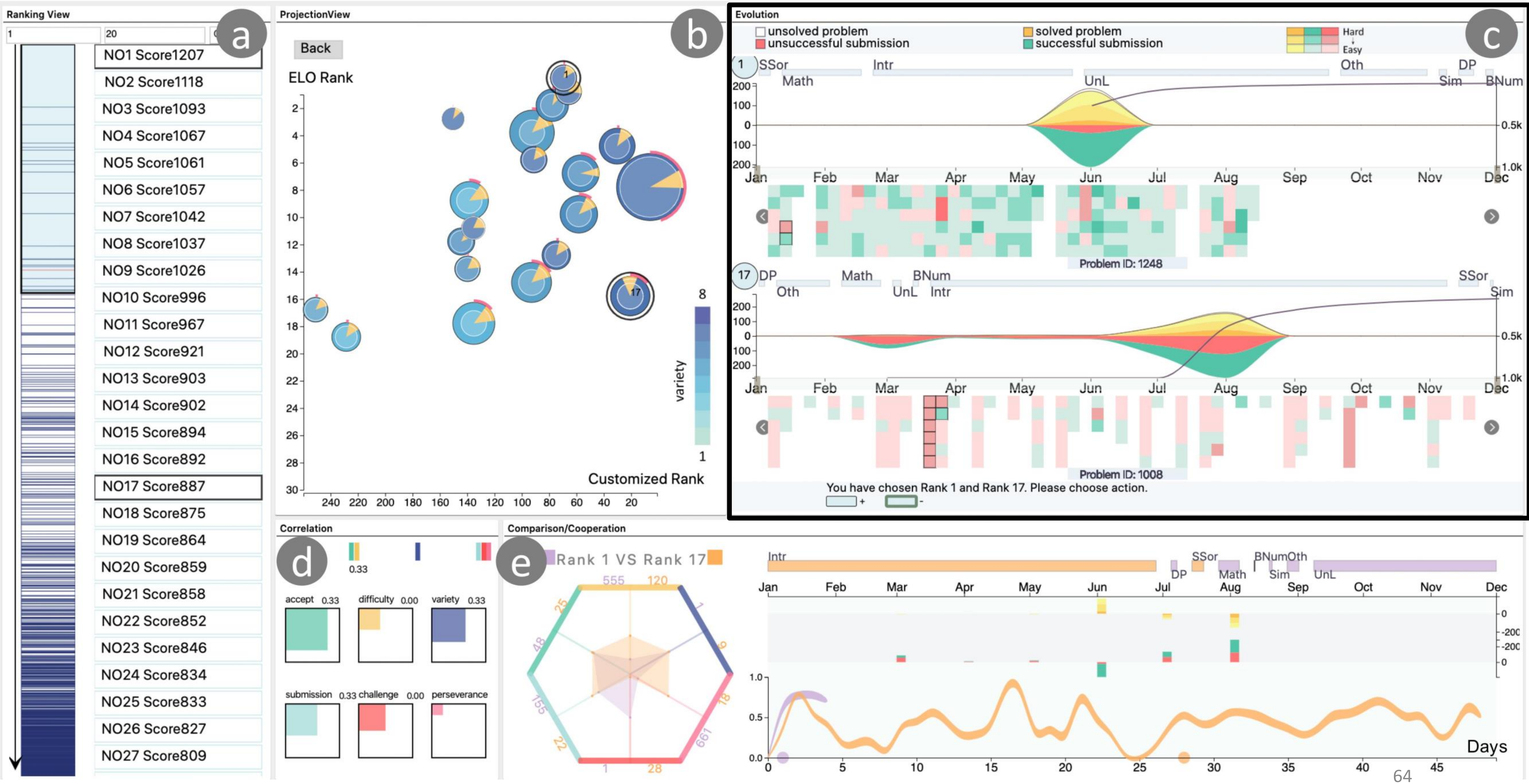

Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
Customized Rank
variety
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days

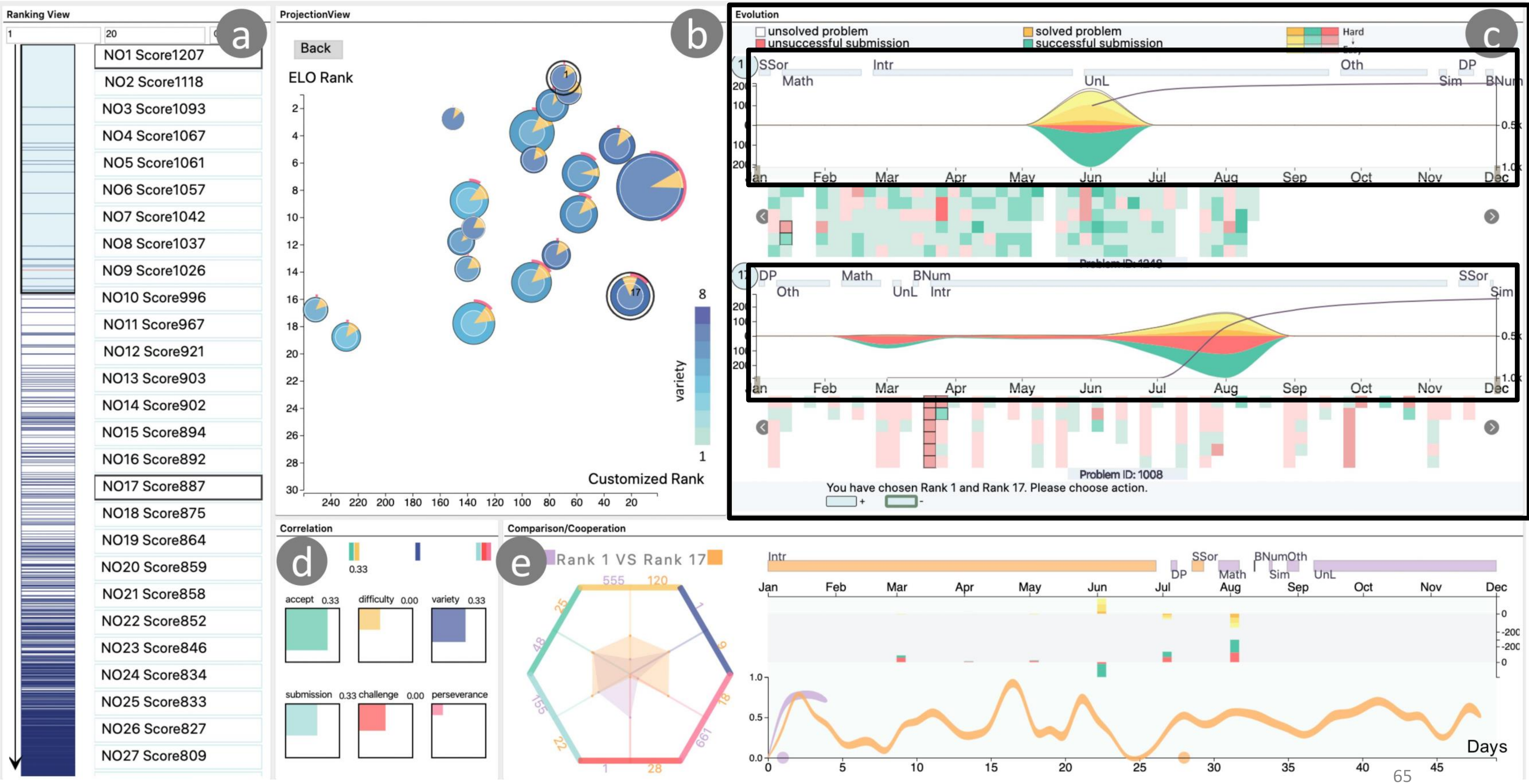

Ranking View
ProjectionView
Evolution
Correlation
Comparison/Cooperation
a
b
c
d
e
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
Back
ELO Rank
Customized Rank
variety
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
accept
difficulty
variety
submission
challenge
perseverance
Rank 1 VS Rank 17
Days


Ranking View
ProjectionView
Evolution
ELO Rank
Customized Rank
Correlation
Comparison/Cooperation
Rank 1 VS Rank 17
You have chosen Rank 1 and Rank 17. Please choose action.
unsolved problem
unsuccessful submission
solved problem
successful submission
Problem ID: 1248
Problem ID: 1008
accept
difficulty
variety
submission
challenge
perseverance
Days

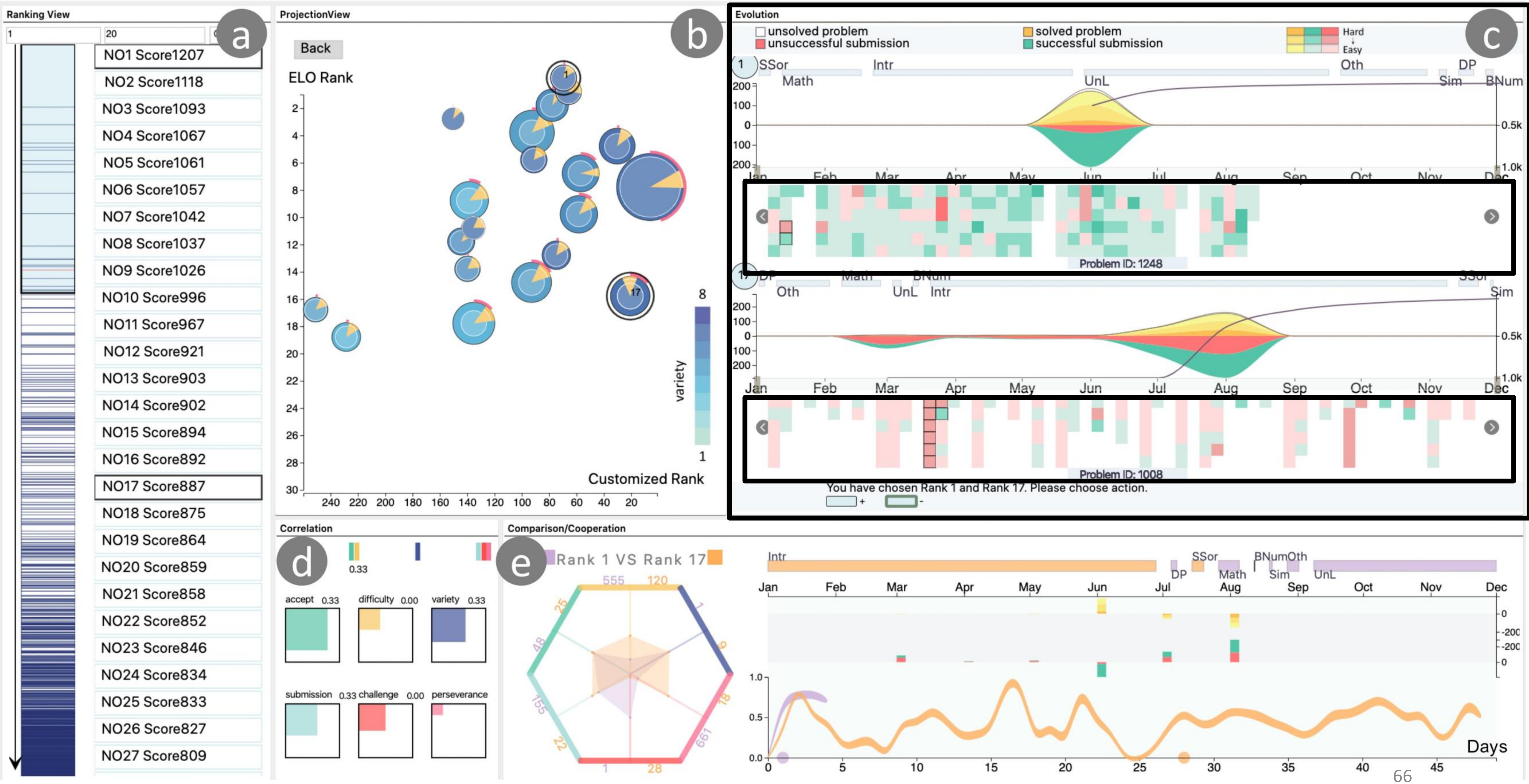

Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
variety
Customized Rank
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days


Ranking View
ProjectionView
Evolution
Correlation
Comparison/Cooperation
a
b
c
d
e
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
Back
ELO Rank
Customized Rank
variety
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Rank 1 VS Rank 17
Days

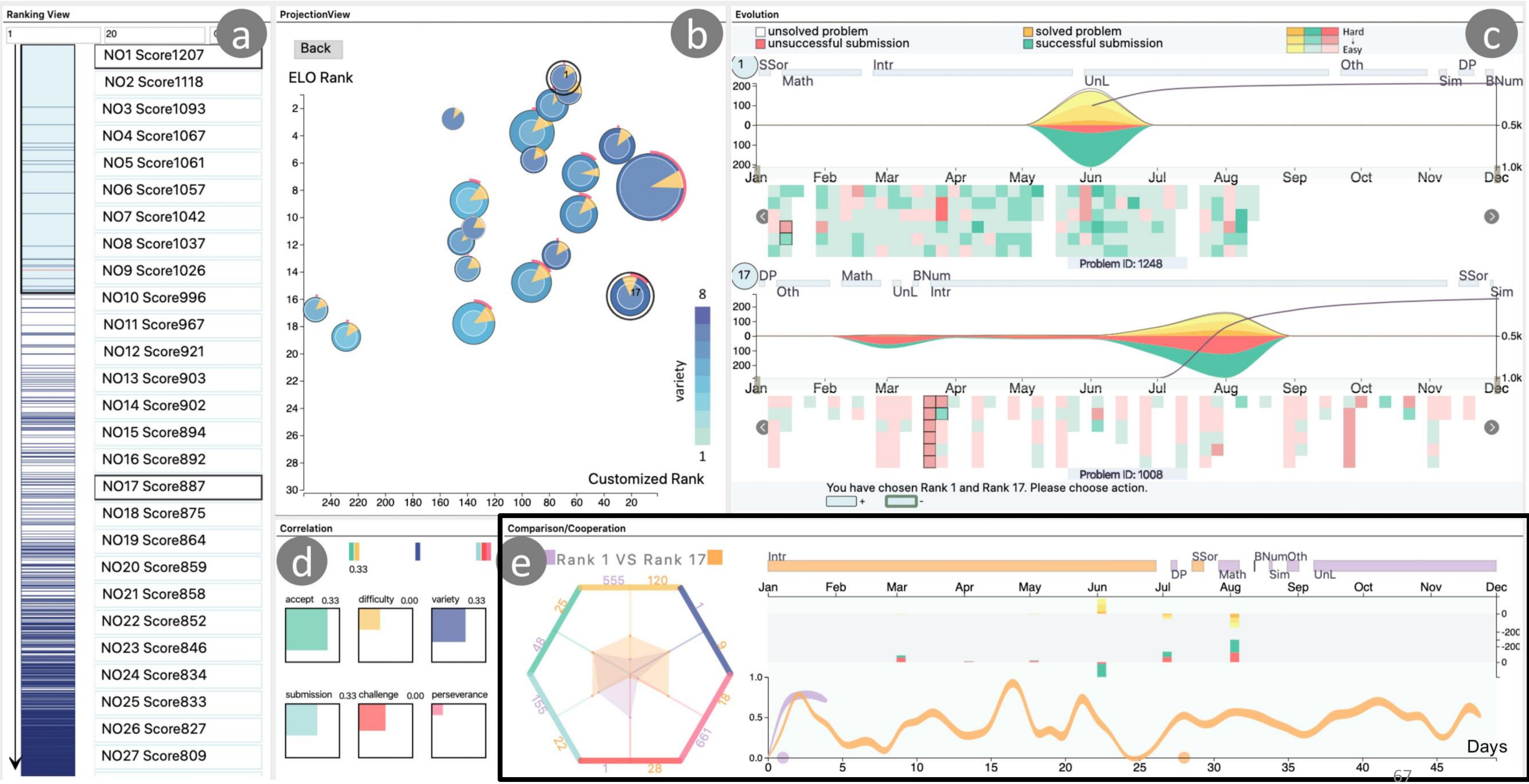

Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
variety
Customized Rank
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days



