THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

Enhancing Personalized Learning Through Interactive Visual Analytics Systems

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HKUST VIS

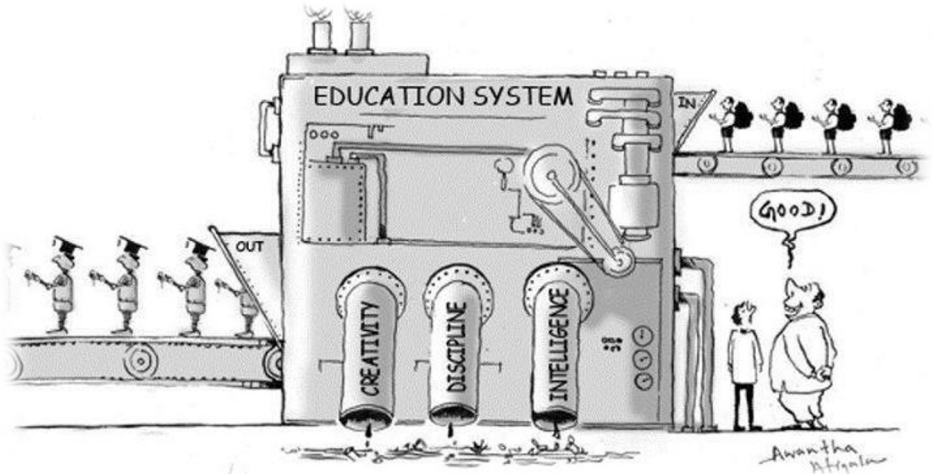
Outline

- Introduction
  - Background
  - Definition
  - Challenges
  - Research Question
  - Motivation
- Taxonomy
- Future Work
- Take-home Message

Background

Modern schooling often utilize a "one-size-fits-all" approach:

- Predetermined curricula,
- Standardized syllabi,
- Uniformly assigned homework,
- Low instructor-student ratio
- …

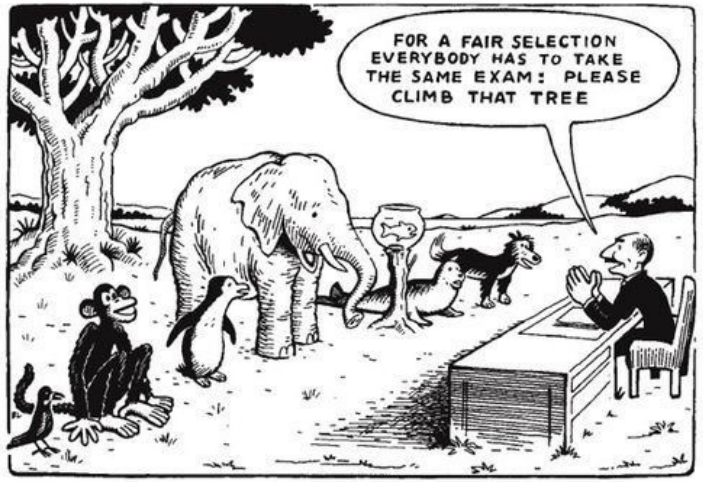


D. Onah, J. Sinclair, and R. Boyatt. (2014). Dropout Rates Of Massive Open Online Courses: Behavioural Patterns. *In Proceedings of International Conference on Education and New Learning Technologies*. 5825–5834

Painpoints of Education

However, we overlooks the fact that students vary considerably in their:

- Abilities,
- Learning preferences,
- Prior knowledge,
- Interests,
- Educational goals,
- …

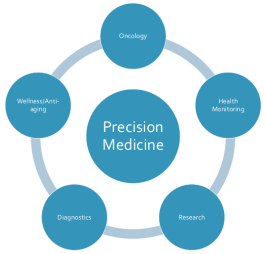


Need a truly tailored educational environment!

A Shemshack, JM Spector. (2020). *A systematic literature review of personalized learning terms*. Smart Learning Environments

What is Personalized Learning

Tailored to an individual learner's **needs** or **conditions** and **adaptable** to the learner's evolving skills and knowledge.



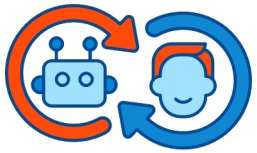
Provide a **learner-centered** learning environment

- Epstein, Sam; Epstein, Beryl (1961). The First Book of Teaching Machines
- A Shemshack, JM Spector. (2020). *A systematic literature review of personalized learning terms*. Smart Learning Environments

Challenges

- How can instructors balance personalization and standardization?
- How can instructors track and review individual learning progress?
- How can students explore best-fit personalized learning pace?
- …

Require human involvement
Not a pure algorithmic problem

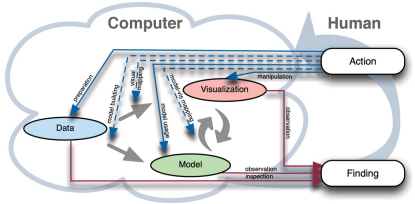


Matthew L. Bernacki. (2021). Educational Psychology Review: *A Systematic Review of Research on Personalized Learning: Personalized by Whom, to What, How, and for What Purpose(s)?*,

Research Question

How we effectively involve human in personalized learning implementation?

Enhancing personalized learning through interactive visual analytics systems!



Automated analysis + Interactive visualizations

D Keim, G Andrienko, JD Fekete. (2008). *Visual Analytics: Definition, Process, and Challenges*. Information Visualization.
D Sacha, A Stoffel. (2014). *Knowledge Generation Model for Visual Analytics*. IEEE transactions on visualization and computer graphics.

Motivation

To enhance the execution of personalized learning, what can we do with the help of interactive VA systems?

- **Who** are the core stakeholders involved in the implementation of PL?
- **Why** they use the VA systems to facilitate PL?
- **How** do they accomplish their objectives and enhance PL?

Outline

- Introduction
- Taxonomy
  - Paper Selection & Citation Graph
  - Taxonomy Overview
  - Learner Side
  - Instructor Side
- Future Work
- Take-home Message

Paper Selection

Resource:

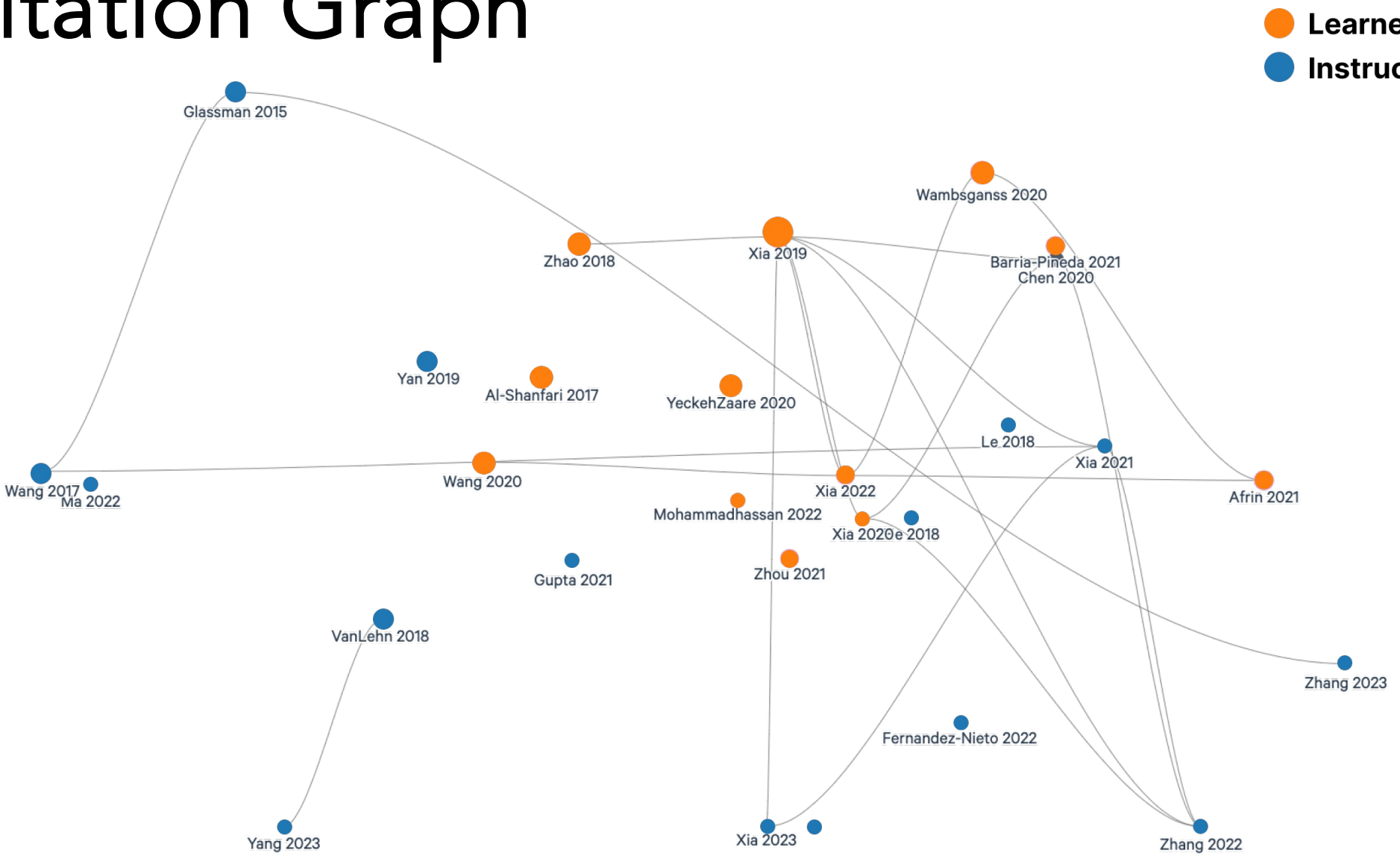
Google Scholar, IEEE Xplore, ACM Digital Library, Springer AIED Conference, …

- Keywords searching: “adaptive learning”, “personalized learning”, “customized learning”, “visual analytics”, “visualization”..
- All Metadata matching
- Exchangeable keywords combination
- Cite and be cited
- Related Paper

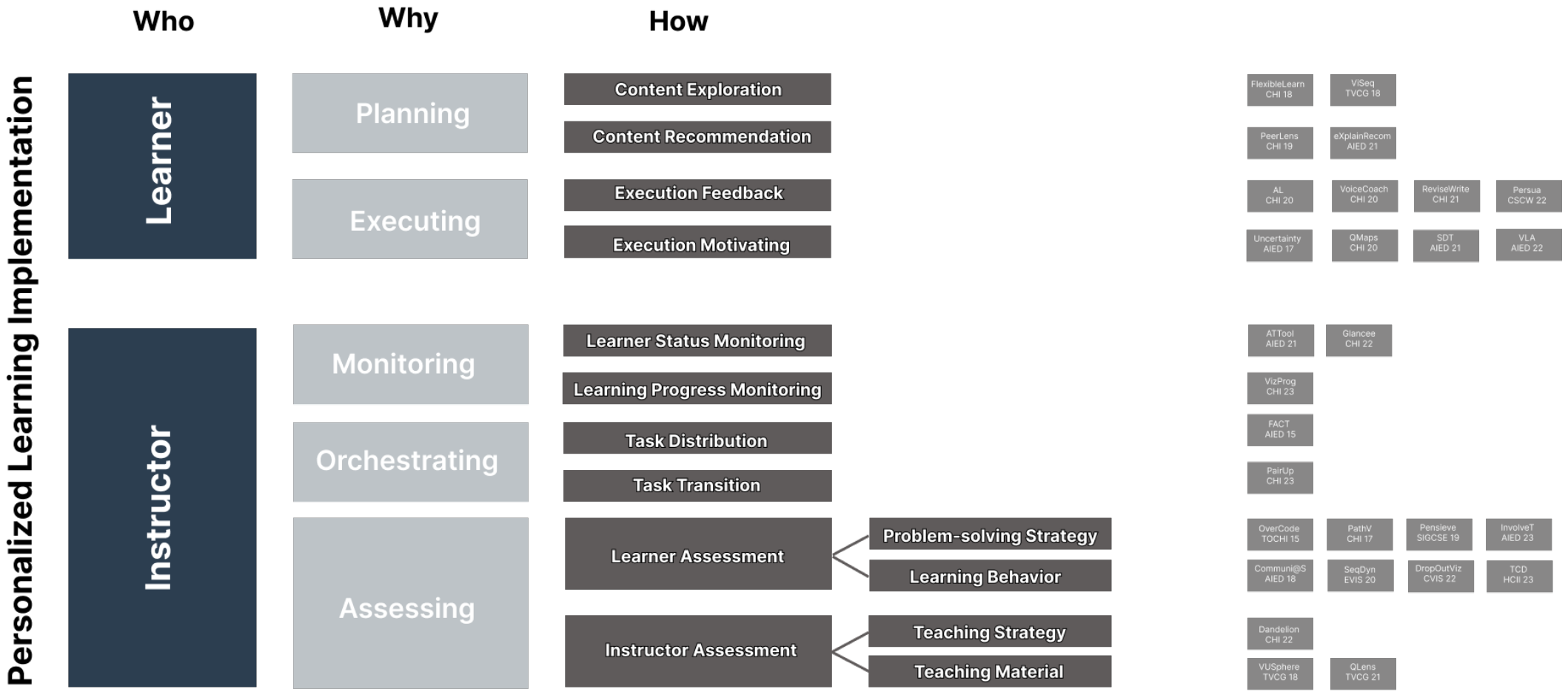
Results:

300+ => **28** papers after focus & quality filtering

Citation Graph

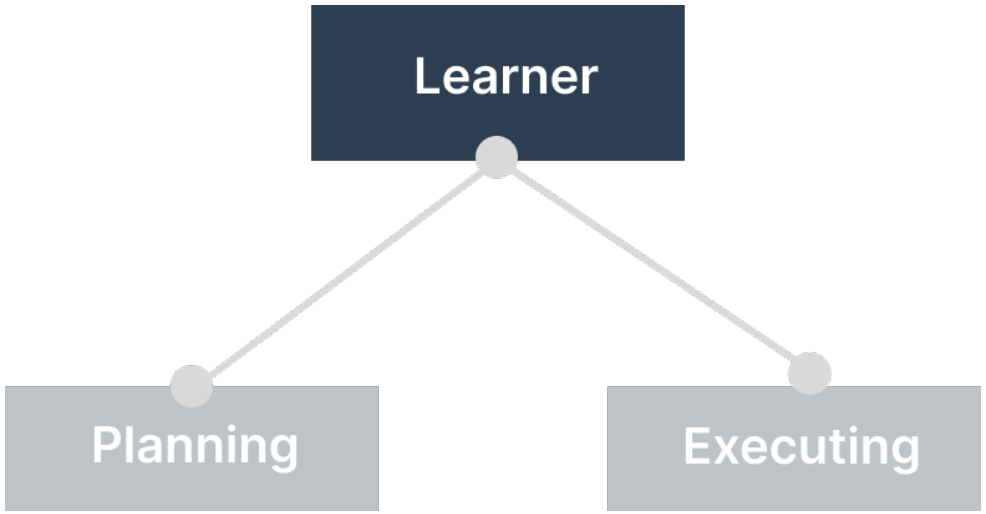


Taxonomy


Who
Why
How
Personalized Learning Implementation
Learner
Planning
Executing
Content Exploration
Content Recommendation
Execution Feedback
Execution Motivating
FlexibleLearn CHI 18
ViSeq TVCG 18
PeerLens CHI 19
eXplainRecom AIED 21
AL CHI 20
VoiceCoach CHI 20
ReviseWrite CHI 21
Persua CSCW 22
Uncertainty AIED 17
QMaps CHI 20
SDT AIED 21
VLA AIED 22
Instructor
Monitoring
Orchestrating
Assessing
Learner Status Monitoring
Learning Progress Monitoring
Task Distribution
Task Transition
Learner Assessment
Problem-solving Strategy
Learning Behavior
Instructor Assessment
Teaching Strategy
Teaching Material
ATTool AIED 21
Glancee CHI 22
VizProg CHI 23
FACT AIED 15
PairUp CHI 23
OverCode TOCHI 15
PathV CHI 17
Pensieve SIGCSE 19
InvolveT AIED 23
Communi@S AIED 18
SeqDyn EVIS 20
DropOutViz CVIS 22
TCD HCII 23
Dandelion CHI 22
VUSphere TVCG 18
QLens TVCG 21

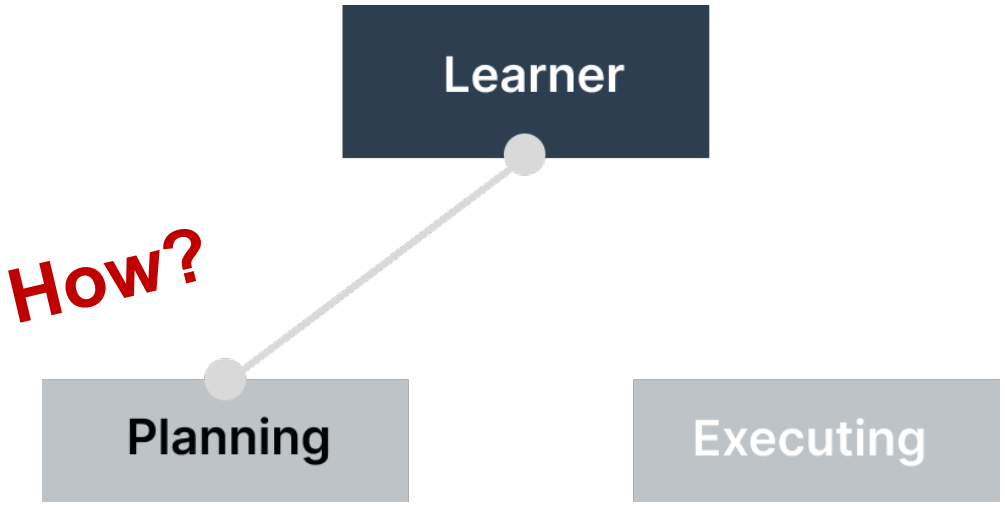
Learner

- Why do learner use the VA systems to support personalized learning?



Planning

Definition: Learners explore and determine what to learn for their particular needs or learning scenario.



Wong, L. H., & Looi, C. K. (2011). A survey of optimized learning pathway planning and assessment paper generation with swarm intelligence. In *Intelligent tutoring systems in e-learning environments: Design, implementation and evaluation* (pp. 285-302). IGI Global.

Plan what to learn

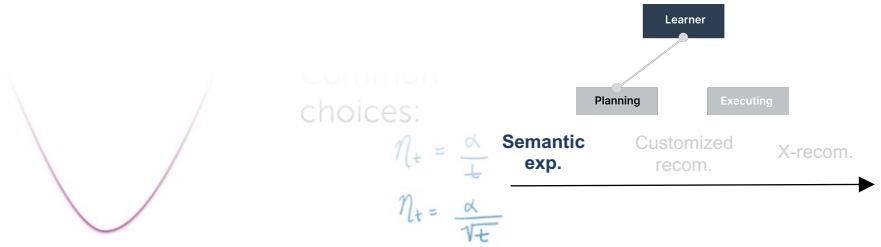
Jimmy, a year-4 business student who takes the course COMP3711 (Algorithm) for his minor degree.

Why do these algorithms, e.g., **Dynamic Programming** matter in real life ?

MOOC Videos follow syllabus sequence!

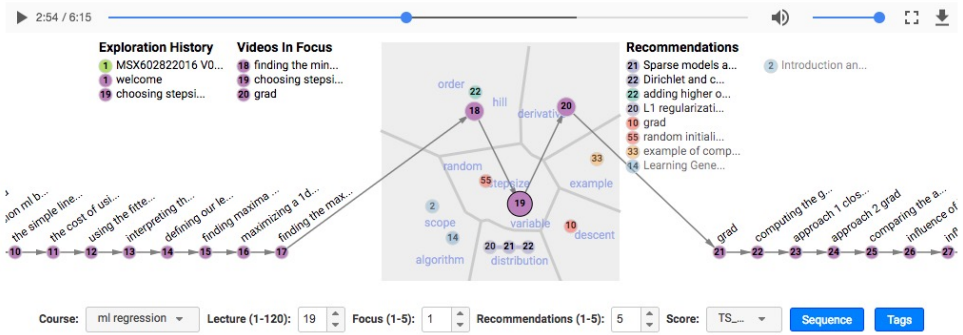
How to plan a learning that extent to coherent contents from different courses to get a comprehensive understanding?

Semantic Exploration



Domain Problem

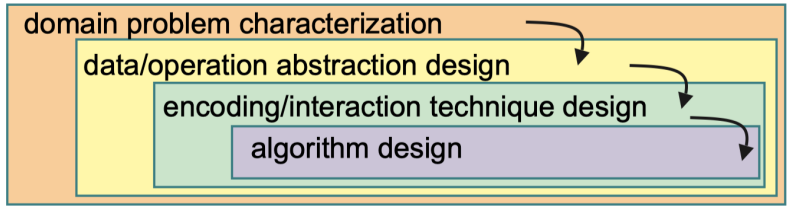
Explore lecture videos based on the concept map by considering both semantic coherent and sequential inter-topic relationships.



Zhao, J., Bhatt, C., Cooper, M., & Shamma, D. A. (2018, April). Flexible learning with semantic visual exploration and sequence-based recommendation of MOOC videos. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1-13).

Pedagogical theory

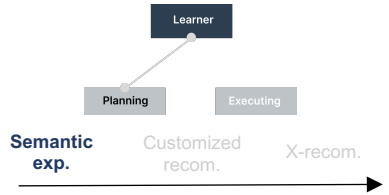
Interactive concept map allows for more personalized learning behaviors [1].

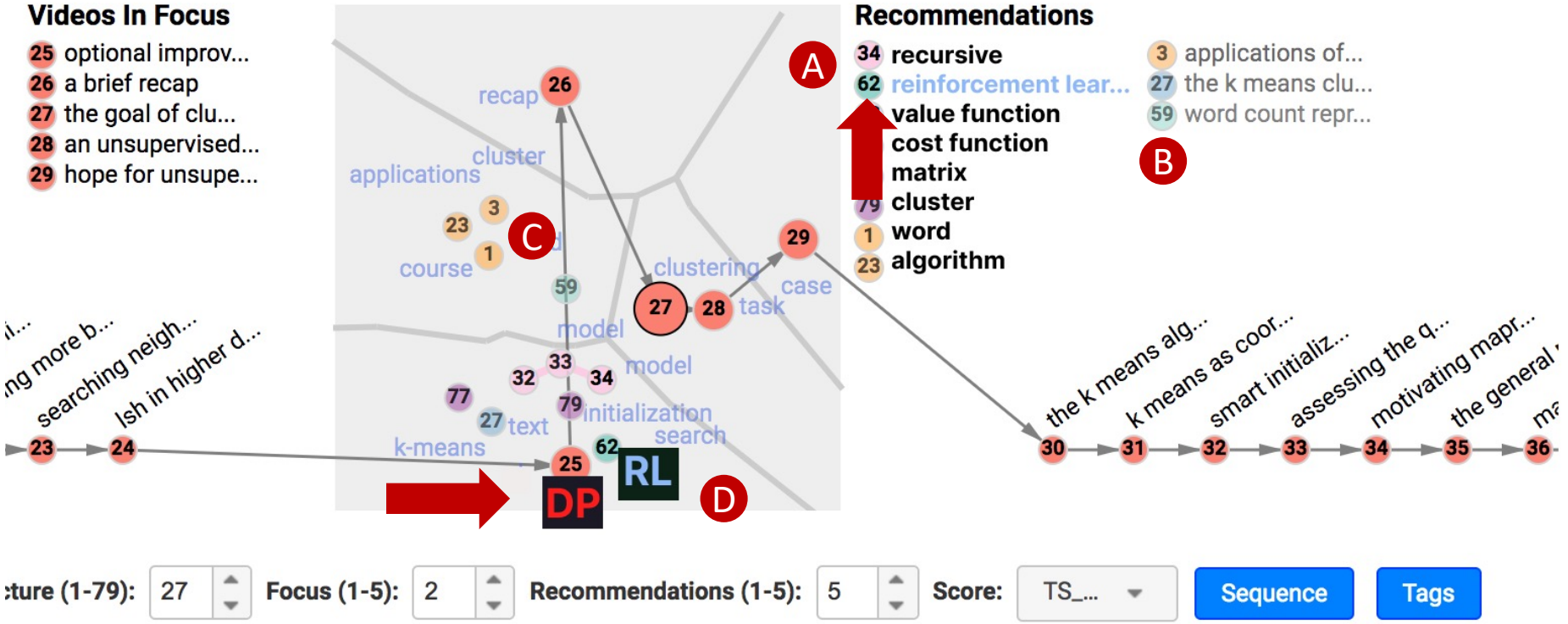


Munzner, T. (2009). A nested model for visualization design and validation. *IEEE transactions on visualization and computer graphics*, *15*(6), 921-928.

[1] J. D. Novak and D. B. Gowin. 1984. Learning how to learn. Cambridge University Press.

Semantic Exploration





Zhao, J., Bhatt, C., Cooper, M., & Shamma, D. A. (2018, April). Flexible learning with semantic visual exploration and sequence-based recommendation of MOOC videos. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1-13).

Data

Text transcripts (not personal, unstructured)
Course syllabi (not personal, semi-structured)

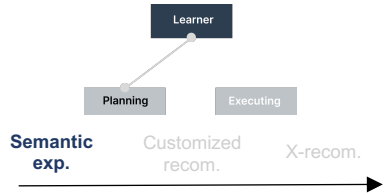
Encoding

Color & opacity: course & rank (A)(B)
Distance: content relevance (C)
Regions: semantic coherence (D)

Algorithm

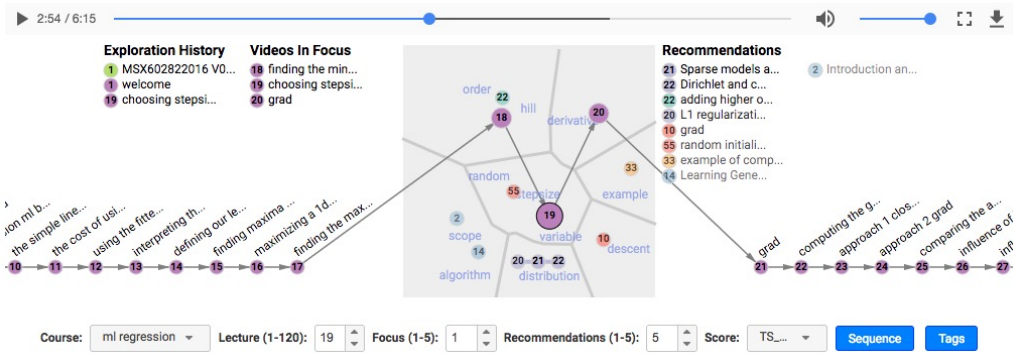
Multi-dimensional scaling
TF-IDF; TKS & TNS (sequential rule mining)

Semantic Exploration



Novelty

Concept-map based exploration from both content semantics and sequential inter-topic relationships.



Limitation

No learner data analysis used.

Zhao, J., Bhatt, C., Cooper, M., & Shamma, D. A. (2018, April). Flexible learning with semantic visual exploration and sequence-based recommendation of MOOC videos. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1-13).

Planning

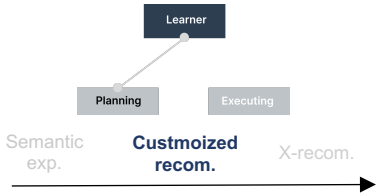
Near the end of semester, Jimmy need to practice for final exam.
He just need to pass.

Leetcode questions are too much!

How to plan what to practice based on Jimmy's needs?

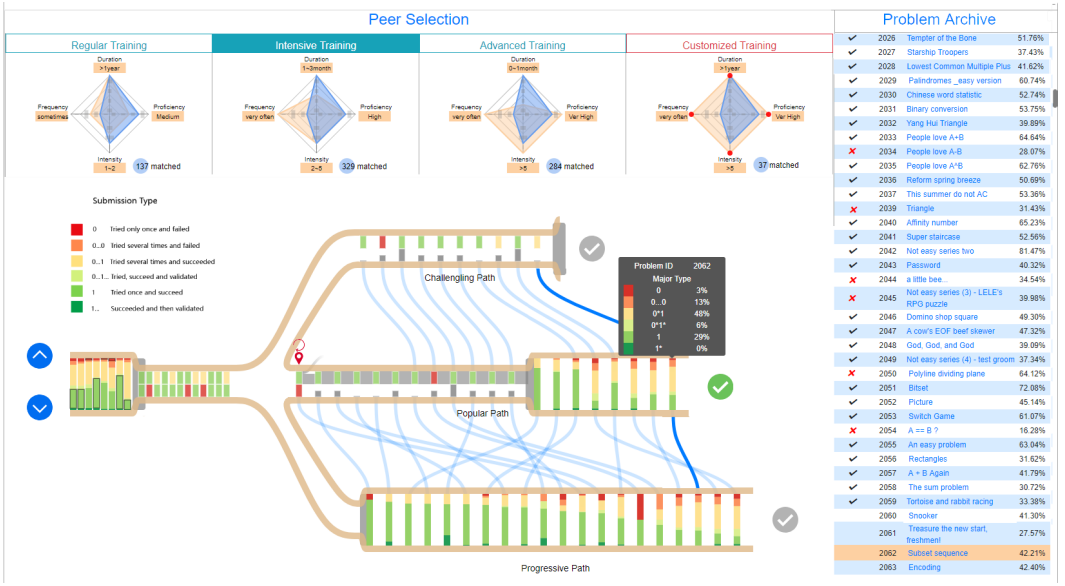
	#	Title	Solution	Acceptance	Difficulty	Frequency
✔	85	Maximal Rectangle		33.0%	Hard	
✔	621	Task Scheduler		45.2%	Medium	
✔	412	Fizz Buzz		59.3%	Easy	
✔	41	First Missing Positive		28.6%	Hard	
✔	54	Spiral Matrix		30.2%	Medium	
	642	Design Search Autocomplete System		37.1%	Hard	
✔	344	Reverse String		63.1%	Easy	
✔	127	Word Ladder		23.7%	Medium	
	124	Binary Tree Maximum Path Sum		29.8%	Hard	
✔	336	Palindrome Pairs		30.7%	Hard	
✔	141	Linked List Cycle		36.5%	Easy	
	193	Valid Phone Numbers		25.1%	Easy	

Customized Recommendation



Domain Problem

Use peer data as source of recommendation to customize learning path planning based on their goals and learning scenario.