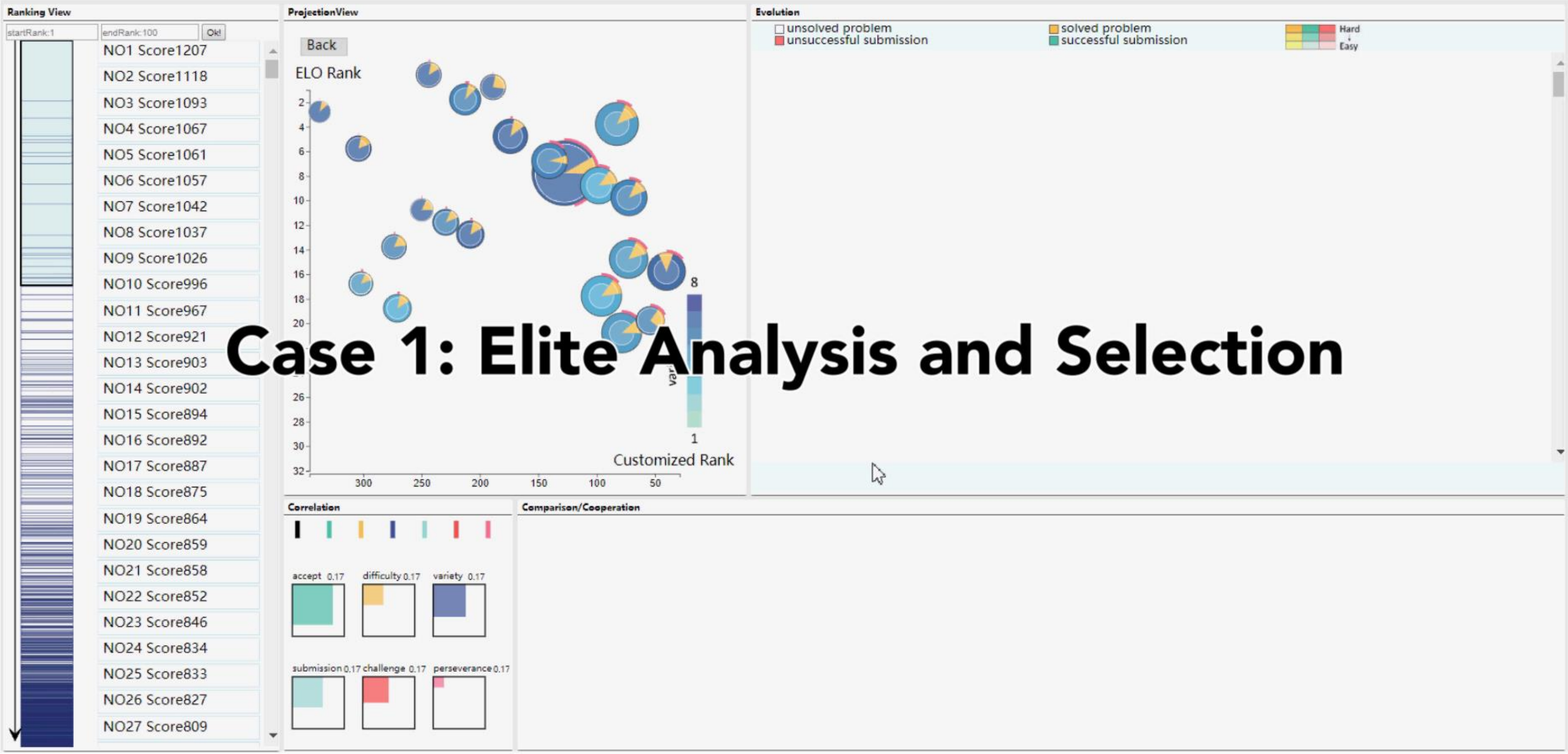
Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
Customized Rank
variety
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
SSor
Math
Intr
UnL
Oth
DP
Sim
BNum
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days



Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
variety
Customized Rank
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days


Ranking View
a
NO1 Score1207
NO2 Score1118
NO3 Score1093
NO4 Score1067
NO5 Score1061
NO6 Score1057
NO7 Score1042
NO8 Score1037
NO9 Score1026
NO10 Score996
NO11 Score967
NO12 Score921
NO13 Score903
NO14 Score902
NO15 Score894
NO16 Score892
NO17 Score887
NO18 Score875
NO19 Score864
NO20 Score859
NO21 Score858
NO22 Score852
NO23 Score846
NO24 Score834
NO25 Score833
NO26 Score827
NO27 Score809
ProjectionView
b
Back
ELO Rank
variety
Customized Rank
Evolution
c
unsolved problem
unsuccessful submission
solved problem
successful submission
Hard
Easy
Problem ID: 1248
Problem ID: 1008
You have chosen Rank 1 and Rank 17. Please choose action.
Correlation
d
accept 0.33
difficulty 0.00
variety 0.33
submission 0.33
challenge 0.00
perseverance
Comparison/Cooperation
e
Rank 1 VS Rank 17
Days

Case 1: Elite Analysis and Selection



Evaluation

“The encoding (glyph) is very intuitive and I can tell a learner’s talent at a glance”

“The hexagon can clearly show the strength and weakness of two candidates”

Three usage scenarios

Elite Analysis and Selection

Personal Analysis and Training

Team Formation

Five expert interviews

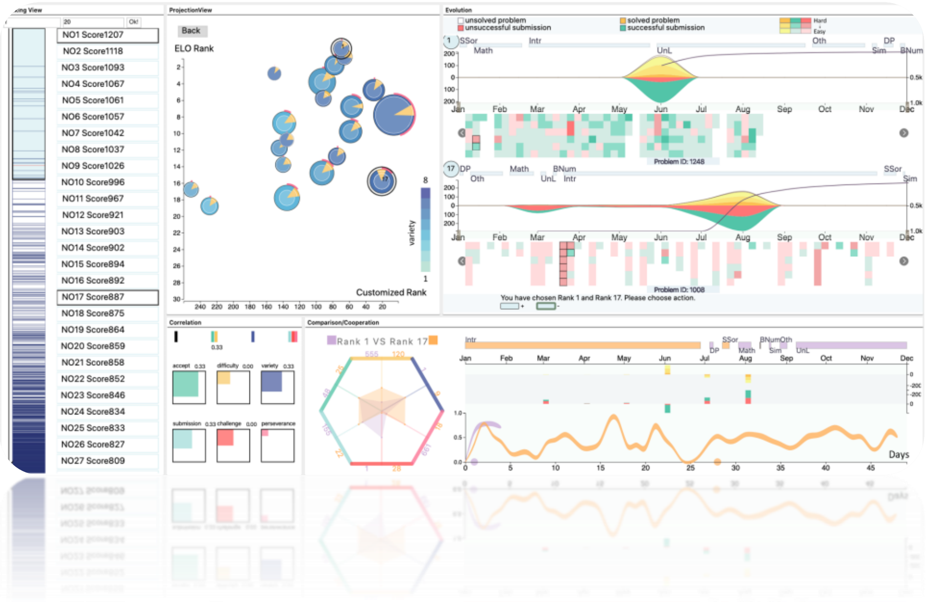
(Three coaches of competitive programming teams and two instructors teaching programming courses)

- ❑System Usability
- ❑System Effectiveness
- ❑Visual Designs
- ❑Interactions

Overall, all five experts commented that SeqDynamics was **useful** and **easy to use**.

Conclusion

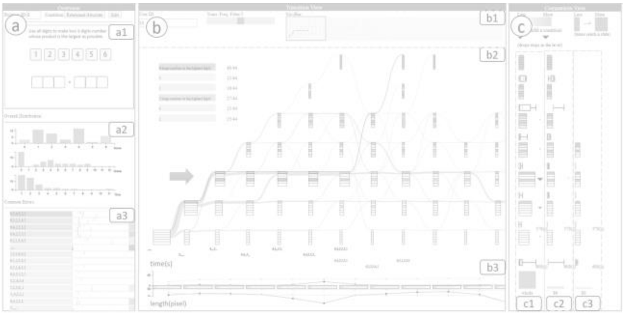
- An interactive visual analytical system
- Novel glyphs and bilateral stacked graph
- Three usage scenarios and five expert interviews



How can students make use of peers' problem-solving data?

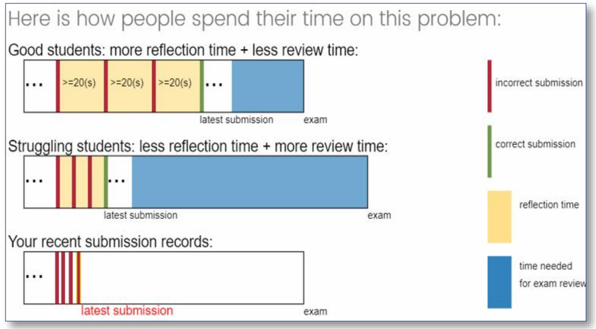
Our works

Qlens: multi-step question analysis.
VIS 2020 (conditionally accepted)



Micro level

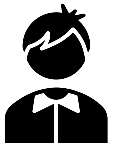
“Game the system”: learning behavior regulation. L@S, 2020

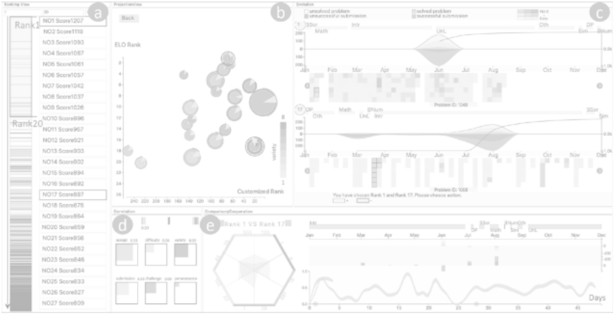


Empower educators

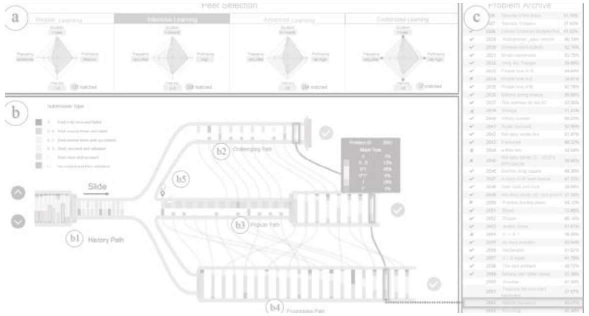
Problem-solving Data

Empower students





Macro level



SeqDynamics: problem-solving dynamics analysis. Euro VIS, 2020

Peerlens: learning path planning. CHI, 2019

Using Information Visualization to Promote Students' Reflection on "Gaming the System" in Online Learning

Meng Xia, Yuya Asano, Joseph Jay Williams, Huamin Qu, Xiaojuan Ma

L@S 2020

“Gaming the system”

Students exploit properties and regularities of the learning system, rather than learning the material *(Ryan Baker et al., 2004)*.

Quickly and repeatedly asking for help until the correct answer is provided

Quickly and systematically guessing the answers until correct *(Ryan Baker et al., 2008)*

Universality and consequences

10-40% of students showed any forms of gaming behavior in MOOCs*(Northcutt et al., 2016)*

Students who game the system tend to have **reduced learning gains and lower long-term academic achievements***(Joseph Beck and Ma Mercedes T Rodrigo, 2014)*.

Related Work

- Added constraints, e.g., **introduced a two-second delay** between each level of a multi-level hint *(Aleven et al., 2001; Joseph et al., 2005)*

- Developed techniques on **detecting gaming behavior** using machine learning or feature engineering *(Pardos et al., 2014)*. Applied interventions only when students were detected as having gaming behavior, e.g., **imposing more exercises** to gaming students

Research gap

- If tweaks fail to **promote people's reflection on why behavior change is necessary**, their effects may fade away quickly once removed *(Caraban et al., 2019)*
- Dual-process of decision-making *(Daniel Kahneman, 2011)*

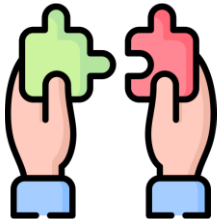
  Automatic(little effort, emotional, and unconscious)

  Reflective(effortful, rational, and conscious)

It is critical to design reflective mechanisms that can promote students' reflection on gaming behavior.

Proposed solution

- The persuasiveness of data visualization has been revealed in a wide range of recent research *(Pierre Dragicevic and Yvonne Jansen, 2017; Pandey et al., 2014; Agapie et al., 2013; Turland et al., 2015)*
  - Estimate drug efficacy
  - Change the attitude toward political topics



Reflective nudge = reasoning information + persuasive visualization

Research questions

RQ1: What are the **typical contexts** in which students may try to game the system and what are the possible **negative consequences** on learning when gaming occurs in these contexts?

RQ2: What are the ways to **encode information** for communicating reasons not to game in various contexts into **reflective nudge** to students?

RQ3: What are the **design considerations** for creating reflective nudge to promote reflection in online learning?

RQ1: Contexts of gaming and its negative consequences on learning

Method: semi-structured interviews

- Students’ perspectives: 16 students (12 males, age: 23±3.38):
  1) How often do you indulge in gaming behavior, if at all?
  2) Under what circumstances are you likely to game the system and why?
- Instructors’ perspectives: three instructors including one system developer:
  1) What are the intentions behind the initial design of the system?
  2) What’s your observed students’ practice on the system?
  3) What are your attitudes toward certain practices?
  4) What are the suggestions and potential solutions?

Results of RQ1

Students:

Contexts of gaming the system	# of interviewees (out of 16)
C1: When students are busy, they may game to save time on this course.	10
C2: When faced with difficult problems, they feel frustrated and game to keep up the pace.	8
C3: They think some concepts are unimportant, thus game quickly through.	3
C4: When the video is not clear, they do not want to spend time on exercises.	2
C5: When the deadline is at noon, they can not get up early in the morning.	2

Instructors:

R1: Randomly guessing answers with the **intent to save time**, which would **cost students' much more time** in the review period.

R2: Gaming in the face of **difficult problems** assuming it is the only way to keep up with their peers, but difficult problems also **take other students' considerable effort** to solve.

R3: Gaming problems related to seemingly **unimportant concepts**, but the negligence of those concepts may **hinder the mastery of later concepts** depending on them.