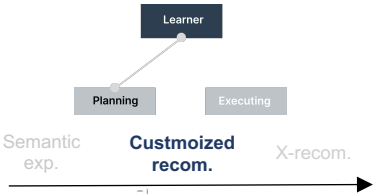


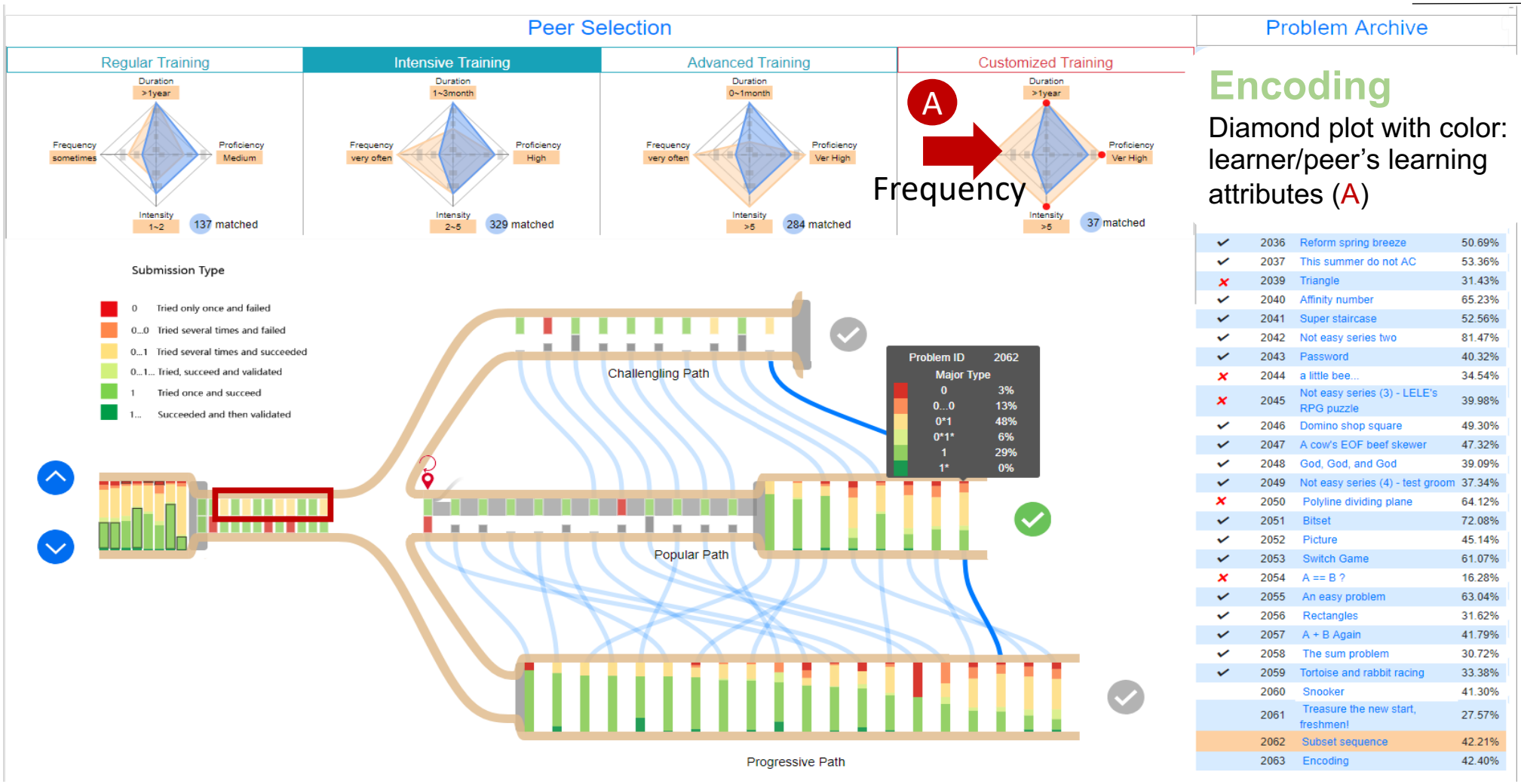
Pedagogical theory

Not explicitly mentioned

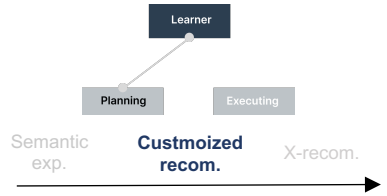
Xia, M., Sun, M., Wei, H., Chen, Q., Wang, Y., Shi, L., ... & Ma, X. (2019, May). Peerlens: Peer-inspired interactive learning path planning in online question pool. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-12).

Customized Recommendation





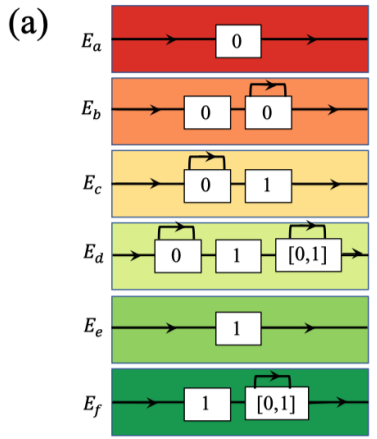
Customized Recommendation

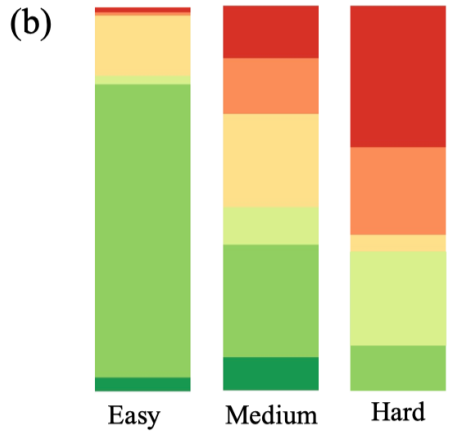


Data

Students' basic info (personal, tabular data)
Problem submission log (personal)

=> Submisstion type (categorical)
=> Submisstion event (event sequence)

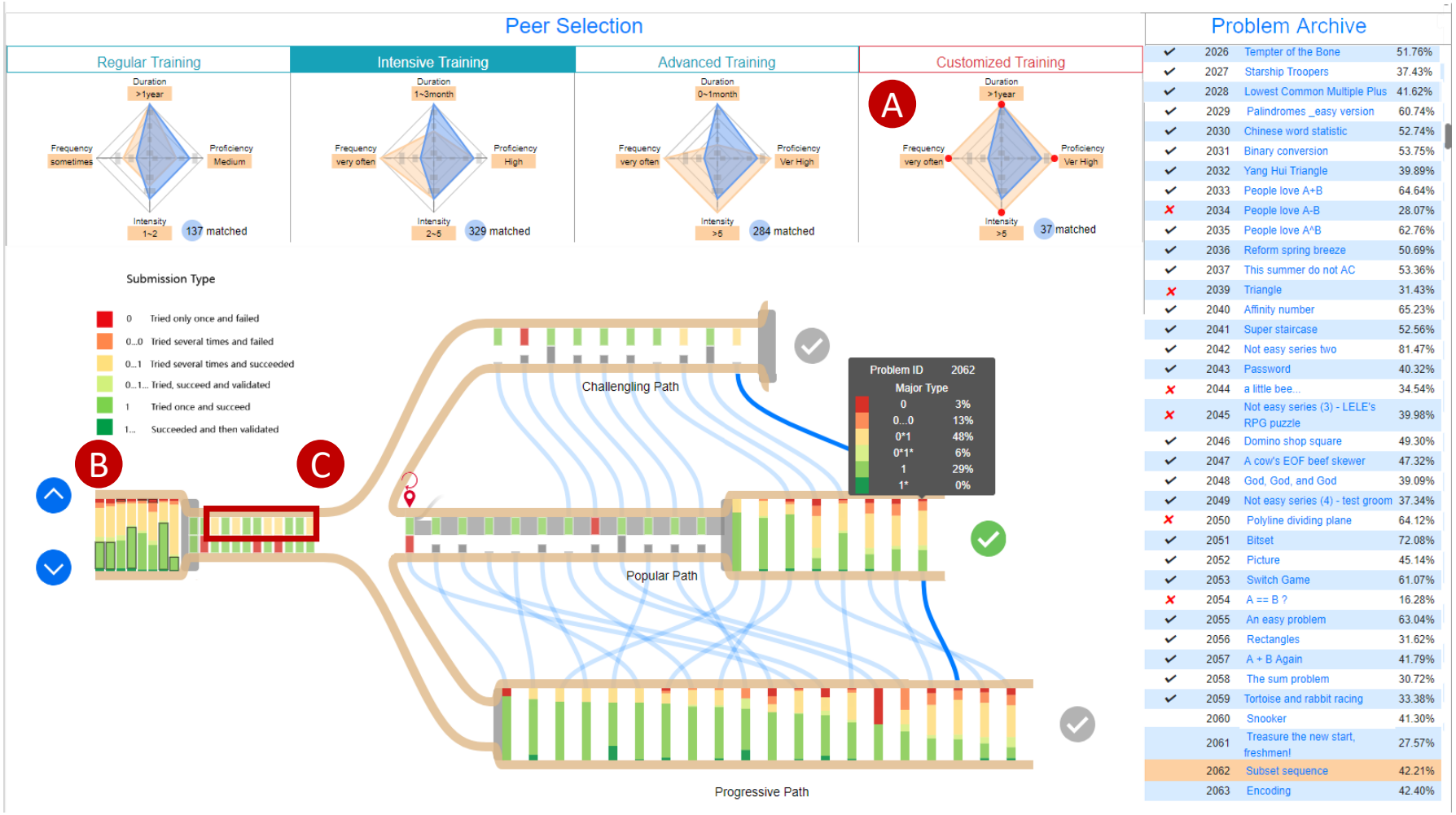




Ea: One failed attempt without success
Eb: Multiple failed attempts without success
Ec: Multiple failed attempts followed by one success
Ed: Multiple failed attempts followed by one success and more attempts
Ee: One success without further attempts
Ef: One success followed by more attempts.

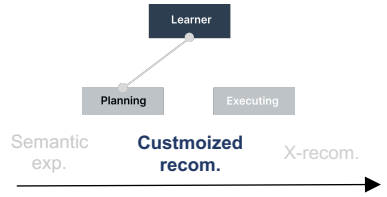
Xia, M., Sun, M., Wei, H., Chen, Q., Wang, Y., Shi, L., ... & Ma, X. (2019, May). Peerlens: Peer-inspired interactive learning path planning in online question pool. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-12).

Customized Recommendation



Problem Archive

✓	2026	Tempter of the Bone	51.76%
✓	2027	Starship Troopers	37.43%
✓	2028	Lowest Common Multiple Plus	41.62%
✓	2029	Palindromes _easy version	60.74%
✓	2030	Chinese word statistic	52.74%
✓	2031	Binary conversion	53.75%
✓	2032	Yang Hui Triangle	39.89%
✓	2033	People love A+B	64.64%
✗	2034	People love A-B	28.07%
✓	2035	People love A^B	62.76%
✓	2036	Reform spring breeze	50.69%
✓	2037	This summer do not AC	53.36%
✗	2039	Triangle	31.43%
✓	2040	Affinity number	65.23%
✓	2041	Super staircase	52.56%
✓	2042	Not easy series two	81.47%
✓	2043	Password	40.32%
✗	2044	a little bee...	34.54%
✗	2045	Not easy series (3) - LELE's RPG puzzle	39.98%
✓	2046	Domino shop square	49.30%
✓	2047	A cow's EOF beef skewer	47.32%
✓	2048	God, God, and God	39.09%
✓	2049	Not easy series (4) - test groom	37.34%
✗	2050	Polyline dividing plane	64.12%
✓	2051	Bitset	72.08%
✓	2052	Picture	45.14%
✓	2053	Switch Game	61.07%
✗	2054	A == B ?	16.28%
✓	2055	An easy problem	63.04%
✓	2056	Rectangles	31.62%
✓	2057	A + B Again	41.79%
✓	2058	The sum problem	30.72%
✓	2059	Tortoise and rabbit racing	33.38%
	2060	Snooker	41.30%
	2061	Treasure the new start, freshmen!	27.57%
	2062	Subset sequence	42.21%
	2063	Encoding	42.40%



Algorithm
Markov Chain

Encoding

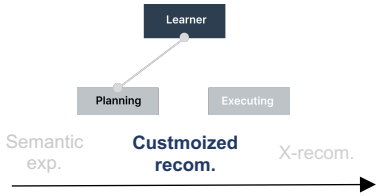
Diamond plot with color: learner/peer's learning attributes (A)

Stacked bar: a question with its submission type (B)

Zipper-like visual metaphor: historical learning path (C)

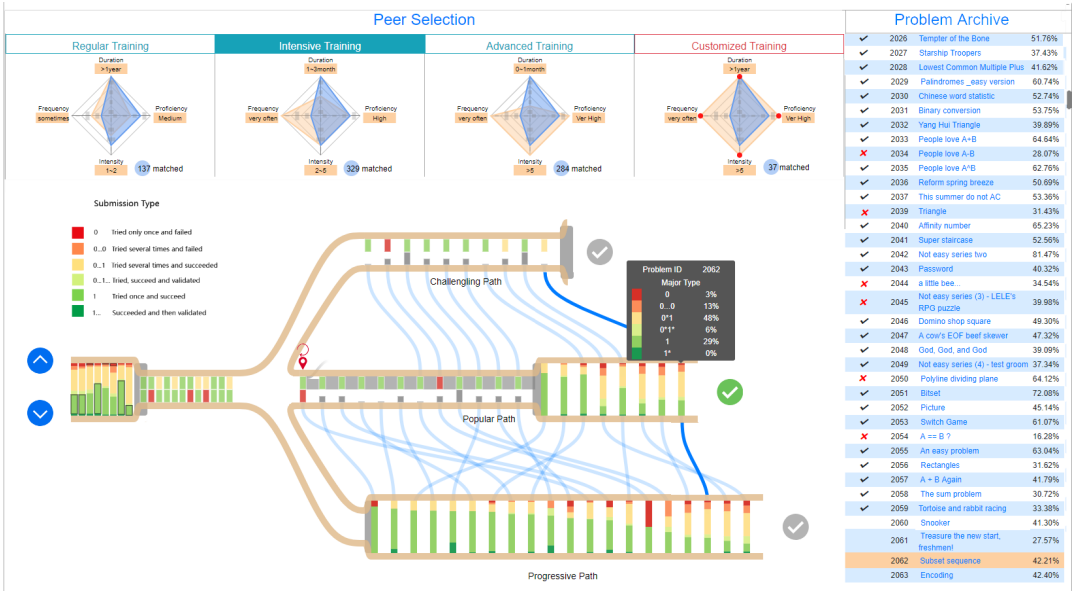
Xia, M., Sun, M., Wei, H., Chen, Q., Wang, Y., Shi, L., ... & Ma, X. (2019, May). Peerlens: Peer-inspired interactive learning path planning in online question pool. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-12).

Customized Recommendation



Novelty

Recommend customized question sequence base on the exercise history & submission type of selected peers in similar learning scenario.



Xia, M., Sun, M., Wei, H., Chen, Q., Wang, Y., Shi, L., ... & Ma, X. (2019, May). Peerlens: Peer-inspired interactive learning path planning in online question pool. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-12).

Limitation

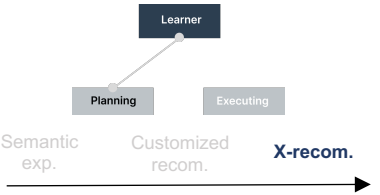
Only considers the existing peer's learning paths regardless of any semantic meanings like learner's concept mastery level.

Planning

Only two days before final, Jimmy need to do a quick review for his weakness.

How to know Jimmy's knowledge level and plan what to review in the last minutes?

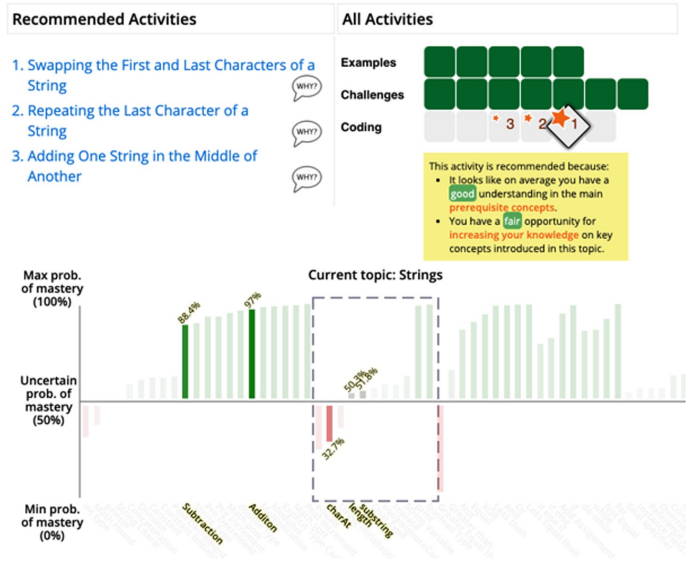
X-Learner Modelling



Domain Problem

Activities recommendation with visual and verbal explanation.

Personalized recommendation based on knowledge mastery level.



Barria-Pineda, J., Akhuseyinoglu, K., Želem-Ćelap, S., Brusilovsky, P., Milicevic, A. K., & Ivanovic, M. (2021, June). Explainable recommendations in a personalized programming practice system. In *International conference on artificial intelligence in education* (pp. 64-76). Cham: Springer International Publishing.

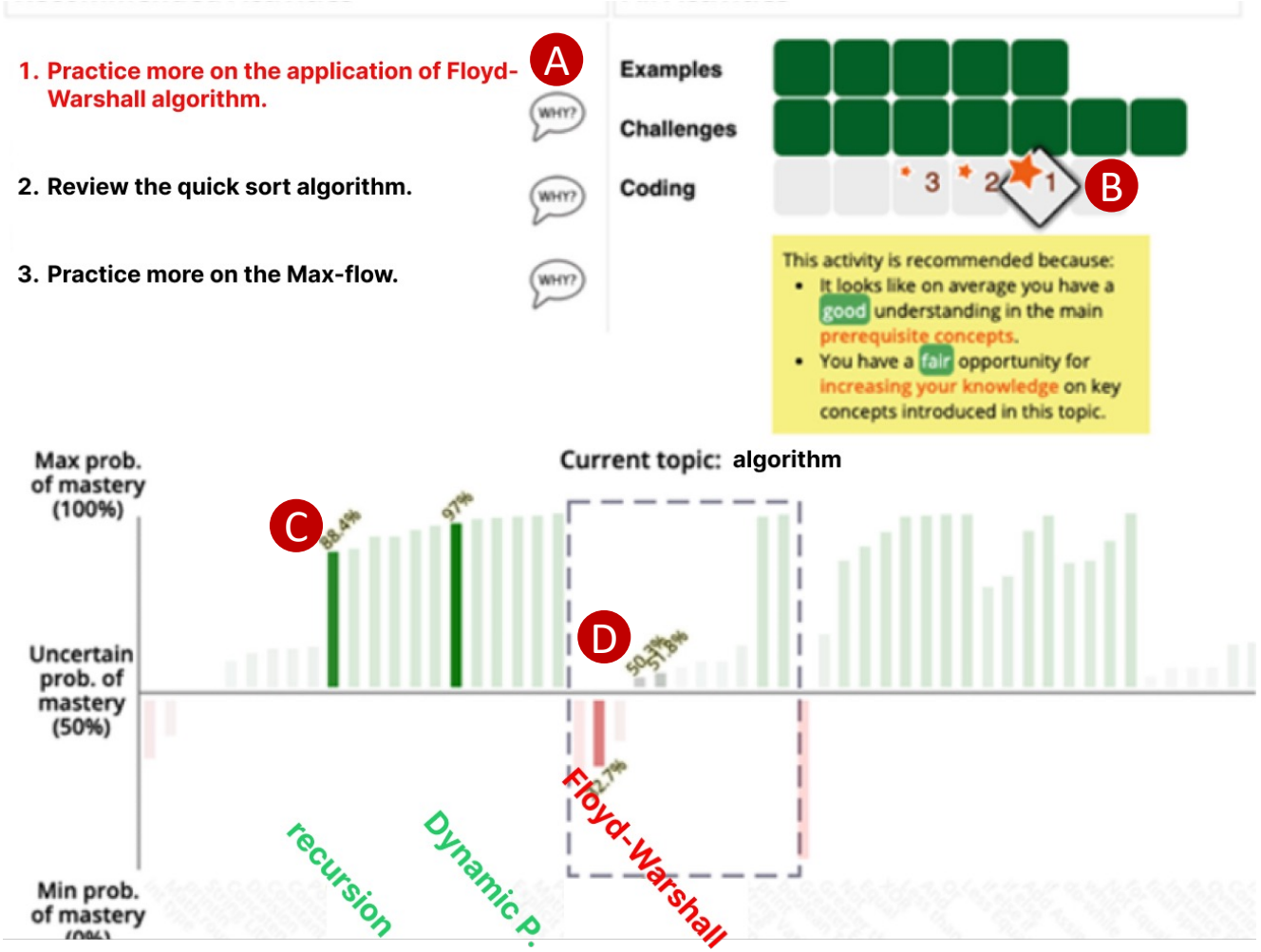
Pedagogical theory

Learner Models are model representations of a learner's knowledge [1].
Open Learner Models could serve promote adaptive educational systems [2].

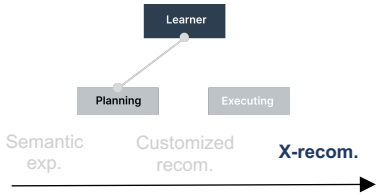
[1] Dillenbourg, P., & Self, J. (1992). A framework for learner modelling. *Interactive Learning Environments*, *2*(2), 111-137.

[2] Bull, S., Kay, J.: SMILI: a framework for interfaces to learning data in open learner models, learning analytics and related fields. Int. J. Artif. Intell. Educ. 26(1), 293331 (2016)

X-Recommendation



Barria-Pineda, J., Akhuseyinoglu, K., Želem-Ćelap, S., Brusilovsky, P., Milicevic, A. K., & Ivanovic, M. (2021, June). Explainable recommendations in a personalized programming practice system. In *International conference on artificial intelligence in education* (pp. 64-76). Cham: Springer International Publishing.



Data

Personal learning log (Structured)

Algorithm

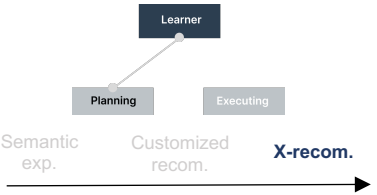
Bayesian Network

Encoding

Hover over for explanations(A)
Size: activity priority(B)
Color & height: concept-level mastery estimation(C)

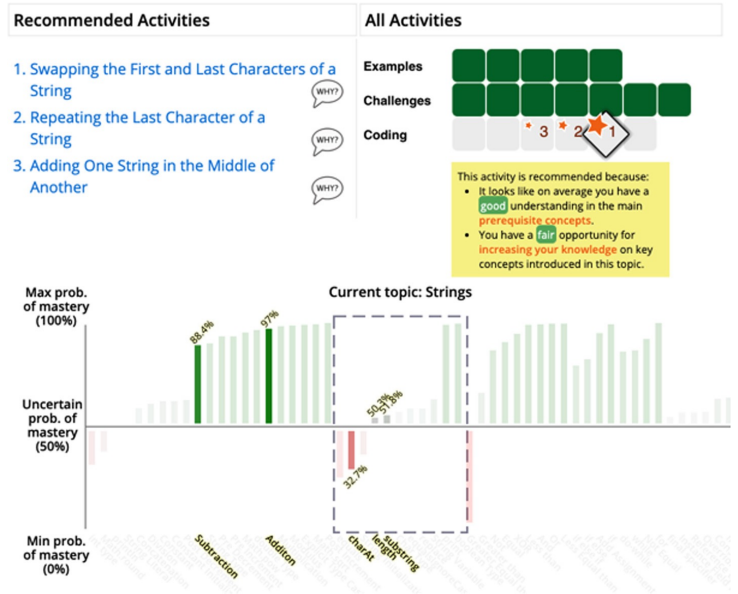
Bar's color opacity and dash region distinguish "prerequisite" and "target knowledge"(D)

X-Recommendation



Novelty

Operationalized OLM: explain the concept-level mastery estimation to learners as support for the recommended activities

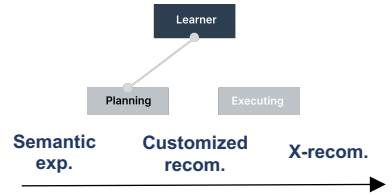


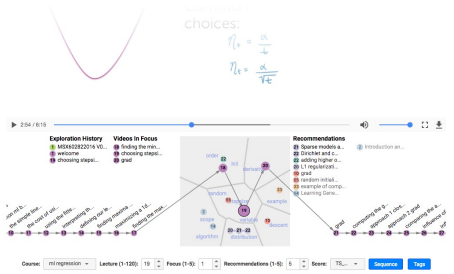
Limitation

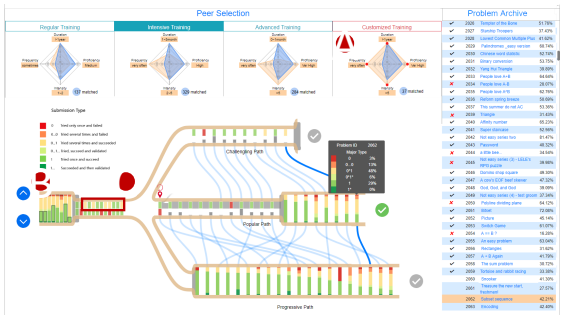
Model selection: more advanced model for learner modelling

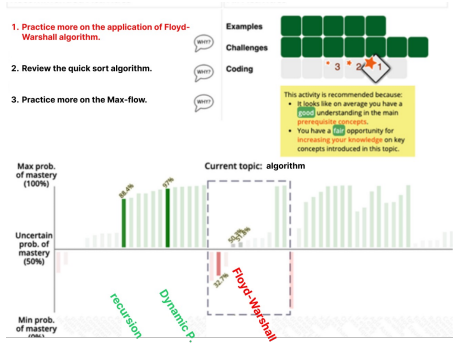
Barria-Pineda, J., Akhuseyinoglu, K., Želem-Ćelap, S., Brusilovsky, P., Milicevic, A. K., & Ivanovic, M. (2021, June). Explainable recommendations in a personalized programming practice system. In *International conference on artificial intelligence in education* (pp. 64-76). Cham: Springer International Publishing.

Planning: summary









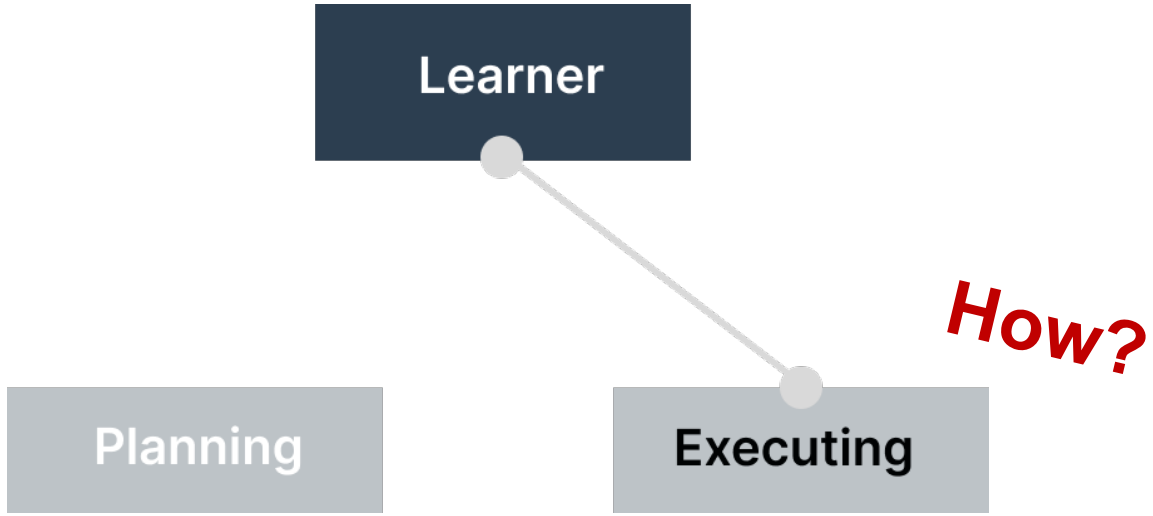
Learners use interactive VA to do planning by explore and explain learning content recommendations.

Trends: in-depth personal data analysis & pedagogical theory operationalization.

Executing

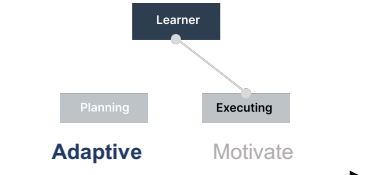
Definition: Carryout learning activities with **Intelligent Tutoring Systems**

Computer-based systems to provide personalized instruction or feedback



VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational psychologist*, *46*(4), 197-221.

Adaptive feedback



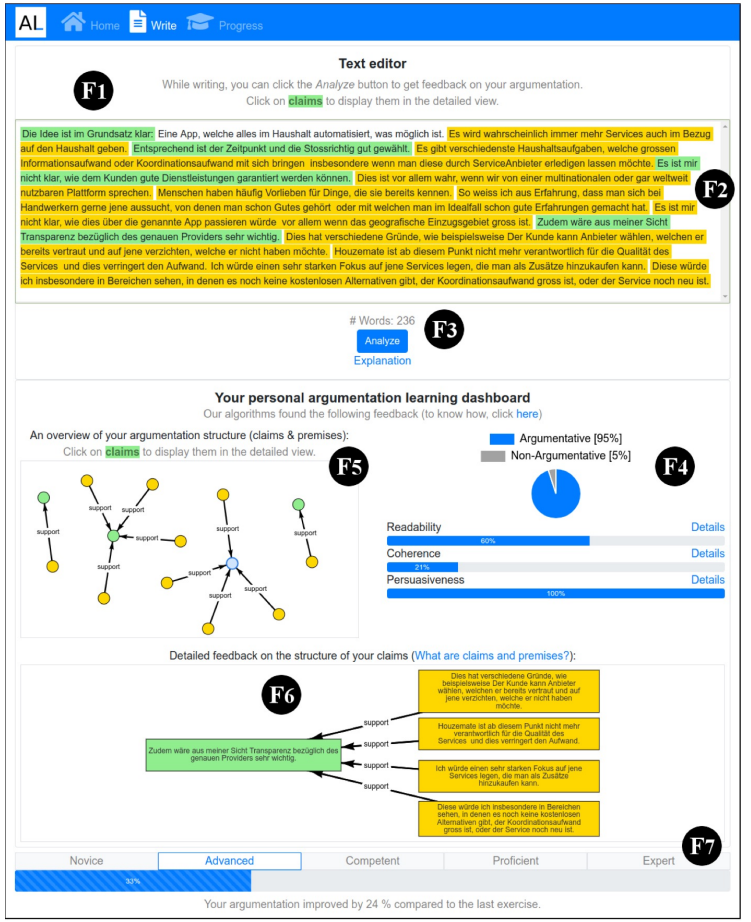
Research Question

How to improve argumentation (higher order thinking skill)?

Pedagogical theory

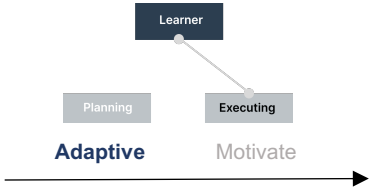
It is of great importance for the individual student to receive continuous feedback throughout their learning journey to learn high order thinking skills [1].