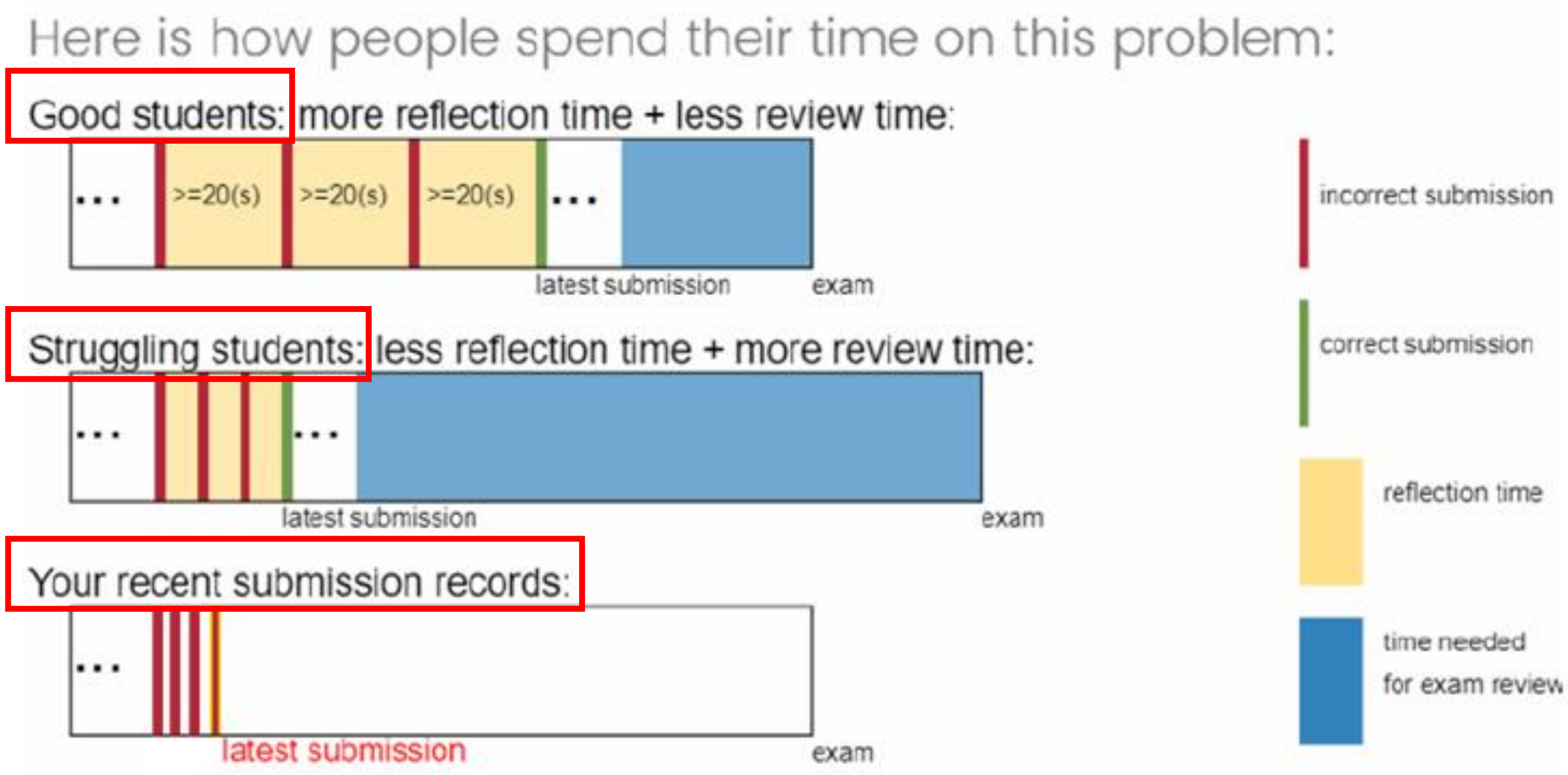
RQ2: Encoding reasons not to game into reflective nudges

Data preprocessing → Data modelling → Visual designs → Interaction

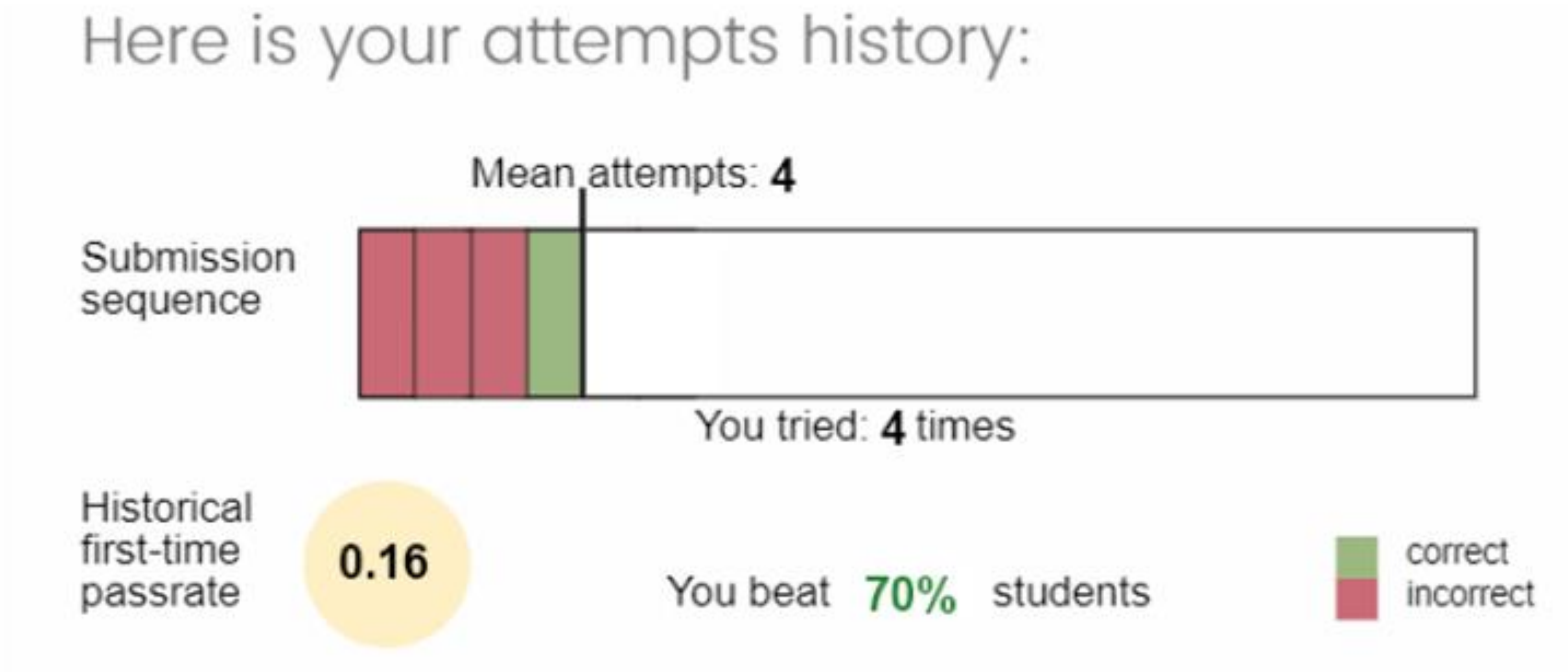
Method: iterative design

- Collect the submissions on **multiple-choice questions**
- Initial ideation and **prototyping** phase: 10+ low-fidelity (sketch)
- **Participatory interviews** with two instructors to get feedback on each visualization, narrowing down to three designs
- **Informal testing** with seven students (two females, five males, age: 24±2.85) to improve the visual designs

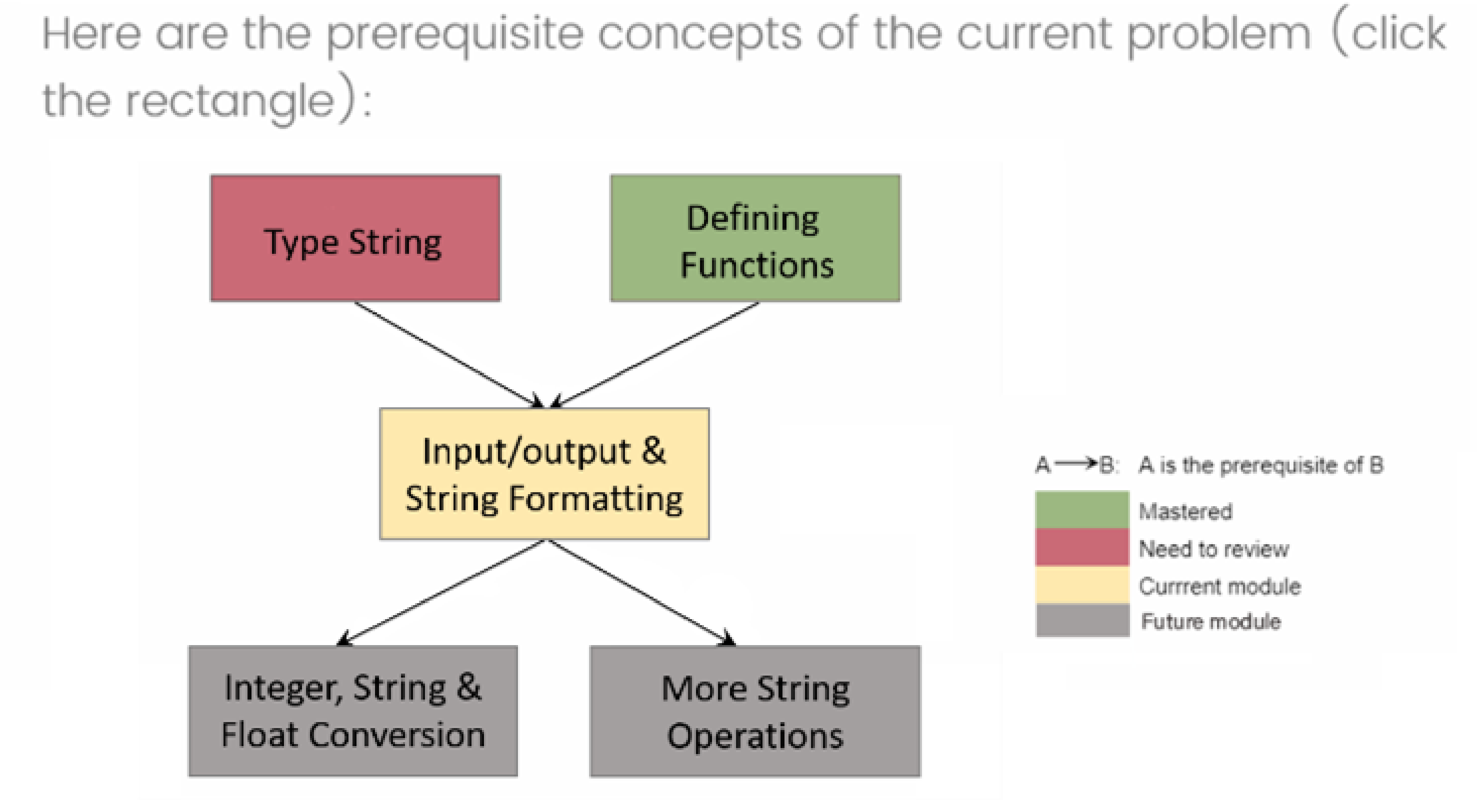
Information Visualization V1: Time on problem



Information Visualization V2: Number of attempts



Information Visualization V3: Prerequisites graph



RQ3: Design consideration for reflective nudge in online learning

Method: we evaluated our information visualizations (V1 - V3) through:

- Deployment on a university-level introductory programming course with 205 students
- Three experimental (V1-V3) groups and one control group
- Questionnaire after students received interventions
- Post-study interviews to gather reasons behind their questionnaire ratings and suggestions

Results of R3 - Potential gaming reduction

	Without intervention		With intervention	
	P1	P2	P3	P4
V1-time spending(37)	0.30	0.65	0.11	0.08
V2-attempt number(44)	0.34	0.63	0.16	0.07
V3-prerequisite graph(38)	0.37	0.63	0.21	0.16
Baseline1-control group(39)	0.26	0.59	0.21	0.23
Baseline2-last semester(138)	0.32	0.65	0.21	0.16
First-time pass rate	0.26	0.09	0.71	0.56

Results of R3 - Potential gaming reduction

Without intervention With intervention

	P1	P2	P3	P4
V1-time spending(37)	0.30	0.65	0.11	0.08
V2-attempt number(44)	0.34	0.63	0.16	0.07
V3-prerequisite graph(38)	0.37	0.63	0.21	0.16
Baseline1-control group(39)	0.26	0.59	0.21	0.23
Baseline2-last semester(138)	0.32	0.65	0.21	0.16
First-time pass rate	0.26	0.09	0.71	0.56

Drop more

Drop less

Results of R3 - Questionnaires

	Q1-Information conveyance	Q2-Reflection on gaming	Q3-Reflection on question-answering	Q4-Easy to understand
V1	4.6(1.7)	4.3(1.8)	4.3(1.8)	3.7(1.9)
V2	5.2(1.5)	4.7(1.2)	4.4(1.3)	5.1(1.2)
V3	5.8(0.7)	5.0(1.2)	5.3(1.1)	4.7(1.8)

•The mean scores are almost all above 4 (neither agree nor disagree), which means our designs can convey the information clearly, arouse students' reflection on gaming behaviour, easy to understand to some extent, except that V1 seems not easy to understand with a mean score lower than 4

•For V1, "too many components" (S1, S3, and S4), that "fonts are small" (S7), and that it is "not clear where you should start reading" (S7)

Results of RQ3 – Design considerations for reflective nudges in online learning

- Color is effective for alert and highlighting information

  “(For V3,) The green and red color are good stimuli, like the traffic light in the psychology area” – S2, female, 19.

- Perceived authenticity increases persuasiveness

  *“(In V2,) Show it explicitly that the data (historical first-time pass rate) is from *** course from 2018 winter semester. People will be more sensitive.” – S5, male, 28.*

- Connecting to peers may hurt people who are low self-esteem

  “Low self-esteem or hard-working students might get hurt by seeing this (their attempts more than the mean attempts).” – S1, male, 25

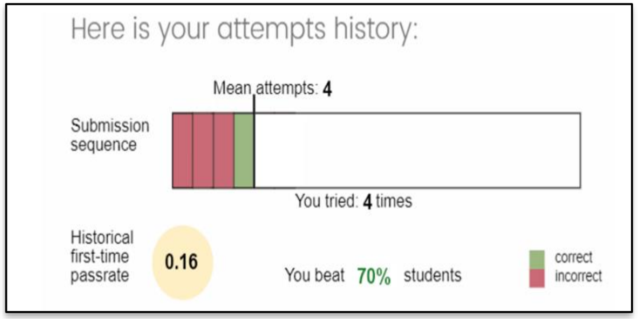
- Ensuring good grasp of information is critical

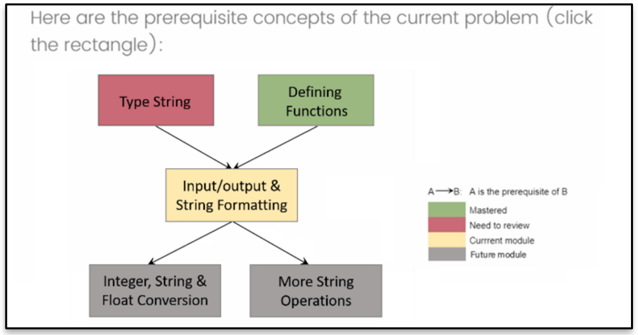
  “It takes me 4-5 seconds to understand, but it needs to reduce down to 2-3 seconds (for V1).” – S3, male, 23.