[1] Paul Black and Dylan Wiliam. 2009. Developing the theory of formative assessment. Educational Assessment, Evaluation and Accountability 21, 1 (2009), 5–31.



Wambsganss, T., Niklaus, C., Cetto, M., Söllner, M., Handschuh, S., & Leimeister, J. M. (2020, April). AL: An adaptive learning support system for argumentation skills. In *Proceedings of the 2020 CHI conference on human factors in computing systems* (pp. 1-14).

Adaptive feedback



Methods

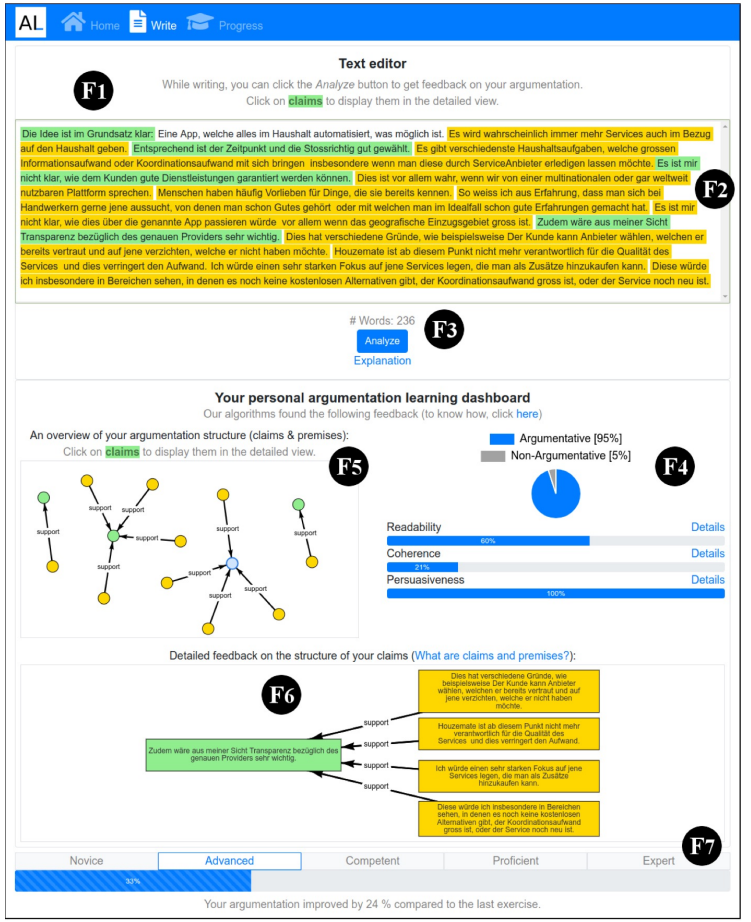
Provide **continuous feedback** to individual learners by argument mining algorithms and visualizing the **argumentation structure** of a text & indicate missing.

Novelty

First intelligent feedback learning tool for high order skills.

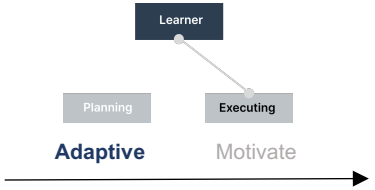
Limitation

Sentence structure decomposition as the only source of feedback, which can be more informative.



Wambsganss, T., Niklaus, C., Cetto, M., Söllner, M., Handschuh, S., & Leimeister, J. M. (2020, April). AL: An adaptive learning support system for argumentation skills. In *Proceedings of the 2020 CHI conference on human factors in computing systems* (pp. 1-14).

Adaptive feedback



Research Question

How to help learner master different voice modulation skills in public speaking (pitch, pause, volume, speed)?

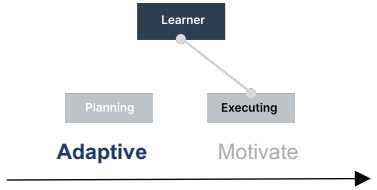
Pedagogical theory

Voice modulation skills play key role in the domain of public speaking [1].

[1] Eva Strangert. 2005. Prosody in public speech: analyses of a news announcement and a political interview. In Proceedings of the European Conference on Speech Communication and Technology. 3401–3404.

Wang, X., Zeng, H., Wang, Y., Wu, A., Sun, Z., Ma, X., & Qu, H. (2020, April). Voicecoach: Interactive evidence-based training for voice modulation skills in public speaking. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1-12).

Adaptive feedback



Methods

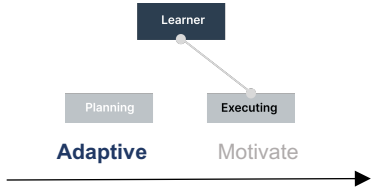
Example-based recommendation with adaptive & quantitative visual feedbacks as training materials.

Limitation

Examples base training without considering context and topic info.

Wang, X., Zeng, H., Wang, Y., Wu, A., Sun, Z., Ma, X., & Qu, H. (2020, April). Voicecoach: Interactive evidence-based training for voice modulation skills in public speaking. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1-12).

Adaptive feedback

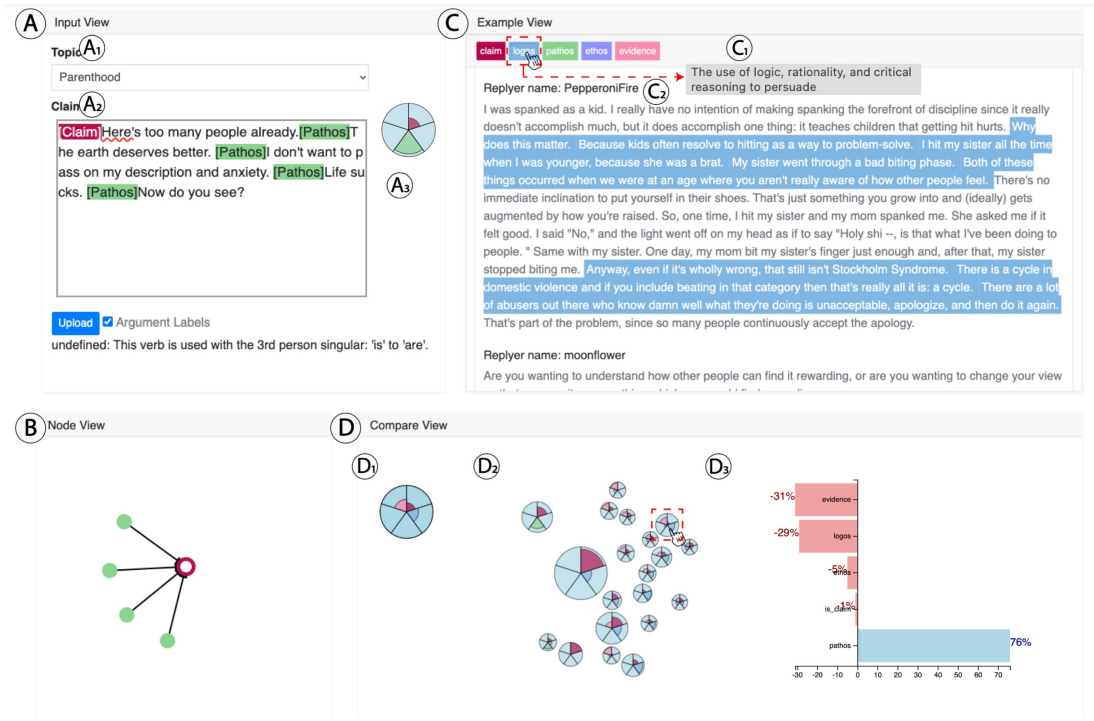


Research Question

How to practice persuasive arguments in online discussion via writing ?

Pedagogical theory

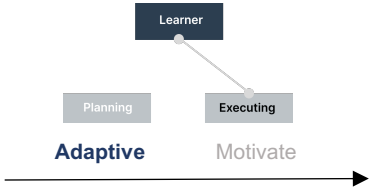
Constructing arguments in adherence to persuasive strategies can enhance the effectiveness of these arguments [1].



[1] Orji, R., Vassileva, J., & Mandryk, R. L. (2014). Modeling the efficacy of persuasive strategies for different gamer types in serious games for health. *User Modeling and User-Adapted Interaction*, *24*, 453-498.

Xia, M., Zhu, Q., Wang, X., Nie, F., Qu, H., & Ma, X. (2022). Persua: A visual interactive system to enhance the persuasiveness of arguments in online discussion. *Proceedings of the ACM on Human-Computer Interaction*, *6*(CSCW2), 1-30.

Adaptive feedback



Methods

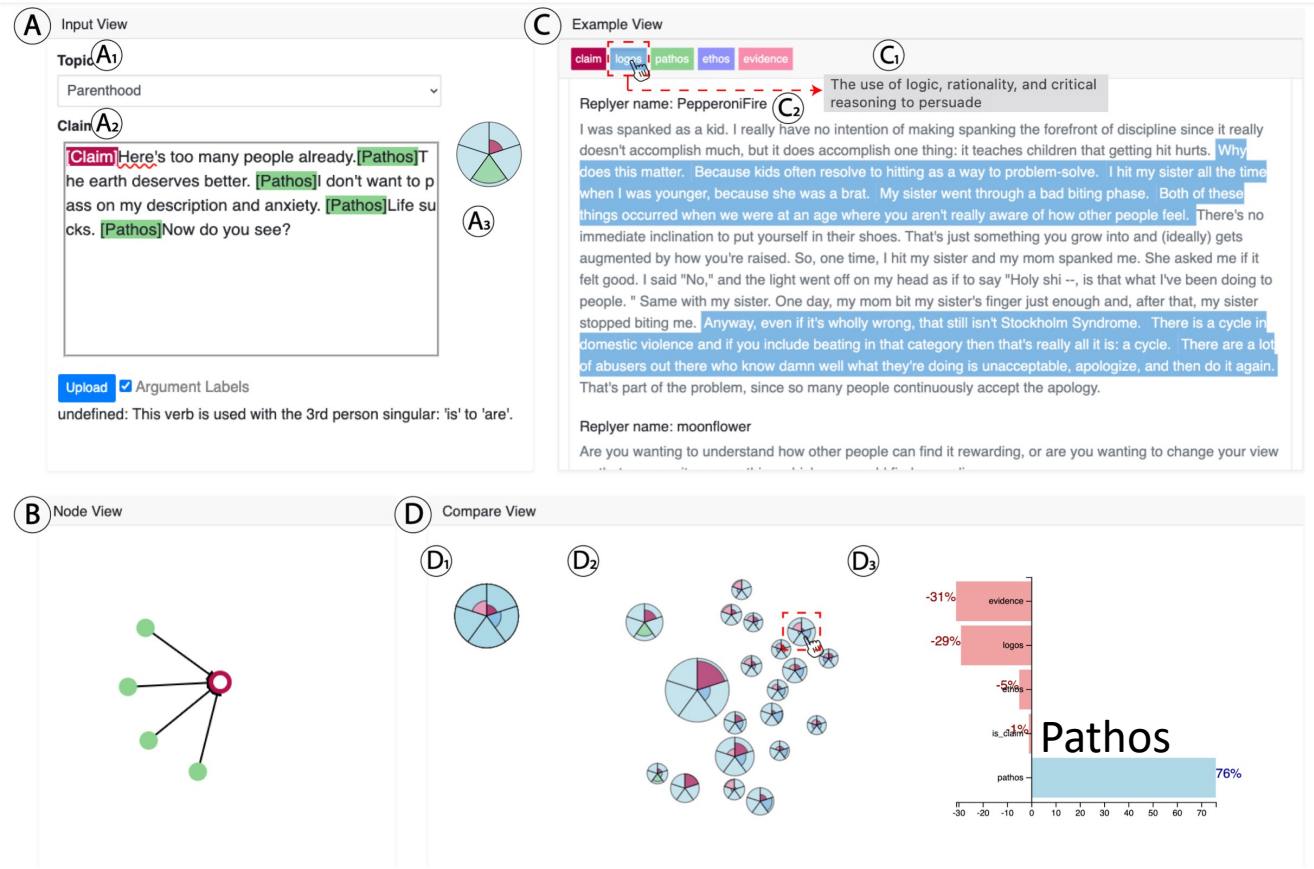
Summarize fine-grained **persuasive strategies**.
Strategies mining and example-based feedback.

Novelty

Taxonomy of argument components. Embed persuasive strategies into feedback design.

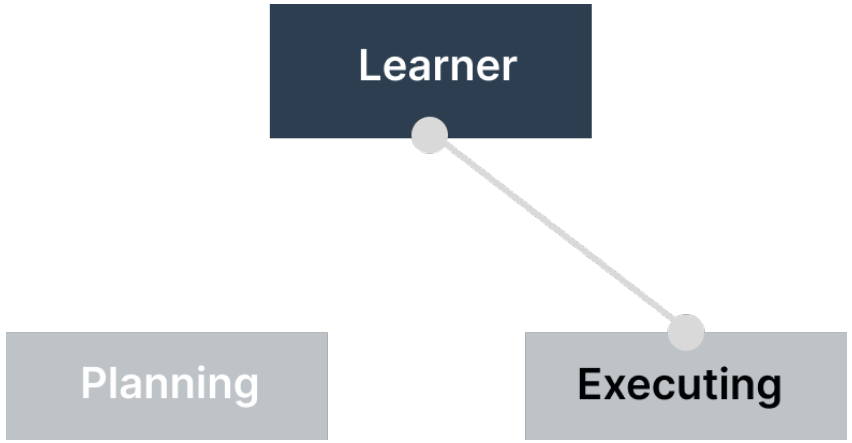
Limitation

Personality & demographic analysis still lack.



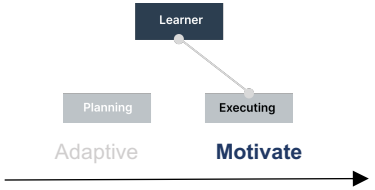
Xia, M., Zhu, Q., Wang, X., Nie, F., Qu, H., & Ma, X. (2022). Persua: A visual interactive system to enhance the persuasiveness of arguments in online discussion. *Proceedings of the ACM on Human-Computer Interaction*, *6*(CSCW2), 1-30.

Executing: What's more

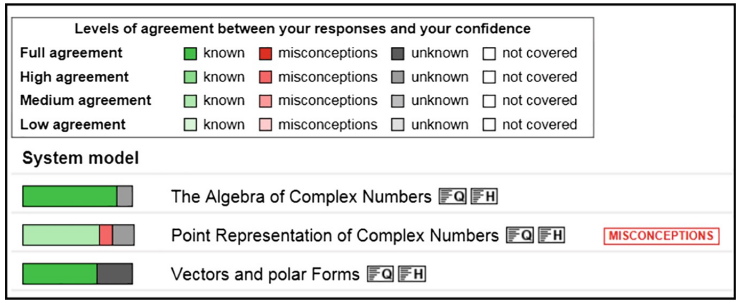


Beyond providing **increasingly theory-based**, **informative adaptive feedback**, what additional capabilities does interactive visual analytics offer to learners during the execution of personalized learning?

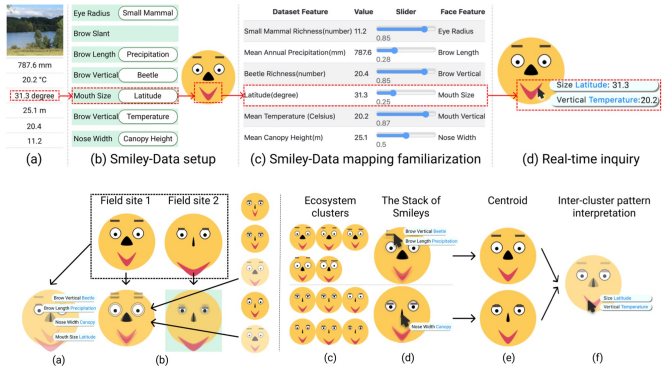
Motivate learning



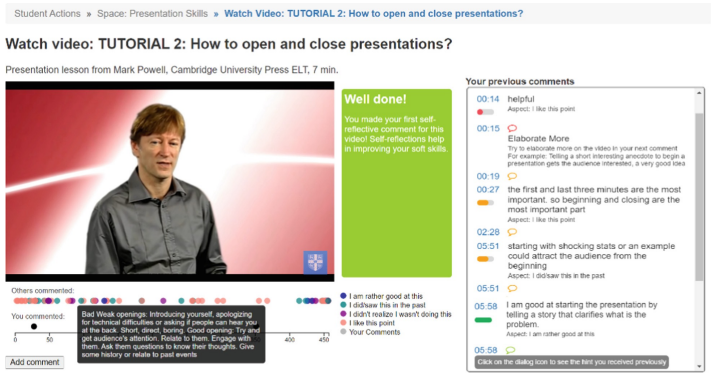
Use interactive visualization to motivate multiple types of self learning!



(Al-Shanfari et al., AIED 17)



(Zhou et al., AIED 21)



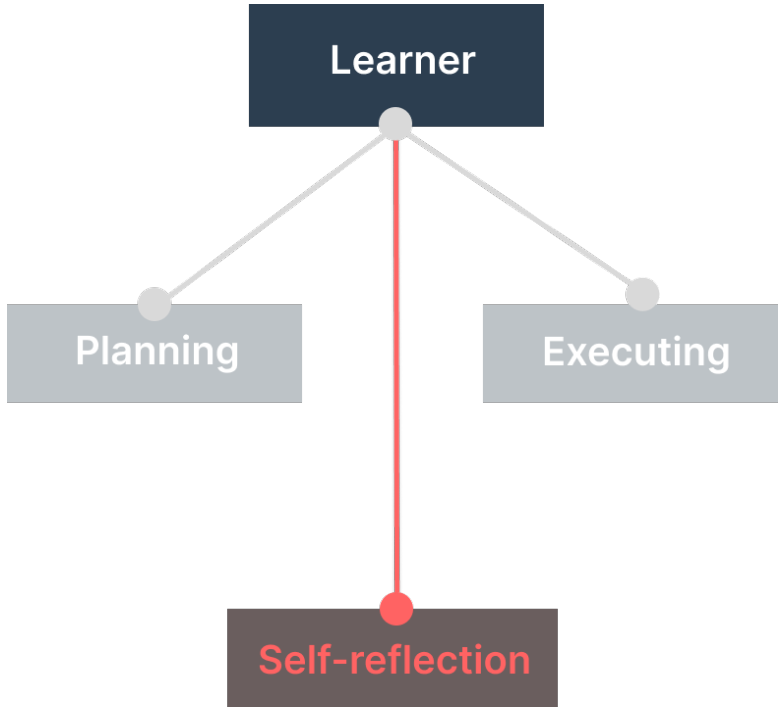
(Mohammadhassan et al., AIED 22)

Motivate students to address their personal weaknesses by **visualizing the disparity** between their assessed knowledge level and their self-confidence.

Motivate K-12 students to **investigate** their personal **scientific hypotheses** through interactive visualization.

Motivate students to **comment** on each-others' learning reviews and receive feedbacks via interactive visualization.

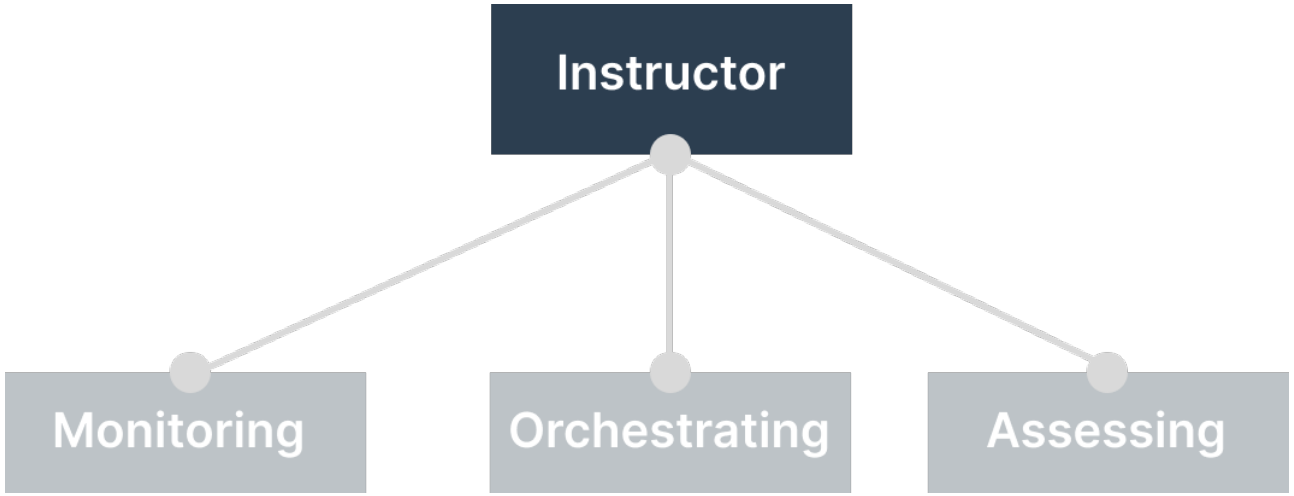
Summary for Learner



- To enhance personalized learning, learner mainly use interactive VA systems to plan learning path and receive adaptive feedback during learning activities execution.
- The trend is moving towards more in-depth personal data analysis and informative feedbacks with the basis of more advanced pedagogical theories.
- Still limited work focus on learner's self-reflection. It can be perfectly linked to some mature pedagogical theories.

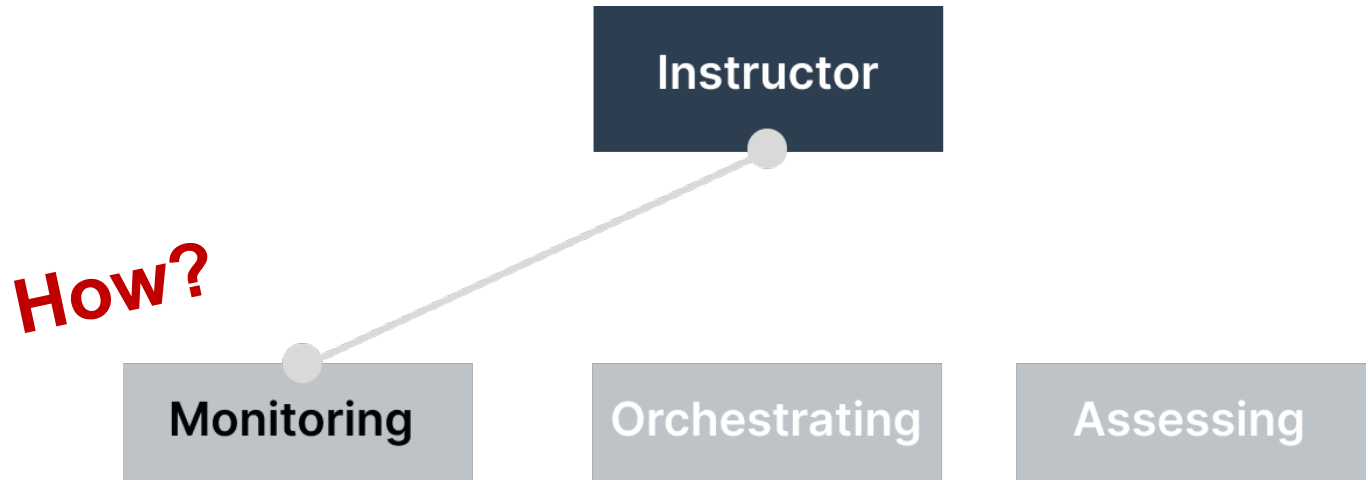
Instructor

Why do instructors use the VA systems to support personalized learning?



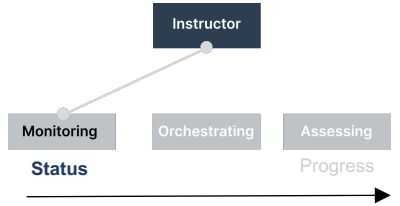
Monitoring

Definition: Instructors monitor learner data, deriving insights from their progress or status to prepare for necessary real-time interventions.

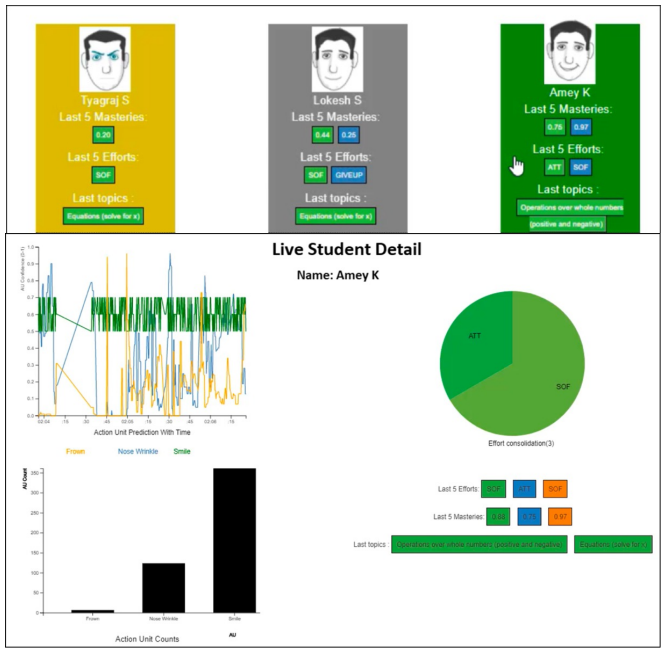


Srinivasa, K. G., Kurni, M., & Saritha, K. (2022). Harnessing the Power of AI to Education. In *Learning, Teaching, and Assessment Methods for Contemporary Learners: Pedagogy for the Digital Generation* (pp. 311-342). Singapore: Springer Nature Singapore.

Monitor learner status

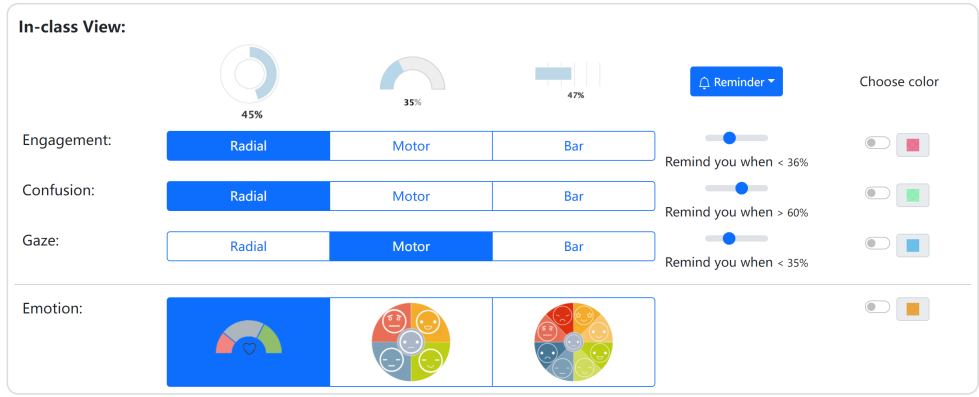


Monitor engagement level or emotional status as reference for instructor intervention or class pace adjustments.



(Gupta et al., AIED 21)

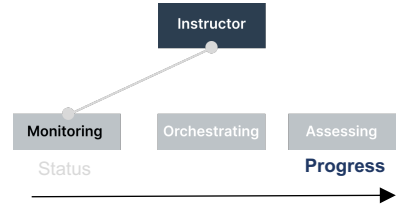
Engagement and affective states analysis from facial expressions, personalized but no intervention



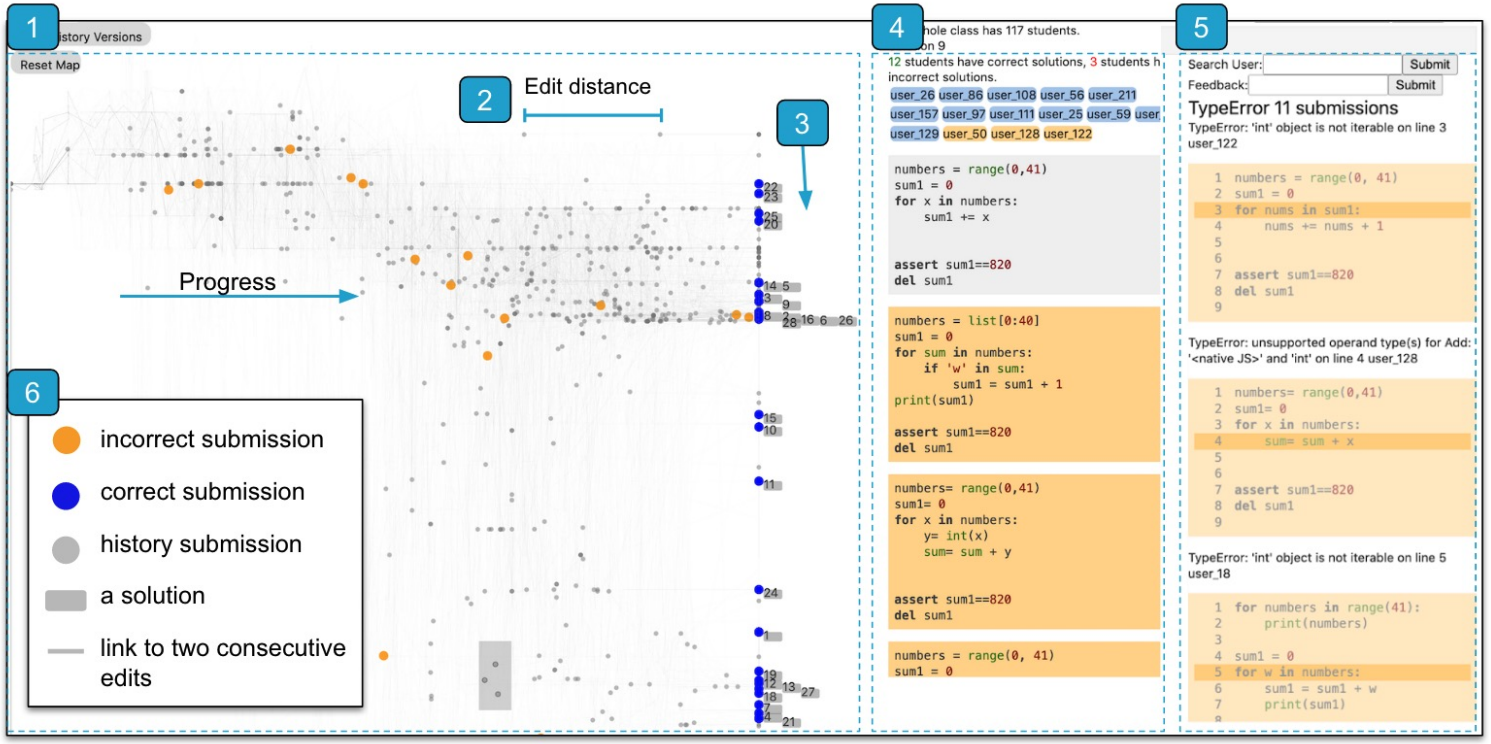
(Ma et al., CHI 22)

Engagement, confusion, Gaze and emotion analysis from facial expression, sacrifice personalization due to data privacy protection.

Monitor learning progress



Monitor real-time problem-solving progress as reference for intervention.