Conclusion

- Identified three common gaming contexts and designed persuasive visualizations
- Deployed our information visualizations in real world
- Summarized design considerations on reflective nudges in online learning

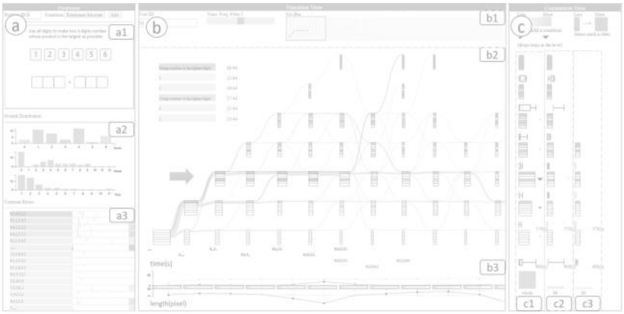
How can we present and utilize peers' learning data on multiple questions to students?





Our works

Qlens: multi-step question analysis. VIS 2020 (conditionally accepted)



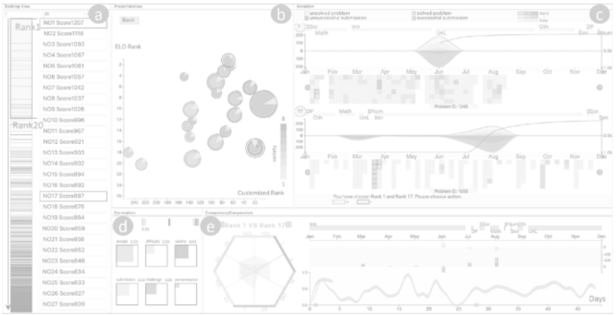
“Game the system”: learning behavior regulation. L@S, 2020

Micro level

Empower educators

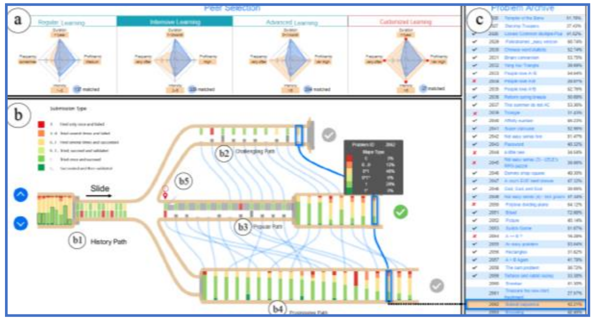
Problem-solving Data

Empower students

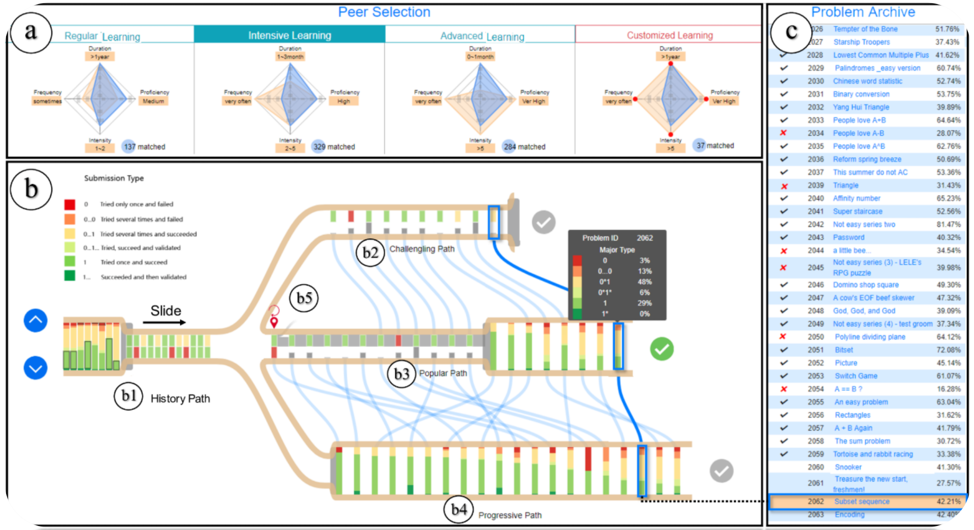


SeqDynamics: problem-solving dynamics analysis. Euro VIS, 2020

Macro level



Peerlens: learning path planning. CHI, 2019



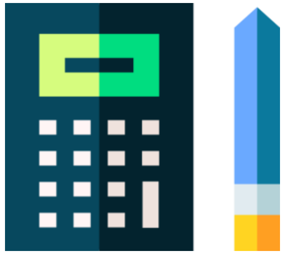
PeerLens: Peer-inspired Interactive Learning Path Planning in Online Question Pool

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

CHI 2019

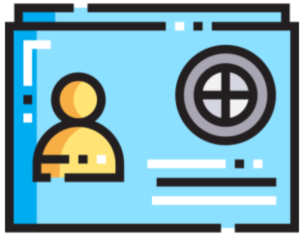
What is an online question pool?

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



Math

Programming



Driving license

https://help.blackboard.com/Learn/Instructor/Tests_Pools_Surveys/Reuse_Questions/Question_Pools_Banks

Features of question pools

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

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

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

Difficulty: Determine an appropriate order in taking these online questions for their particular learning scenarios

Current situation

Programming question pools	Has recommendation?
AtCoder	NO
CodeChef	NO
CodeFights	NO
Codeforces	NO
Codewars	YES (Similar questions)
LeetCode	YES (Similar questions)
CodinGame	NO
Coderbyte	NO
CSAcademy	NO
HackerEarth	NO

Programming question pools	Has recommendation?
HackerRank	NO
Kattis	NO
uDebug	NO
OmegaUp	NO
Sphere Online Judge	NO
Topcoder	NO
Toph	NO
URI Online Judge	NO
UVa Online Judge	NO

Demand: planning personalized learning path in the context of existing list-based question pools

Related work: Educational Recommendation Techniques

Memory-based techniques

Continuously analyze current data *(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)*

Lack of information

Model-based techniques

Utilize a large amount of historical data to model the learning process over time

- 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)*

No explanation on the recommendations

A user-centered design process

- Four domain experts
  - Experts in online learning (E1, E2)
  - Online question pool users (S1, S2)

- Requirements gathering iteratively for three months

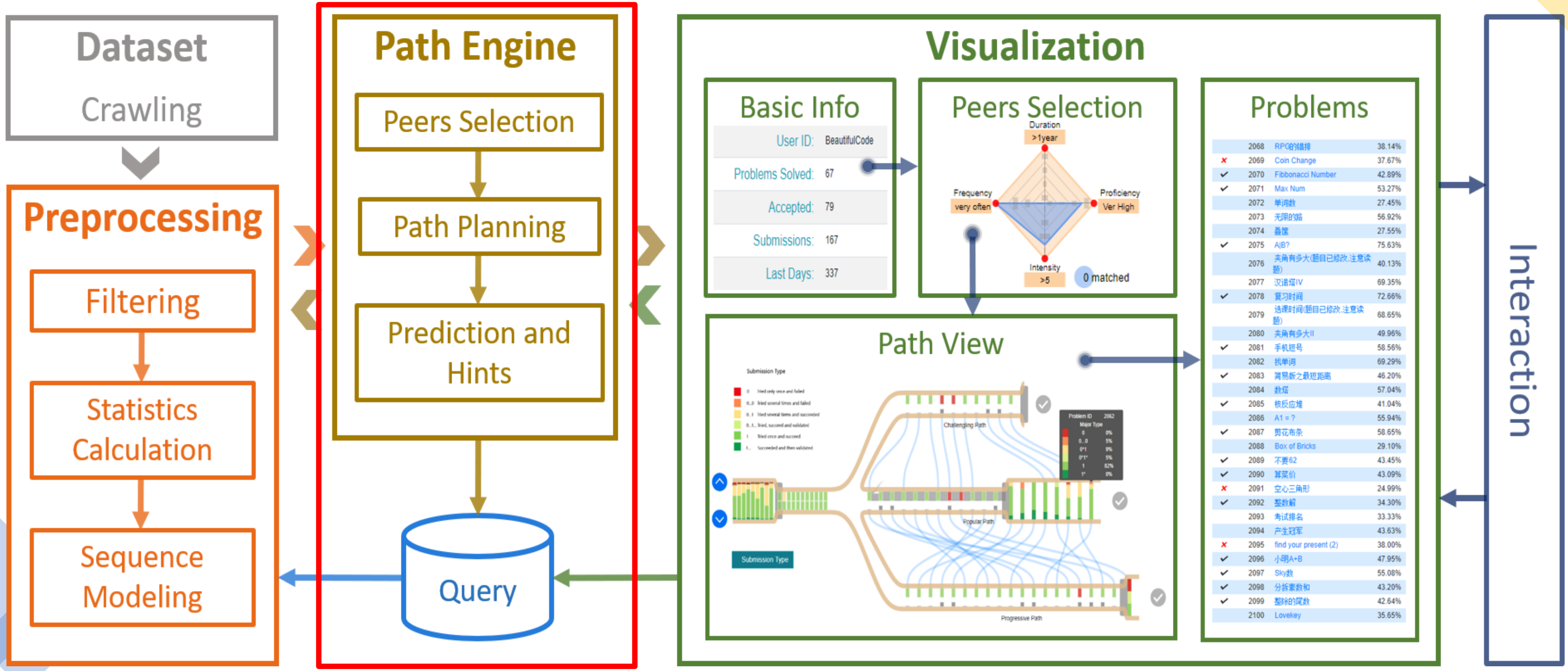
  R1: Find peers for a specific learning scenario.

  R2: Compare with peers' performance.

  R3: Offer flexible learning path suggestions.

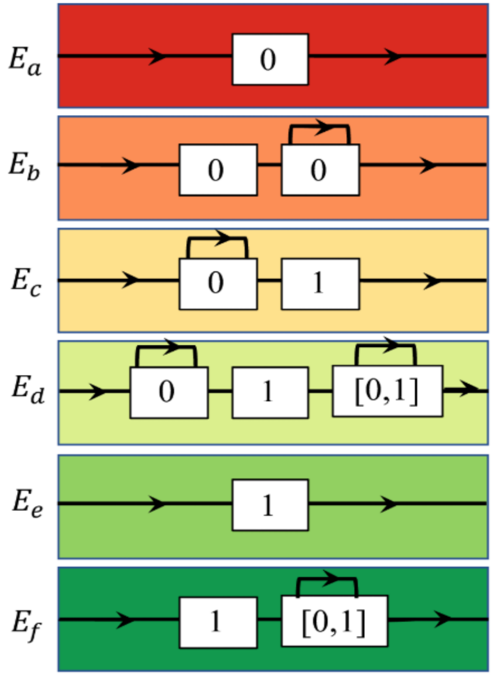
  R4: Provide convenient interaction and intuitive visual designs for learning path planning.

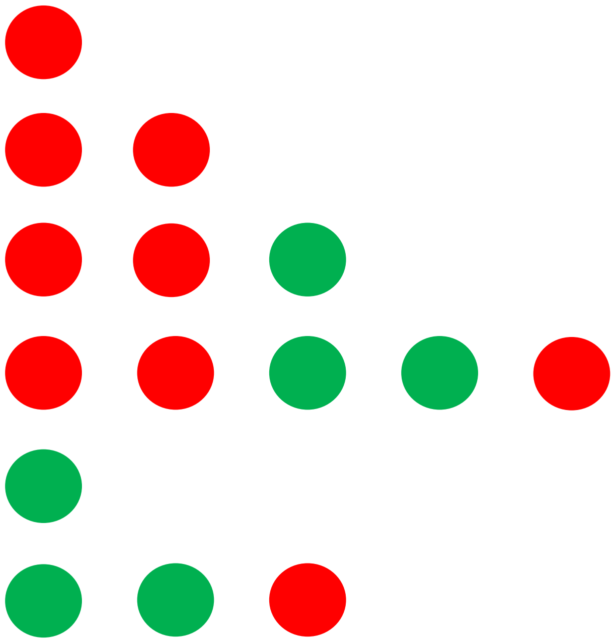
System overflow

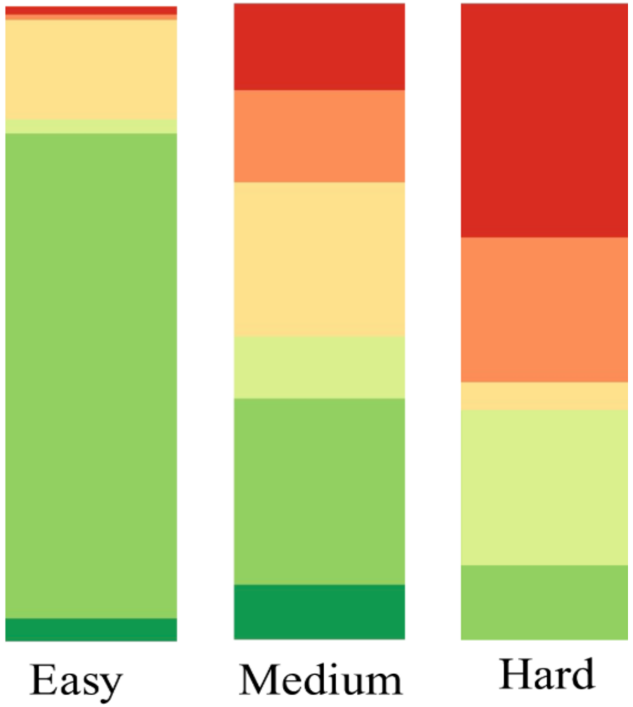


Path Planning Engine: Learning Path Modeling

Submission type: the way a user interacts with a problem.