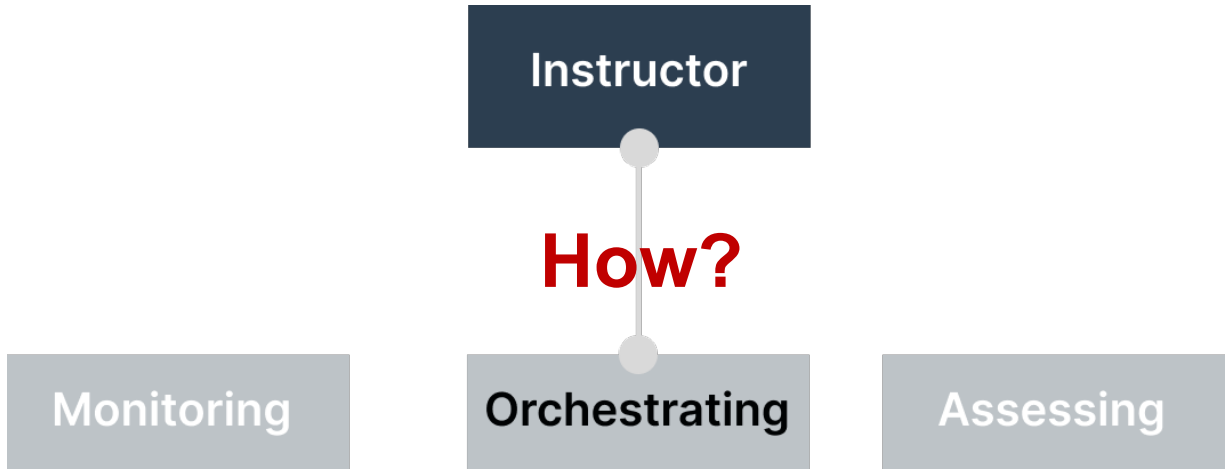


(Zhang et al., CHI 23)

Monitor each learners' real-time code progress and edit distance towards potential solutions.

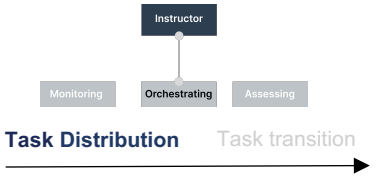
Orchestrating

Definition: Instructors conduct real-time learning activities management of multiple social planes (e.g., individuals, groups, and classes)



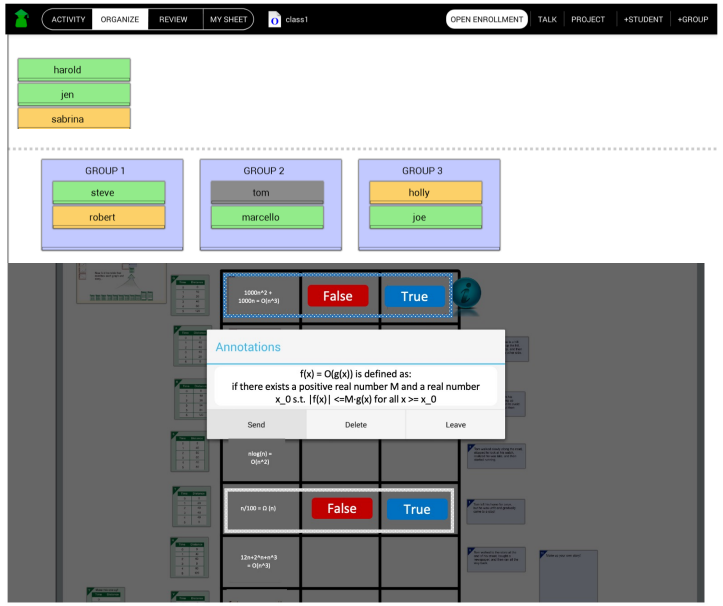
Dillenbourg, P., Prieto, L. P., & Olsen, J. K. (2018). Classroom orchestration. *International handbook of the learning sciences*, 180-190.

Learning Task Distribution



Domain Problem

Instructors **distribute** students into collaborative learning groups to discuss and solve problems.



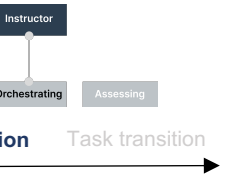
Cheema, S., et al.: Electronic posters to support formative assessment. In: CHI EA Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, pp. 1159–1164. ACM (2016)

Pedagogical theory

Promoting collaborative learning between learners is demonstrated to be effective on promoting personalized learning skills [1].

[1]Abdelaziz, H. A., & Al-Ali, A. (2020). Promoting personalized learning skills: The impact of collaborative learning (a case study on the general Directorate of residency and foreigners affairs in Dubai). *International Journal of Learning, Teaching and Educational Research*, *19*(2), 163-187.

Learning Task Distribution



Data

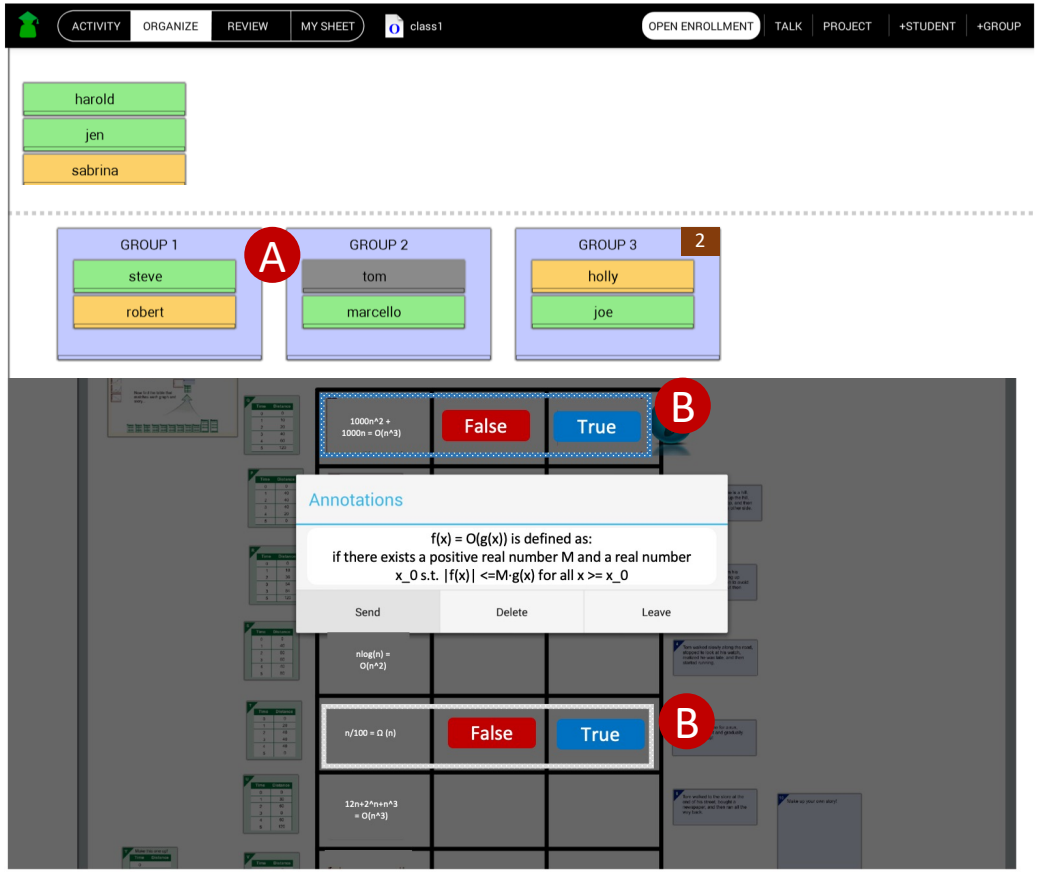
Students' online status &
Students' learning stage (Real-time tabular)

Encoding

Color scheme to encode:

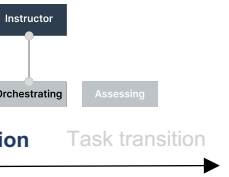
learner's online status (A: synced/non-synced/absent)
learning stage (B: working on/passed the question)

Algorithm: None



Cheema, S., et al.: Electronic posters to support formative assessment. In: CHI EA Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, pp. 1159–1164. ACM (2016)

Learning Task Distribution

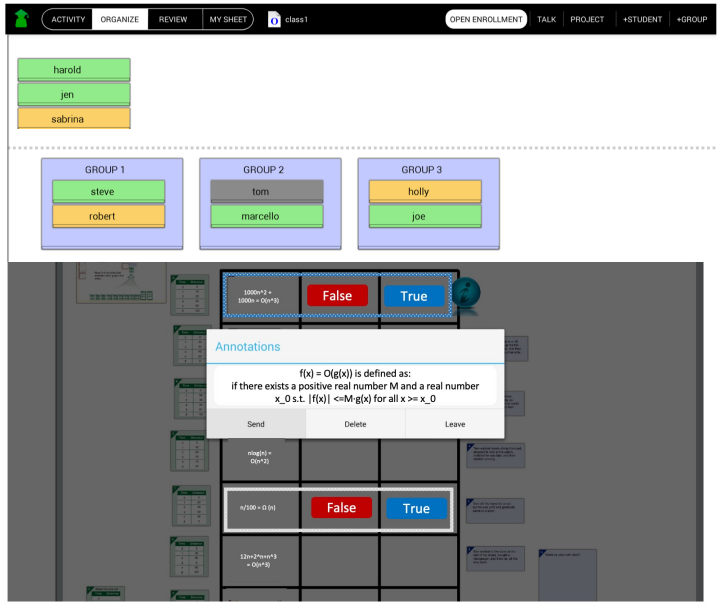


Novelty

First system to help instructor conduct collaborative learning and crafting learning experience.

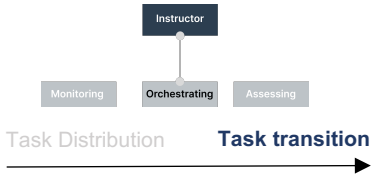
Limitation

Limited analysis on students' status and progress.



Cheema, S., et al.: Electronic posters to support formative assessment. In: CHI EA Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, pp. 1159–1164. ACM (2016)

Learning Task Transition



Domain Problem

Instructors orchestrate the dynamic transitions of students' individual and collaborative learning.

When to choose whom to pair up, role of each, and what collaborative assignment they should work on.

Pedagogical theory

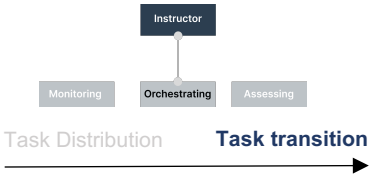
Switching learners to learning activities most suitable for them yield better learning [1].
Transitions between individual/collaborative learning can leverage the complementary benefits of both [2].

Yang, K. B., Echeverria, V., Lu, Z., Mao, H., Holstein, K., Rummel, N., & Aleven, V. (2023, April). Pair-Up: Prototyping Human-AI Co-orchestration of Dynamic Transitions between Individual and Collaborative Learning in the Classroom. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-17).

[1] Haoran Xie, Hui-Chun Chu, Gwo-Jen Hwang, and Chun-Chieh Wang. 2019. Trends and development in technology-enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2017. Computers & Education 140 (06 2019), 1–16. https://doi.org/10.1016/j.compedu.2019.103599

[2] Pierre Dillenbourg and Patrick Jermann. 2010. Technology for Classroom Orchestration. Springer New York, New York, NY, 525–552. https://doi.org/10.1007/9781-4419-5716-0_26

Learning Task Transition



Data

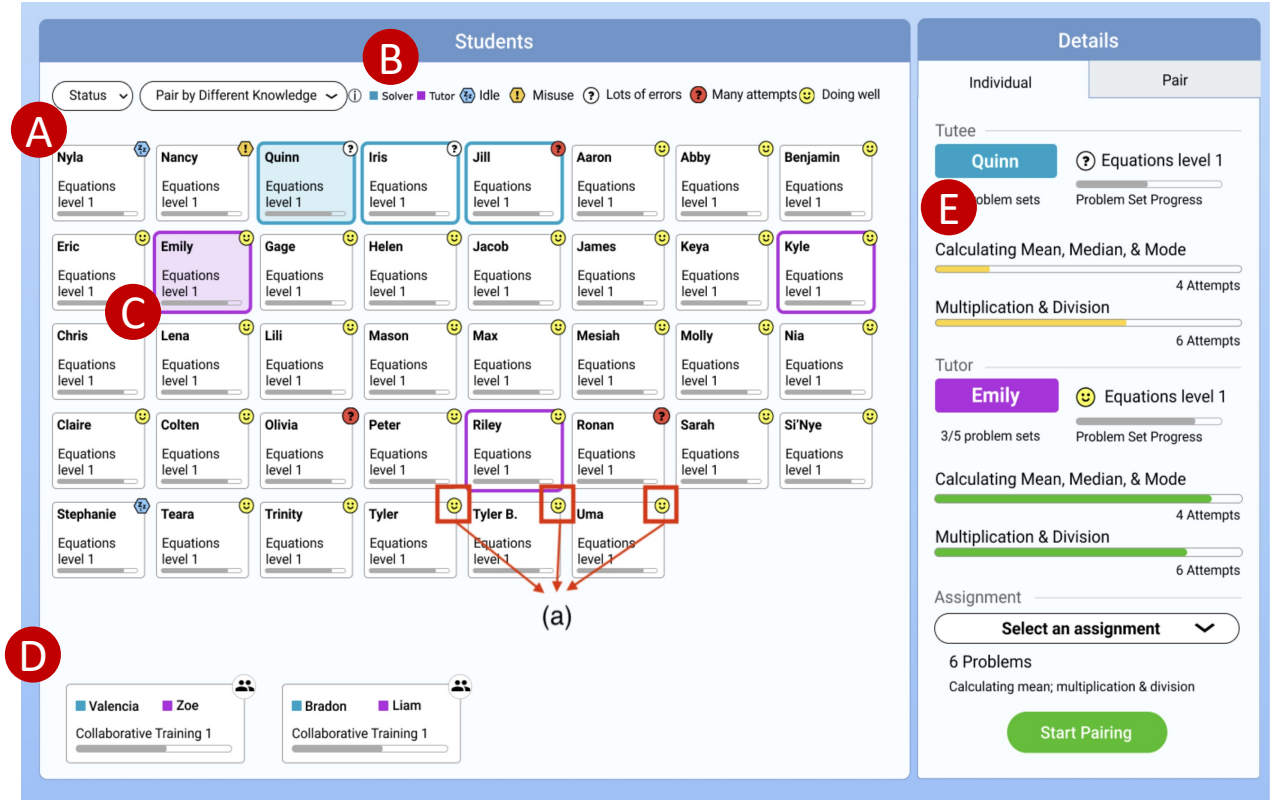
Students' learning log data
Students' learning state data (Real-time tabular)

Encoding

Displays students in card format (A)
Icon encode learner status (B)
Color encode learner role (C: **solver/tutor**)
Bar (D) encode collaboration progress
Bar (E) encode knowledge mastery level

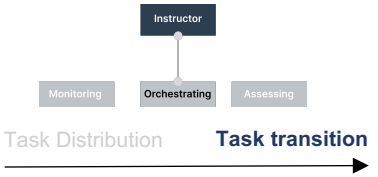
Algorithm

Bayesian Knowledge Tracing to model mastery of the knowledge.



Yang, K. B., Echeverria, V., Lu, Z., Mao, H., Holstein, K., Rummel, N., & Aleven, V. (2023, April). Pair-Up: Prototyping Human-AI Co-orchestration of Dynamic Transitions between Individual and Collaborative Learning in the Classroom. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-17).