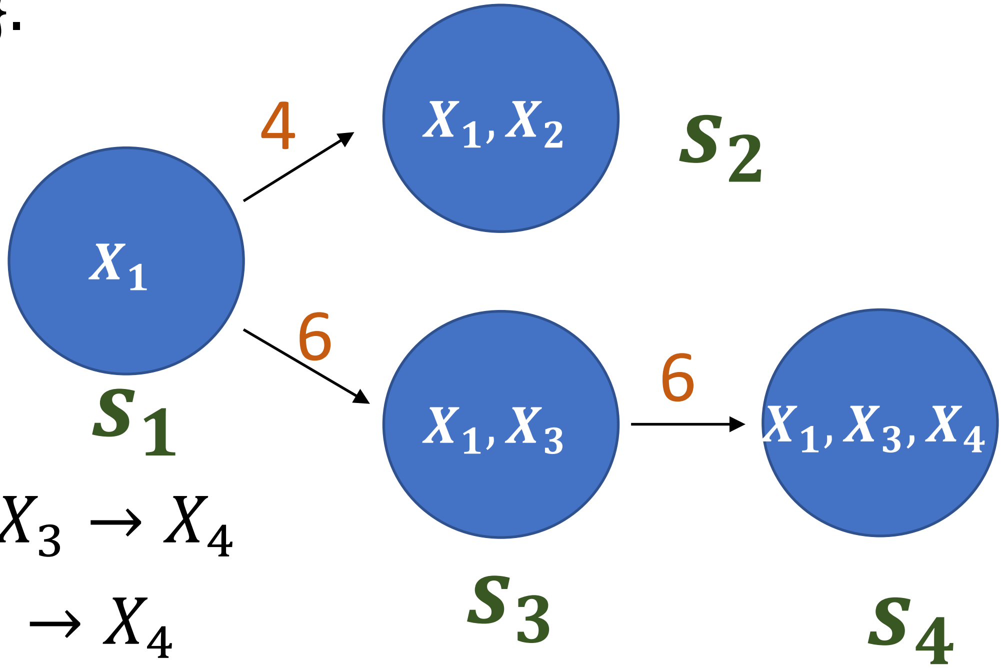


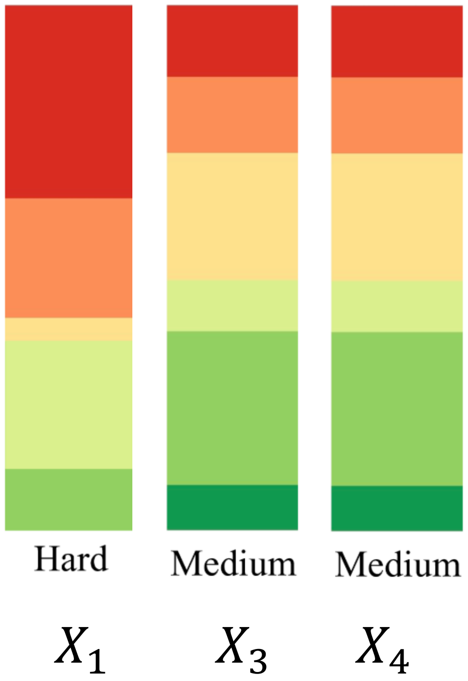
- Captures learners' knowledge proficiency
- Enables the inference of question difficulty level

Path Planning Engine: Path Suggestion

A given peer path $[(X_{i_0}, E_{i_0}, t_{i_0}), \dots, (X_{i_n}, E_{i_n}, t_{i_n})]$ corresponds to a state $s = \{X_{i_0}, X_{i_1}, \dots, X_{i_n}\}$.

Markov Chain:

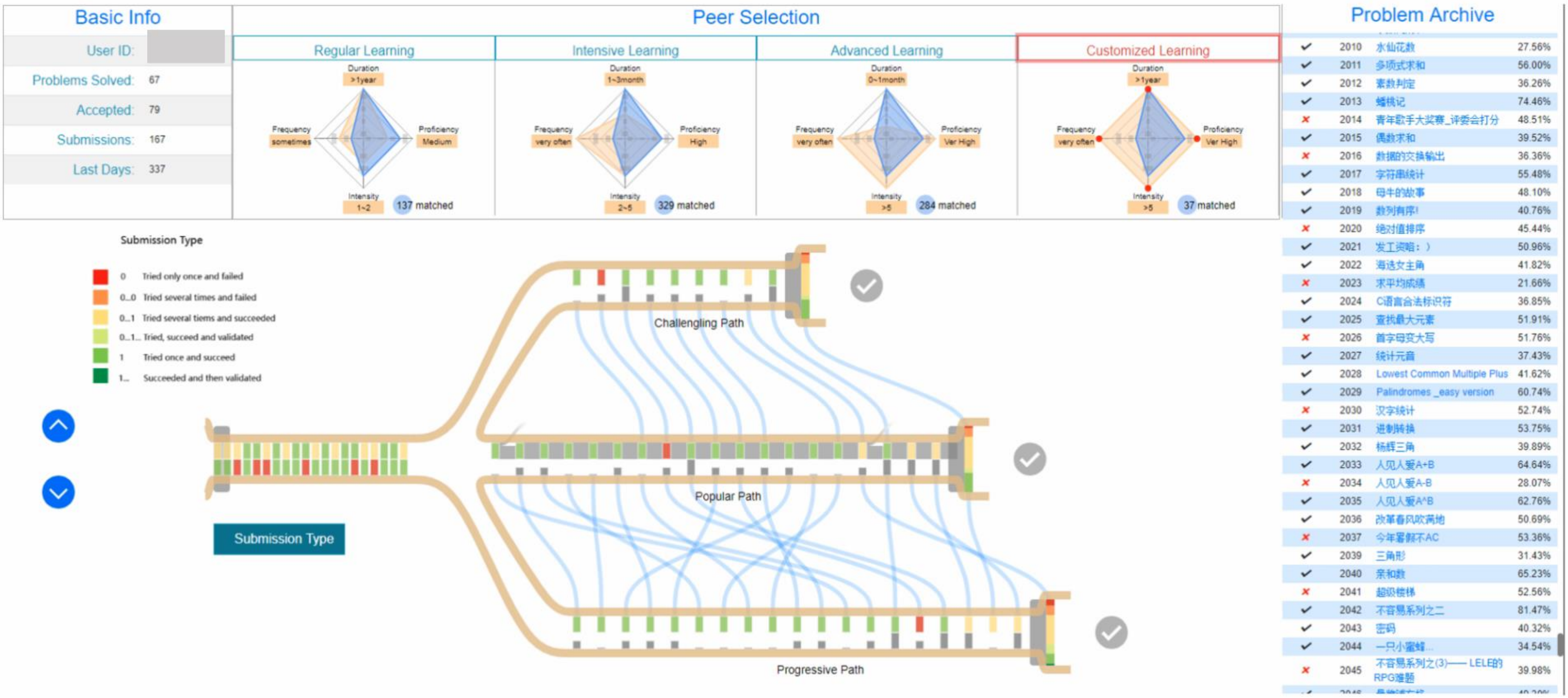




Popular path: $X_1 \rightarrow X_3 \rightarrow X_4$

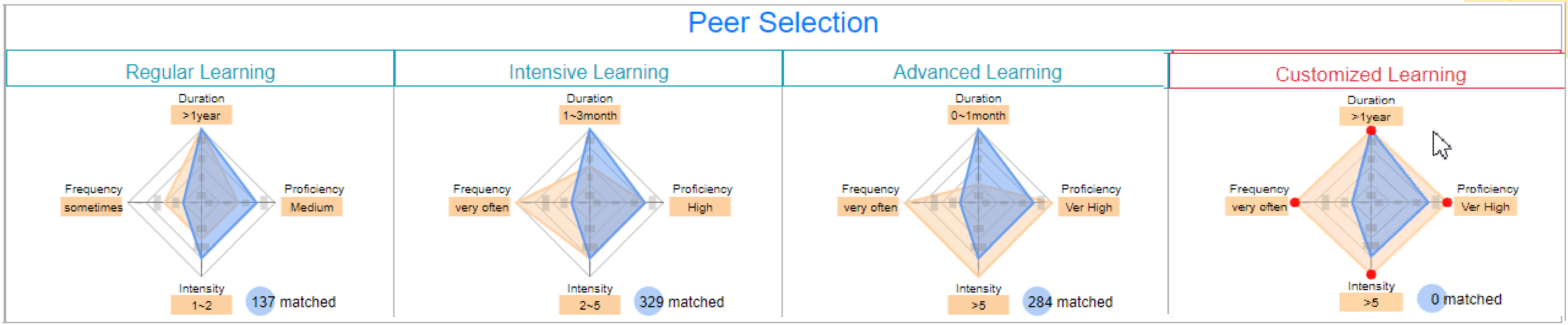
Challenging path: $X_1 \rightarrow X_4$

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



Basic Info
User ID:
Problems Solved: 67
Accepted: 79
Submissions: 167
Last Days: 337
Peer Selection
Regular Learning
Intensive Learning
Advanced Learning
Customized Learning
Duration
>1year
1~3month
0~1month
Frequency
sometimes
very often
Proficiency
Medium
High
Ver High
Intensity
1~2
2~5
>5
137 matched
329 matched
284 matched
37 matched
Submission Type
0 Tried only once and failed
0...0 Tried several times and failed
0...1 Tried several tiems and succeeded
0...1... Tried, succeed and validated
1 Tried once and succeed
1... Succeeded and then validated
Challengling Path
Popular Path
Progressive Path
Submission Type
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 蟠桃记 74.46%
2014 青年歌手大奖赛_评委会打分 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 发工资咯：) 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 首字母变大写 51.76%
2027 统计元音 37.43%
2028 Lowest Common Multiple Plus 41.62%
2029 Palindromes _easy version 60.74%
2030 汉字统计 52.74%
2031 进制转换 53.75%
2032 杨辉三角 39.89%
2033 人见人爱A+B 64.64%
2034 人见人爱A-B 28.07%
2035 人见人爱A^B 62.76%
2036 改革春风吹满地 50.69%
2037 今年暑假不AC 53.36%
2039 三角形 31.43%
2040 亲和数 65.23%
2041 超级楼梯 52.56%
2042 不容易系列之二 81.47%
2043 密码 40.32%
2044 一只小蜜蜂... 34.54%
2045 不容易系列之(3)—— LELE的RPG难题 39.98%

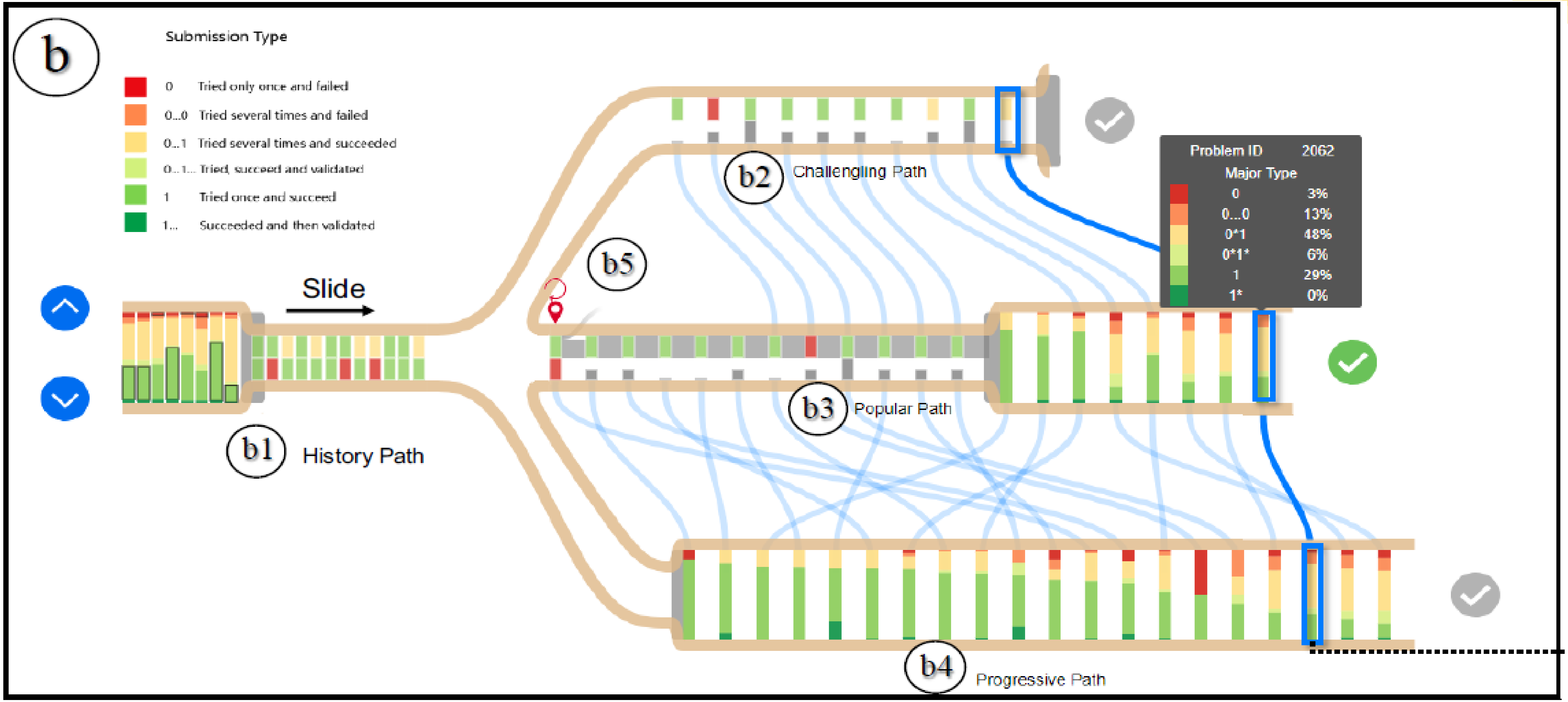
Visual Design: Peer Selection View



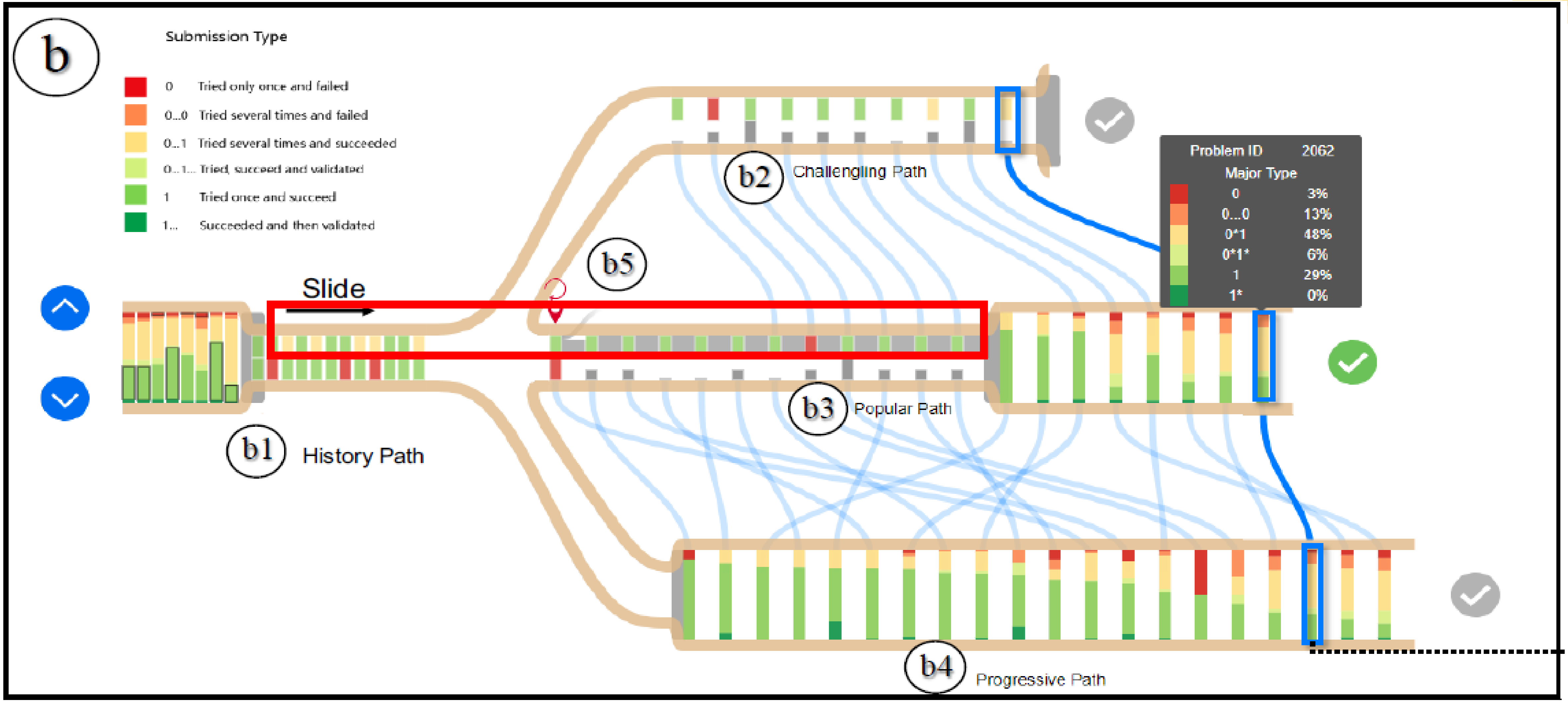
Yellow diamond plot: selected peers **Blue diamond plot: learner himself**

- **Regular Learning**: regularly for a long time and solve 1-2 problems per day.
- **Intensive Learning**: 1-3 months, solve 2-5 questions per day with high proficiency.
- **Advanced Learning**: solve many problems per day in short time with high proficiency.

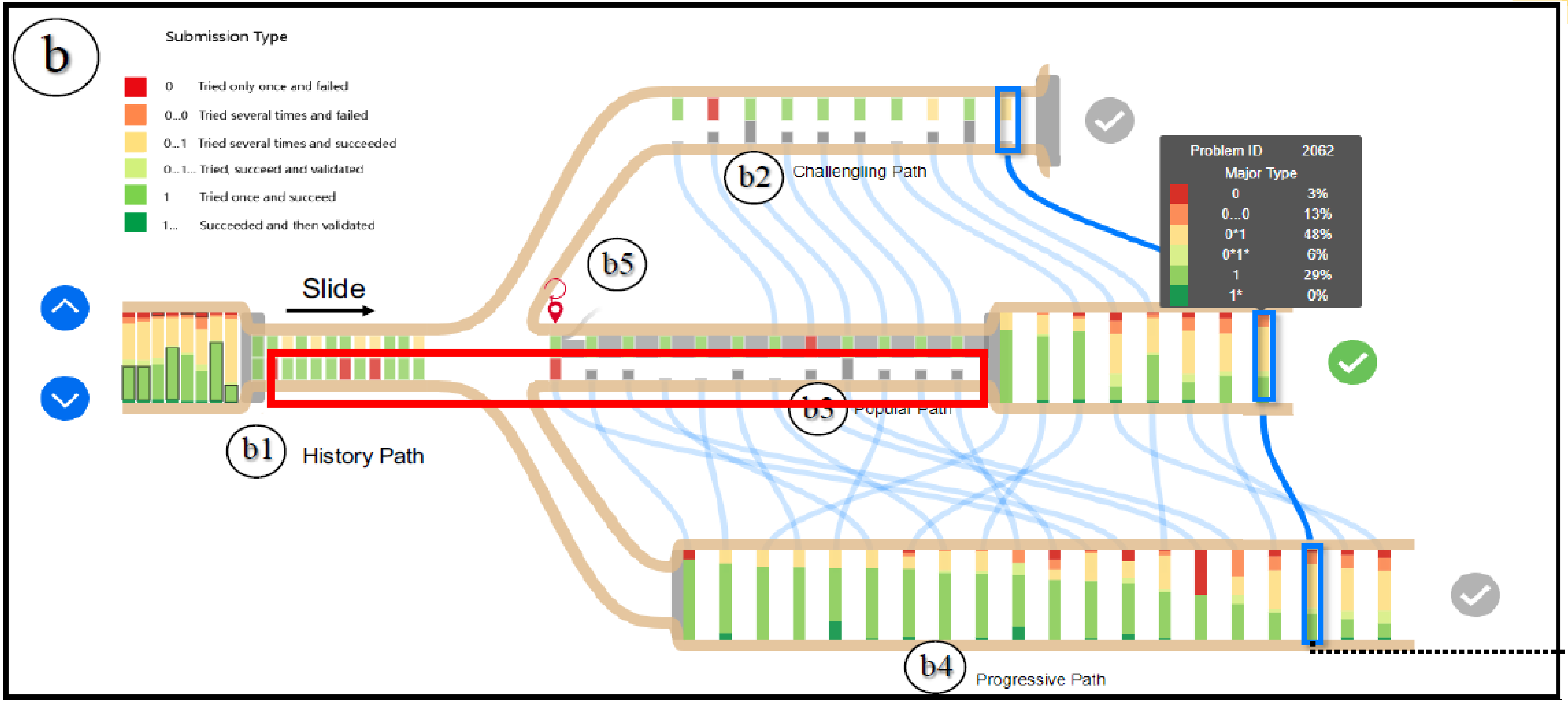
Visual Design: Learning Path View



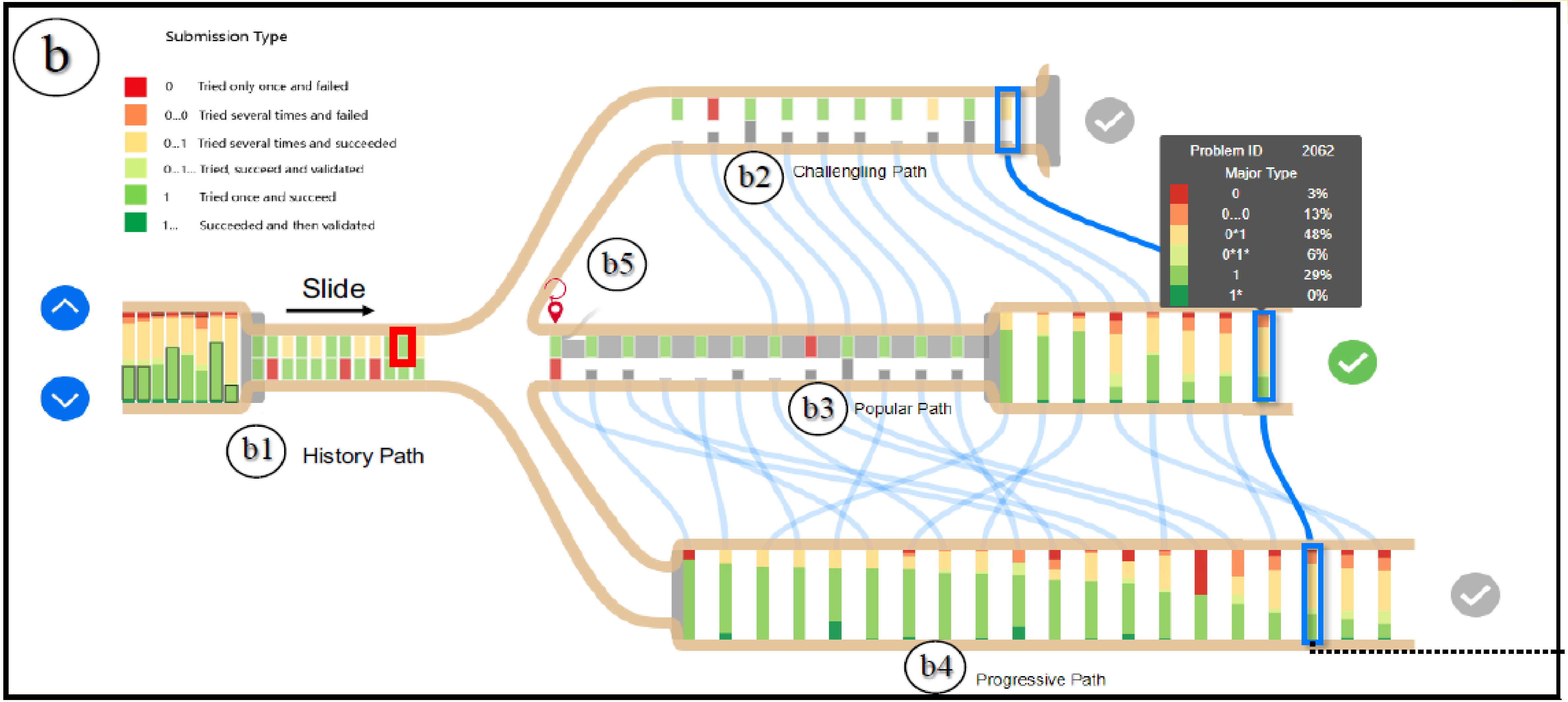
Visual Design: Learning Path View



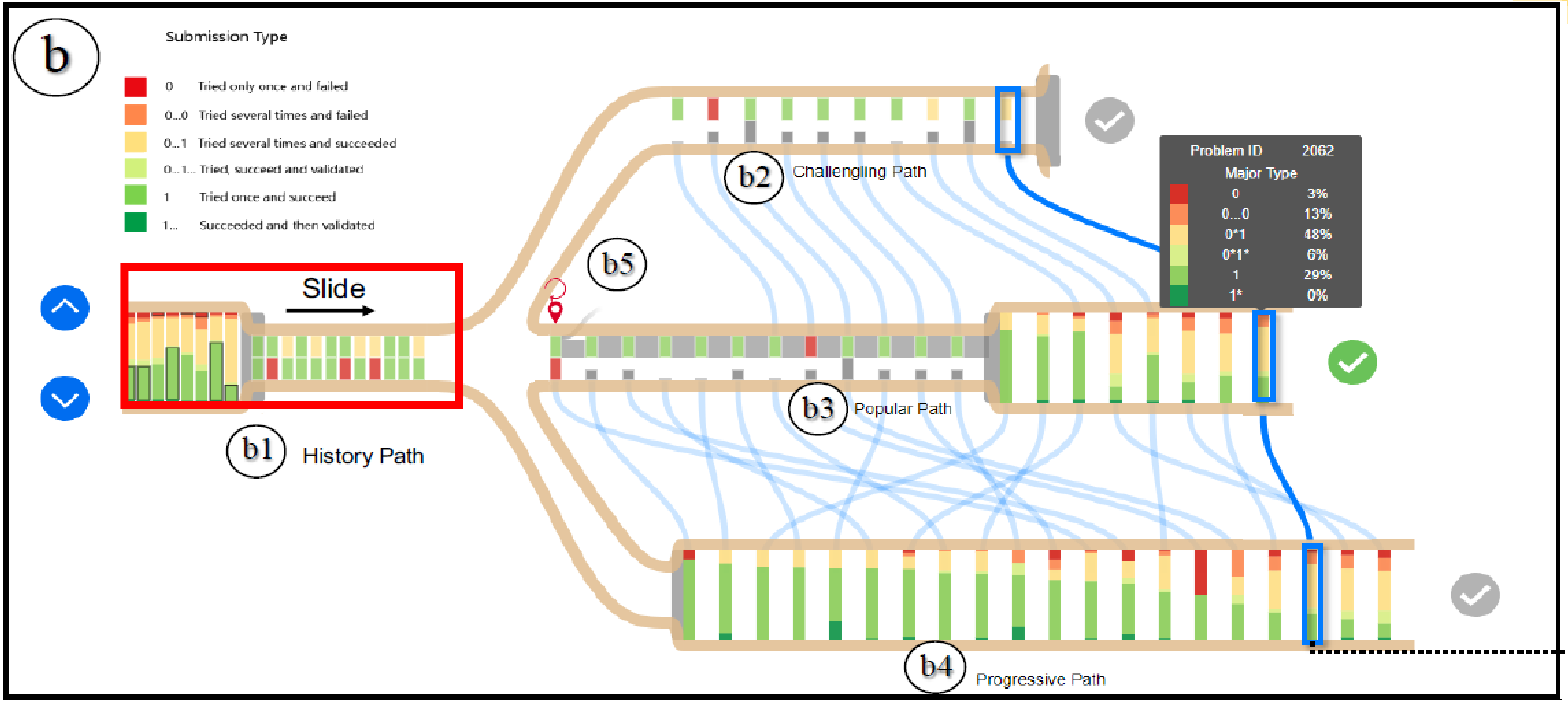
Visual Design: Learning Path View



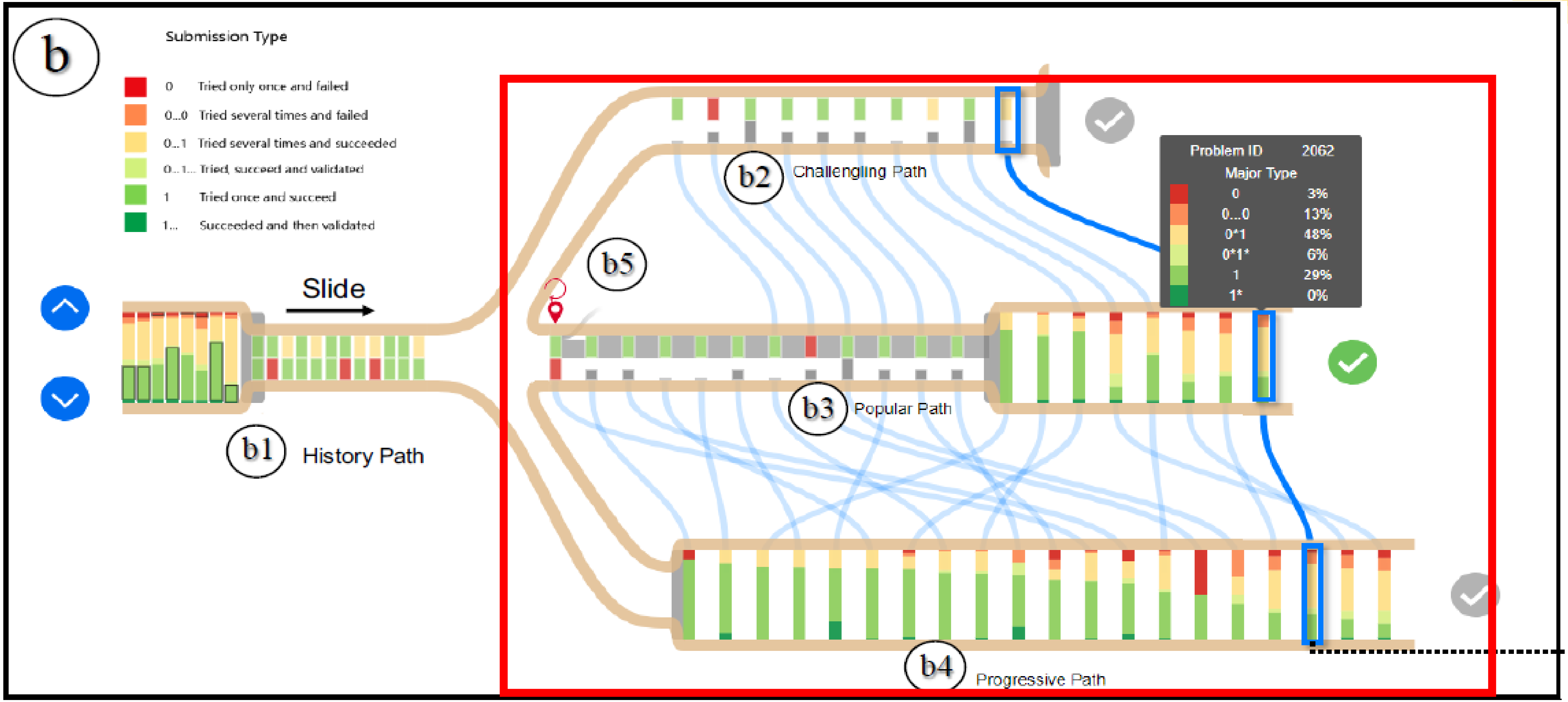
Visual Design: Learning Path View



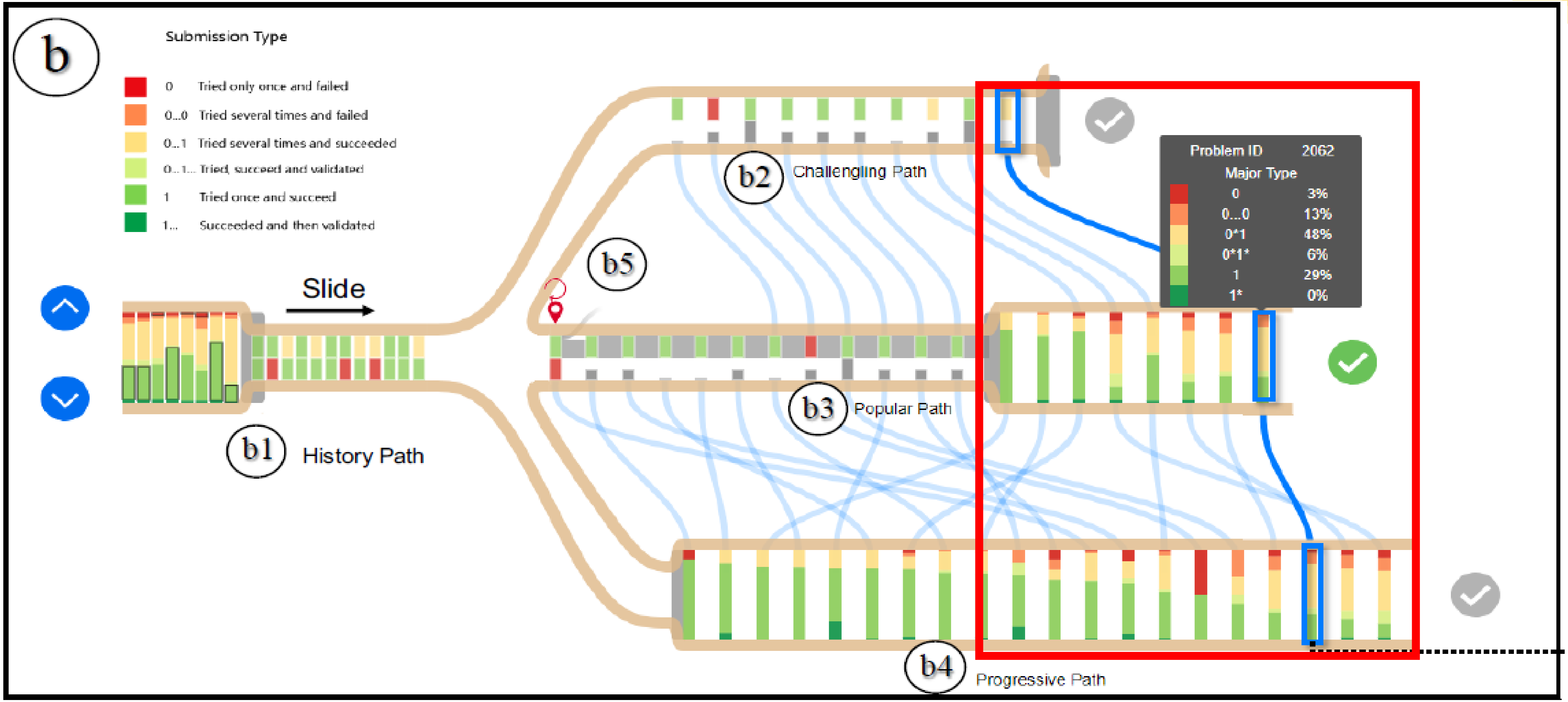
Visual Design: Learning Path View



Visual Design: Learning Path View



Visual Design: Learning Path View



Evaluation: Experiment Design

Dataset:

A popular programming question pool

~4.6M submission records

~54K learners

~5K programming questions

Participants:

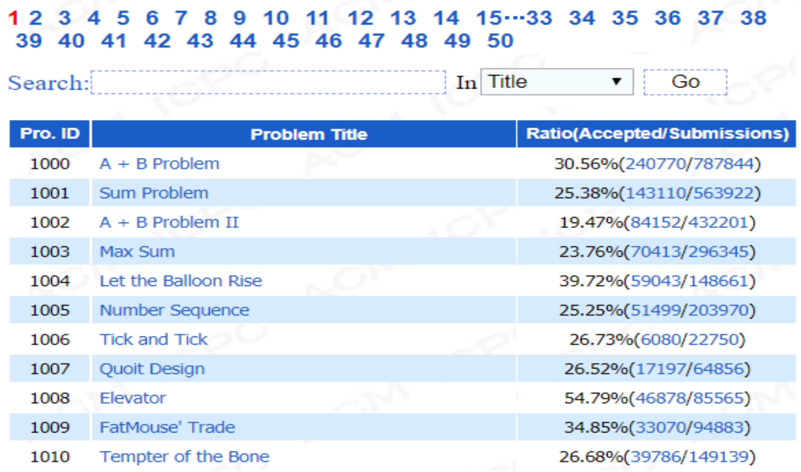
18 (7 females, 11 males, age:24±2.85), from a local computer science department

Systems:

S1. Full PeerLens

S2. Baseline system

S3. Primitive PeerLens

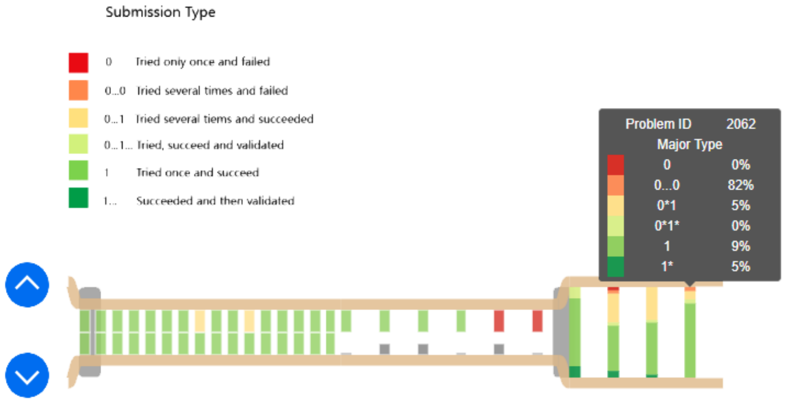


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15···33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

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



Primitive PeerLens

Evaluation: Experiment Design

Within-subject：
Counter balance the three learning scenarios and three systems

Learning scenarios:

L1. Basic programming practice

L2. Coding qualification test for IT company interviews

L3. International Programming Contest

Tasks:

1. Determine the starting question under a specific learning scenario
2. Find the next question to solve given an existing historical learning path

Evaluation: Questionnaires

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

Results

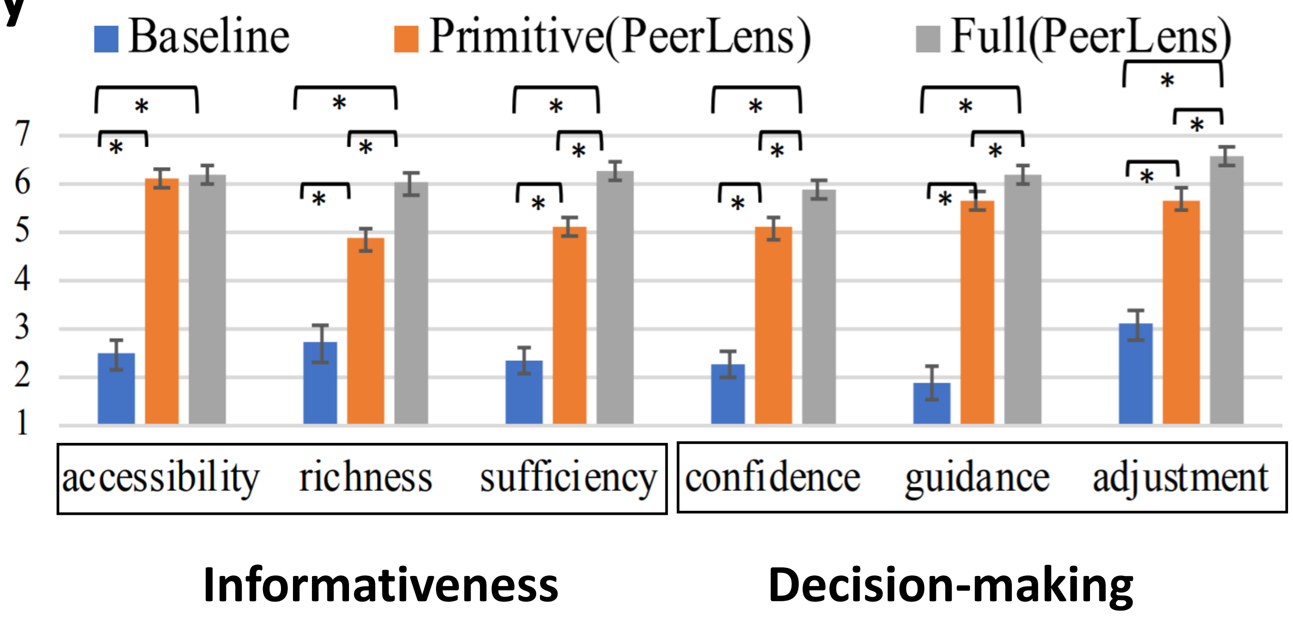
Informativeness and decision-making efficacy

- Primitive and Full PeerLens > Baseline

- Information richness & sufficiency：
  Full PeerLens > Primitive

- Information accessibility:
  No significant differences between Full and Primitive

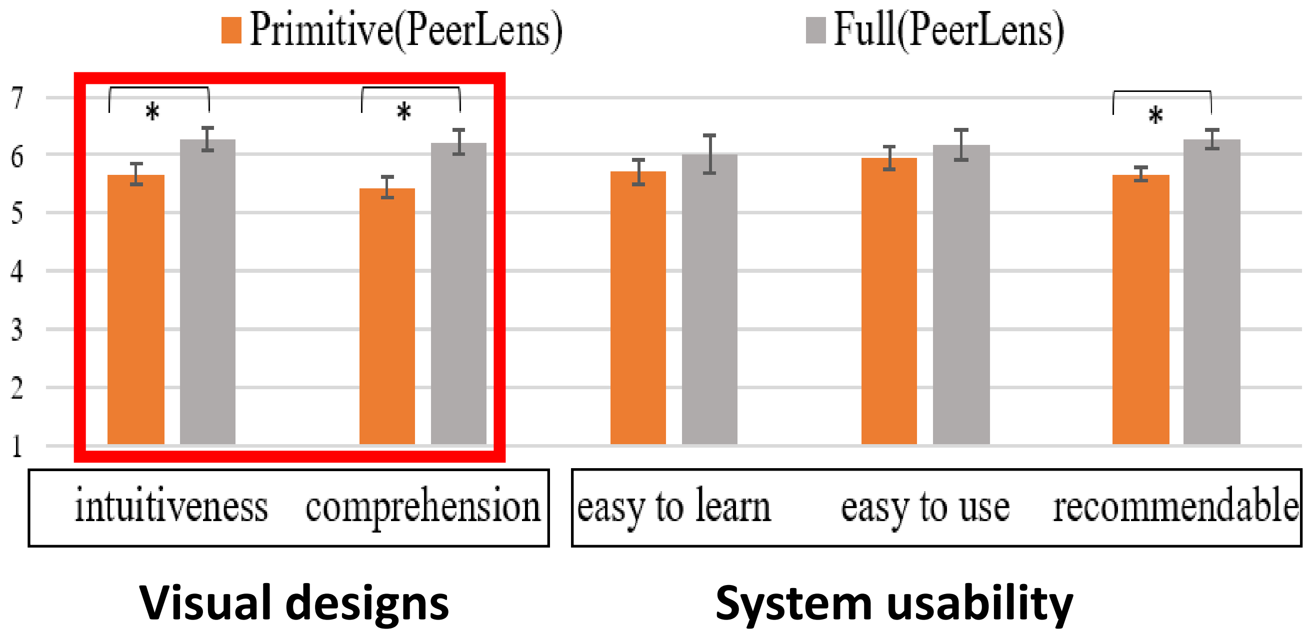
- Decision-making metrics:
  Full PeerLens > Primitive



Results

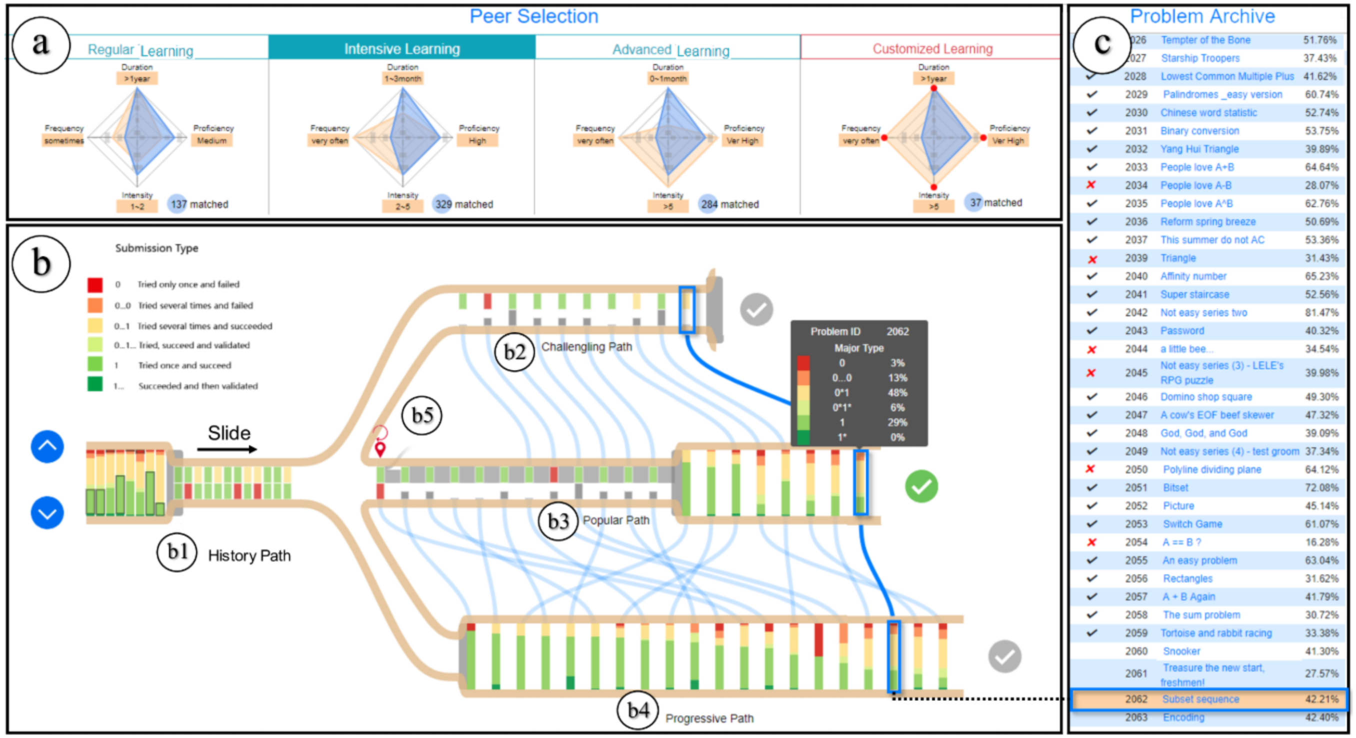
Visual designs and system usability

- Intuitiveness & comprehension: Full PeerLens > Primitive
- Easy to learn & use: No significant difference between Full and Primitive
- Recommendation: Full PeerLens > Primitive



Conclusion

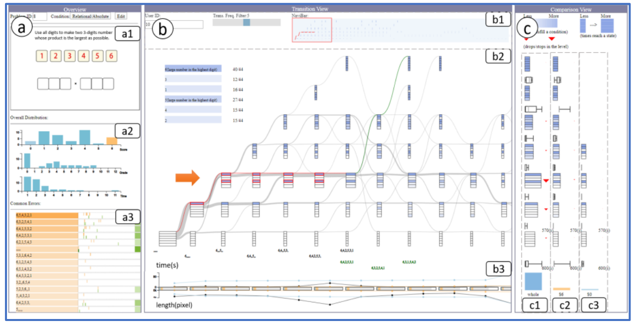
- A novel visual analytics system
- A novel zipper-like visualization
- A within-subject user experiment



Our works

[Qlens](#): multi-step question analysis.
VIS 2020 (conditionally accepted)

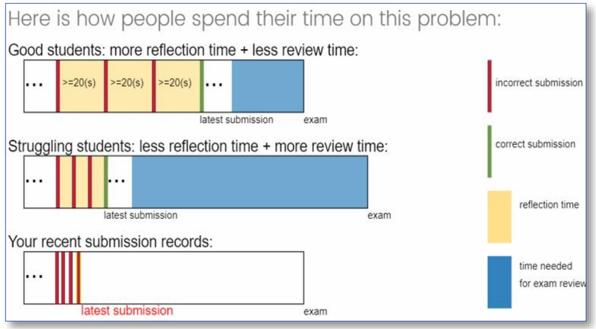
1



Micro level

3

"Game the system": learning behavior regulation. L@S, 2020

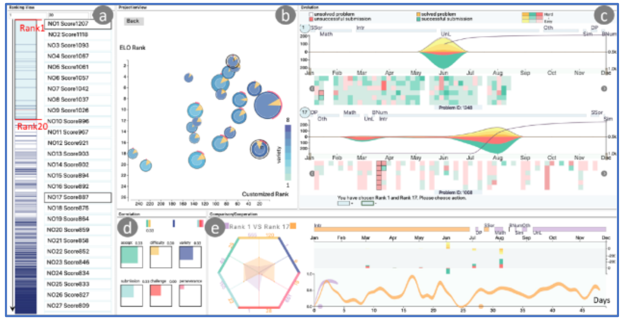


Empower educators

Problem-solving Data

Empower students

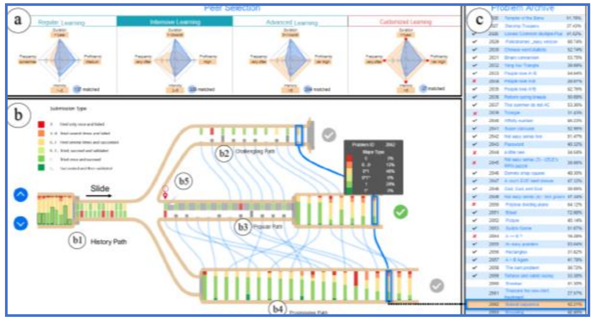
2



SeqDynamics: problem-solving dynamics analysis. Euro VIS, 2020

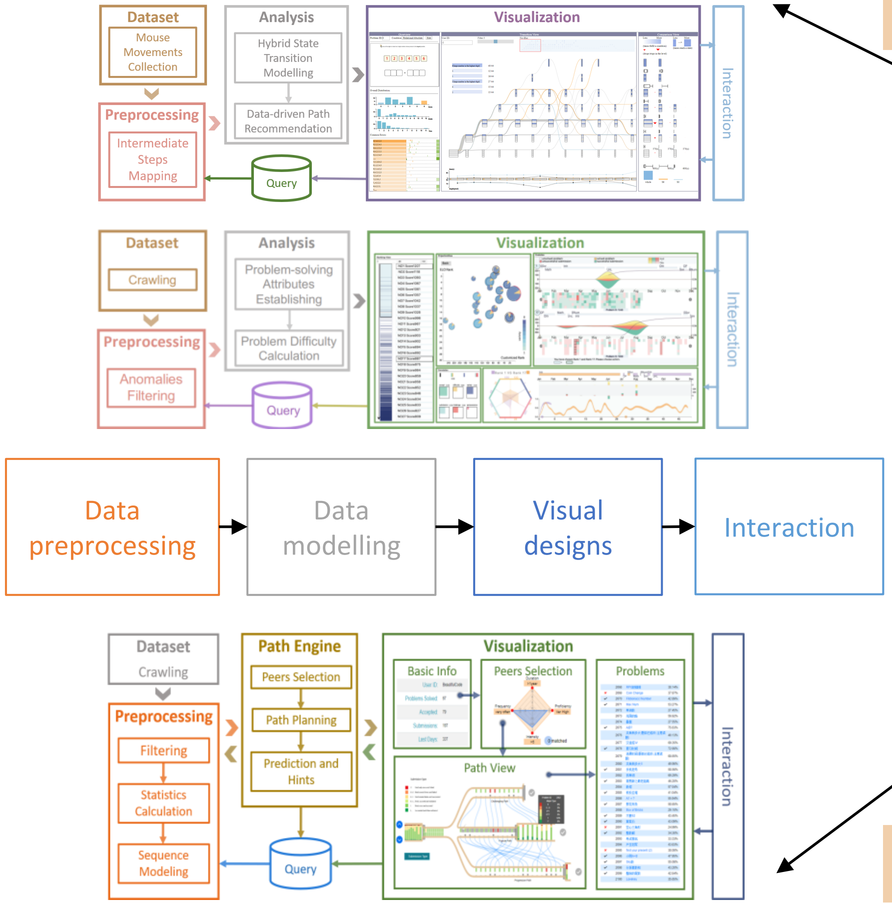
Macro level

4



Peerlens: learning path planning.
CHI, 2019

Discussion - Methodology



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

Data/task abstraction:
Data: event sequence data
Tasks: representation, summarization, and comparison

Problem-solving behavior Modelling:
represent the sequences from levels of detail
Question: difficulty level, test knowledge
Students: cognitive skills, non-cognitive traits

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

Visual Analytics Model on Learning Sequences *(adapted from Tamara's nested model for visualization design)*

Pipeline for Visualization of Problem-solving behaviors:

1. Design a workflow (i.e., from which level to which level) for the analysis process according to users and tasks.

Level	**Data**	**Tasks (examples)**	**Views**
many to many (macro)	all students, all questions	Select best candidates	Over view Main view Comparison view
one to many (micro)	all students, one question	Question design	Main view Comparison view
	one student, all questions	Personalized instruction	
	many (one group) students, one question	Comparison among groups	
	one student, many (one group) of questions	Comparison among students	
one to one (micro)	one student, one question	On the fly guidance	Main view

Pipeline for Visualization of Problem-solving behaviors:

2. Design the visualization:

Overview:

- **Summarize the features** of students or the questions to facilitate the level jump
- If one attribute, use list or bar chart (QLens); If more attributes, consider using glyph (SeqDynamics)

Main view:

- If the problem-solving sequence is **order-oriented**, model the sequence using state and transition (QLens, PeerLens)
- If the problem-solving sequence is **time-oriented**, model the sequence on different time bins (SeqDynamics, Game the system)

Comparison view:

- Embedded in one view (PeerLens)
- Separated using another view (QLens, SeqDynamics)

Discussion: Design Considerations

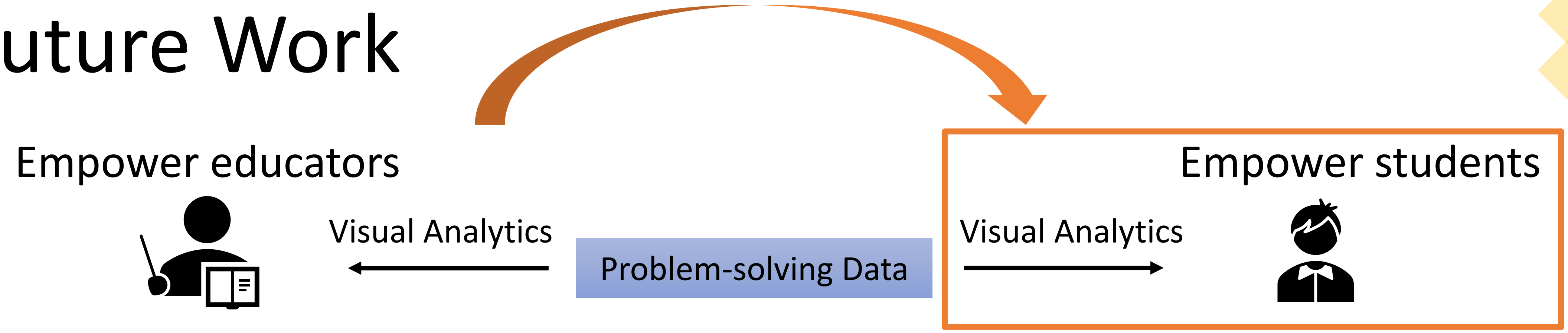
Online problem-solving:

- Students are **eager for more guidance** in their learning online
- Students have different perception of the same data, thus **the inference of students' motivation, personality, phycology state** are also important, apart from ability.

Visualization:

- **Color** is the most effective channel across our designed systems
  - They are frequently used for **alert or highlighting information**
- For both students and educator
  - It is required to provide intuitive designs
  - It is vital to **show information step by step**, even in one single view
- For students, they need simpler visual designs to understand quicker

Future Work



Collect Data: Infer students' psychology states from multiple channels

Methodology:
1. Refine the problem-solving process modeling with learning scientists
2. Apply more advanced AI techniques

Applications:
1. Providing on-the-fly guidance
2. Explore collaborative problem-solving behaviors

Evaluation:
1. Deploy and test proposed systems in the real-world setting for a longer time
2. More rigorous studies to test the effects of education data visualization

Publications

- **Meng Xia**, Reshika Palaniyappan Velumani, Panpan Xu, Yong Wang, Huamin Qu, Xiaojuan Ma, QLens: Visual Analytics of Multi-step Problem-solvingBehaviors for Improving Question Design, Conditionally accepted, IEEE VIS 2020 (TVCG track)
- **Meng Xia**, Yuya Asano, Joseph Jay Williams, Huamin Qu, Xiaojuan Ma, Using Information Visualization to Promote Students' Reflection on "Gaming the system" in Online Learning, *L@S 2020*
- **Meng Xia**, Min Xu, Chuan-en Lin, Ta-ying Cheng, Huamin Qu, Xiaojuan Ma, SeqDynamics: Visual Analytics for Evaluating Online Problem-solving Dynamics, *EuroVis 2020*
- Huan Wei, Haotian Li, **Meng Xia**, Yong Wang, Huamin Qu, Predicting Student Performance in Interactive Online QuestionPools Using Mouse Interactions, *ACM LAK 2020 (Learning Analytics & Knowledge)*
- **Meng Xia**, Huan Wei, Min Xu, Leo Yu Ho Lo, Yong Wang, Rong Zhang, Huamin Qu, Visual Analytics of Student Learning Behaviors on K-12 Mathematics E-learning Platforms, Poster, *IEEE VIS 2019 Posters, Best Poster Award*
- **Meng Xia**, Mingfei Sun, Huan Wei, Qing Chen, Yong Wang, Lei Shi, Huamin Qu, Xiaojuan Ma, PeerLens: Peer-inspired Interactive Learning PathPlanning in Online Question Pool, video *ACM CHI 2019*
- **Meng Xia**, Rong Zhang, Ren Peng, Jinhui Yu, Generation of Thangka Relief from Line Drawings, *SCIENTIA SINICA Informationis 2018*
- Ke Xu, **Meng Xia**, Xing Mu, Yun Wang, Nan Cao, EnsembleLens: Ensemble-based Visual Exploration of Anomaly Detection Algorithms with Multidimensional Data, *TVCG 2018*
- Zhenhui Peng, Jeehoon Yoo, **Meng Xia**, Sunghun Kim, Xiaojuan Ma, Exploring How Software Developers Work with Mention Bot in GitHub, *Chinese CHI 2018*
- Mingfei Sun, Yiqing Mou, Hongwen Xie, **Meng Xia**, Michelle Wong, Xiaojuan Ma, Estimating Emotional Intensity from Body Poses for Human-Robot Interaction, *IEEE SMC 2018*, demo

Acknowledgement

Prof. Huamin Qu

Prof. Xiaojuan Ma

Prof. Jeseph Jay Williams

Acknowledgement

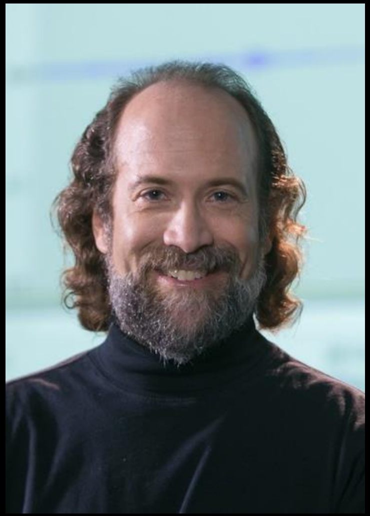

HKUST


Prof Charles Wing Hoi CHAN,
Division of Humanities


Prof. Weichuan YU (ECE)


Prof. Ke Yi (CSE)


Prof Nancy Wai Ying LAW
Department of Education (HKU)


Prof. Andrew Brian HORNER (CSE)

Bridge the Gap between Educators and Students

in Online Learning:

A Visualization Approach based on Problem-solving Data

Thank you!

Q & A