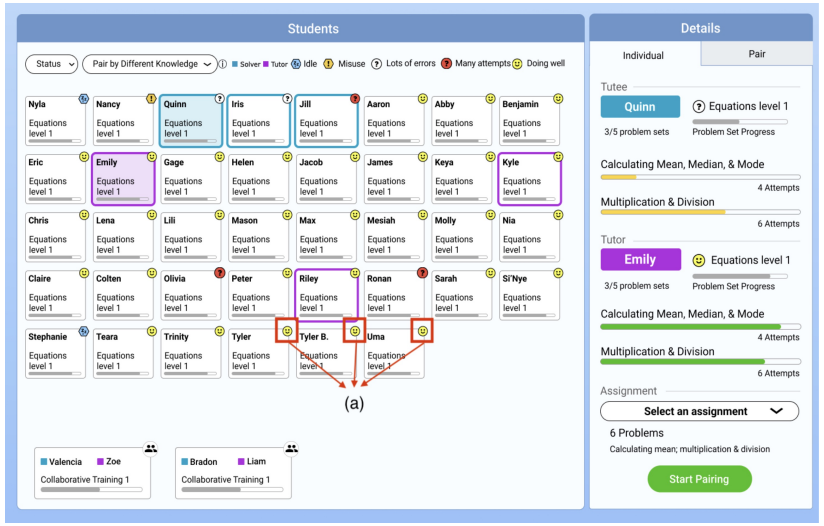
Learning Task Transition



Novelty

Progressively implementation of advanced pedagogical theories.

Human-AI Collaborative Approach for students pair up.



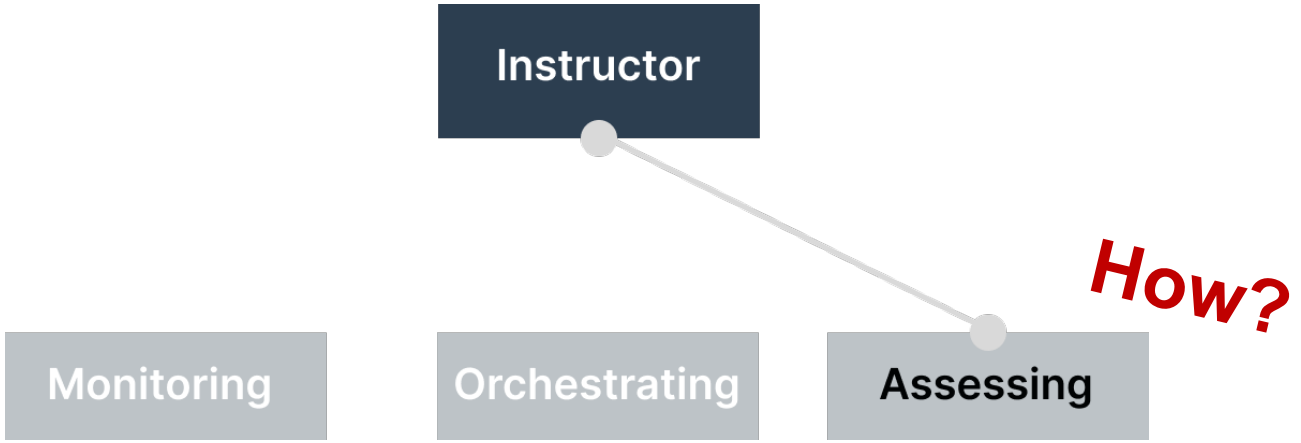
Yang, K. B., Echeverria, V., Lu, Z., Mao, H., Holstein, K., Rummel, N., & Aleven, V. (2023, April). Pair-Up: Prototyping Human-AI Co-orchestration of Dynamic Transitions between Individual and Collaborative Learning in the Classroom. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-17).

Limitation

No students' control on learning activities (to be learner-centered).

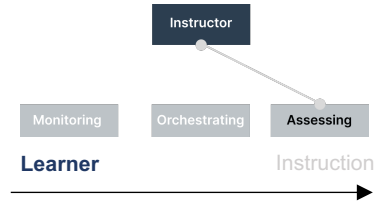
Assessing

Focus: Assessment on learner and assessment on instructor for reflection and individualized feedback.



Beghetto, R. A. (2019). Large-scale assessments, personalized learning, and creativity: Paradoxes and possibilities. *ECNU Review of Education*, *2*(3), 311-327.

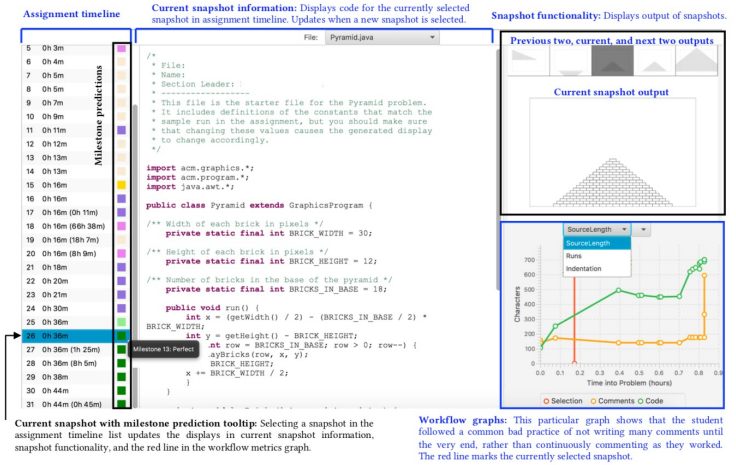
Learner Assessment



Conduct comprehensive learner assessment (knowledge-level, cognitive level, meta-cognitive level,…)

(Zhang et al., HCII 23)

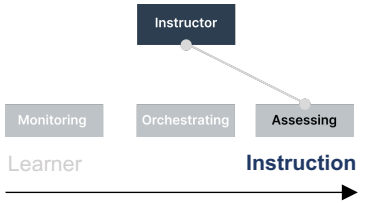
Assess students' learning behavior and reasoning into their learning outcome.



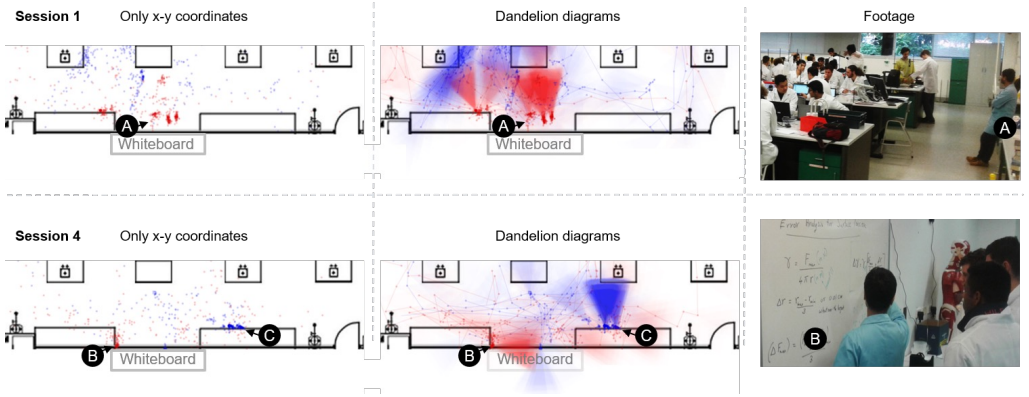
(Yan et al., SIGCSE 19)

Assess students' problem-solving strategy by review their problem-solving historical log data

Instructor Assessment

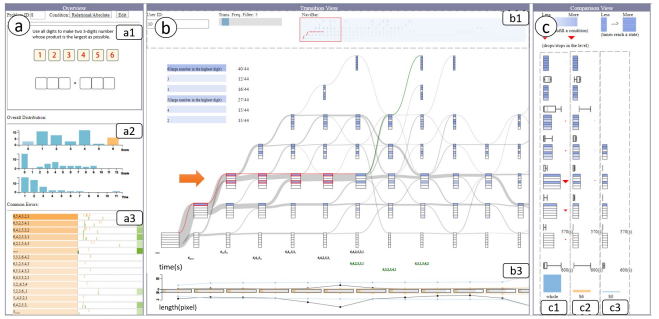


Assess the question design and their in-class instruction strategy.



(Fernandez-Nieto et al., CHI 22)

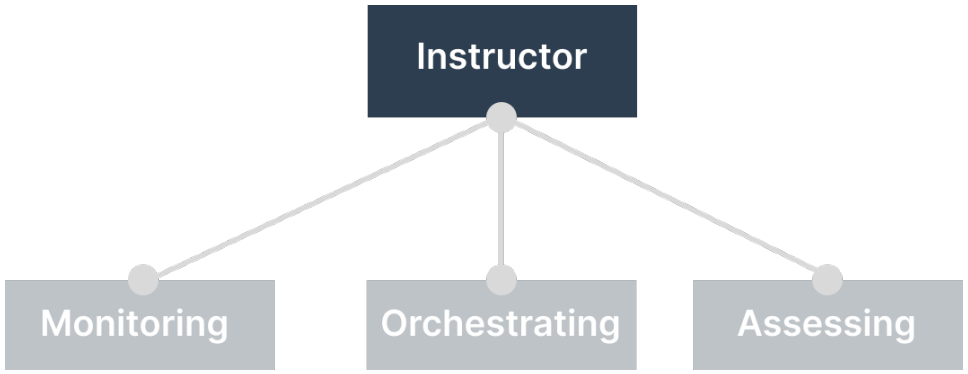
Visualize instructor' classroom trajectory to reflect on instruction strategy.



(Xia et al., TVCG 21)

Assess the matching between students' problem-solving logic with questions' design to refine the question design for specific learners' needs.

Instructor: summary



- To enhance personalized learning, instructors mainly use interactive VA systems to monitor their students, orchestrate learning activities and assess both students and themselves.
- The growing tendency is similar to the ones for learner side: pedagogical theorys, learner data analysis and student-centered design.

Outline

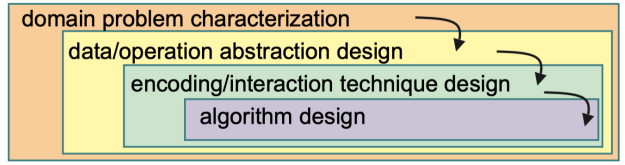
- Introduction
- Taxonomy
- **Future Work**
  - Four dimensions
- Take-home Message

Future Work

How can we **improve** the design of interactive visual analytics system to further promote more learner-centered personalized learning environment?

Borrow from the idea of the nested model for visualization design, we can think from the following perspectives:

- domain task to address
- data to use
- visualization representation and interaction
- algorithm to use



Munzner, T. (2009). A nested model for visualization design and validation. *IEEE transactions on visualization and computer graphics*, *15*(6), 921-928.

Future Work

Data to Use

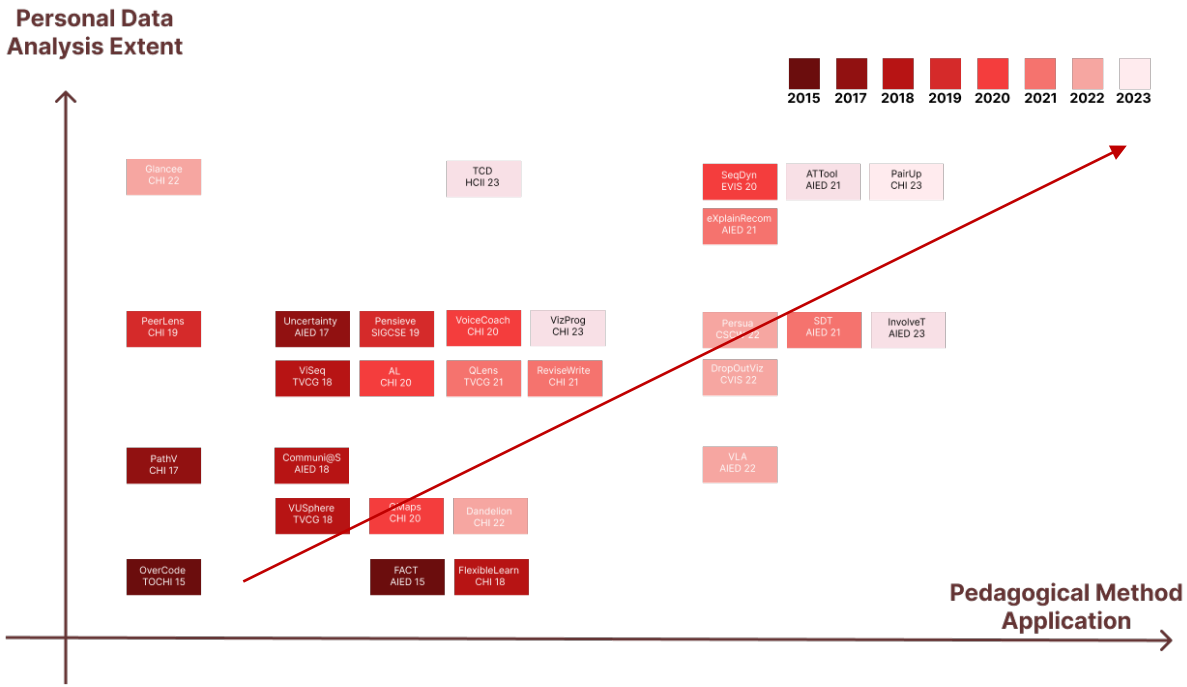
Go in-depth into personal data utilization

e.g., personality, demographic, multi-modality analysis

Vis Representation

More learner-centered design

e.g., Balance the informativeness, Adaptiveness as well as user's cognitive load



Algorithm

Advanced Learner Model. ChatGPT serve as AI TA to operationalize pedagogical methods:

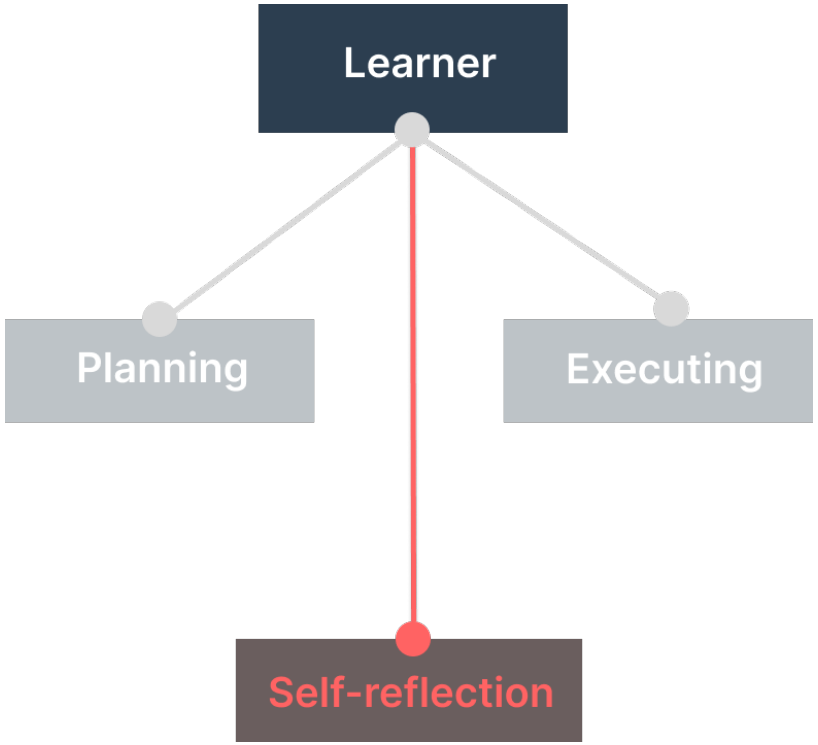
e.g., scaffolding for complex concept learning

Domain Task

VA as **medium** to operationalize personalized learning theories

e.g., specific training on personalized meta-cognitive abilities

Future Work



Short-term gap identified from taxonomy!

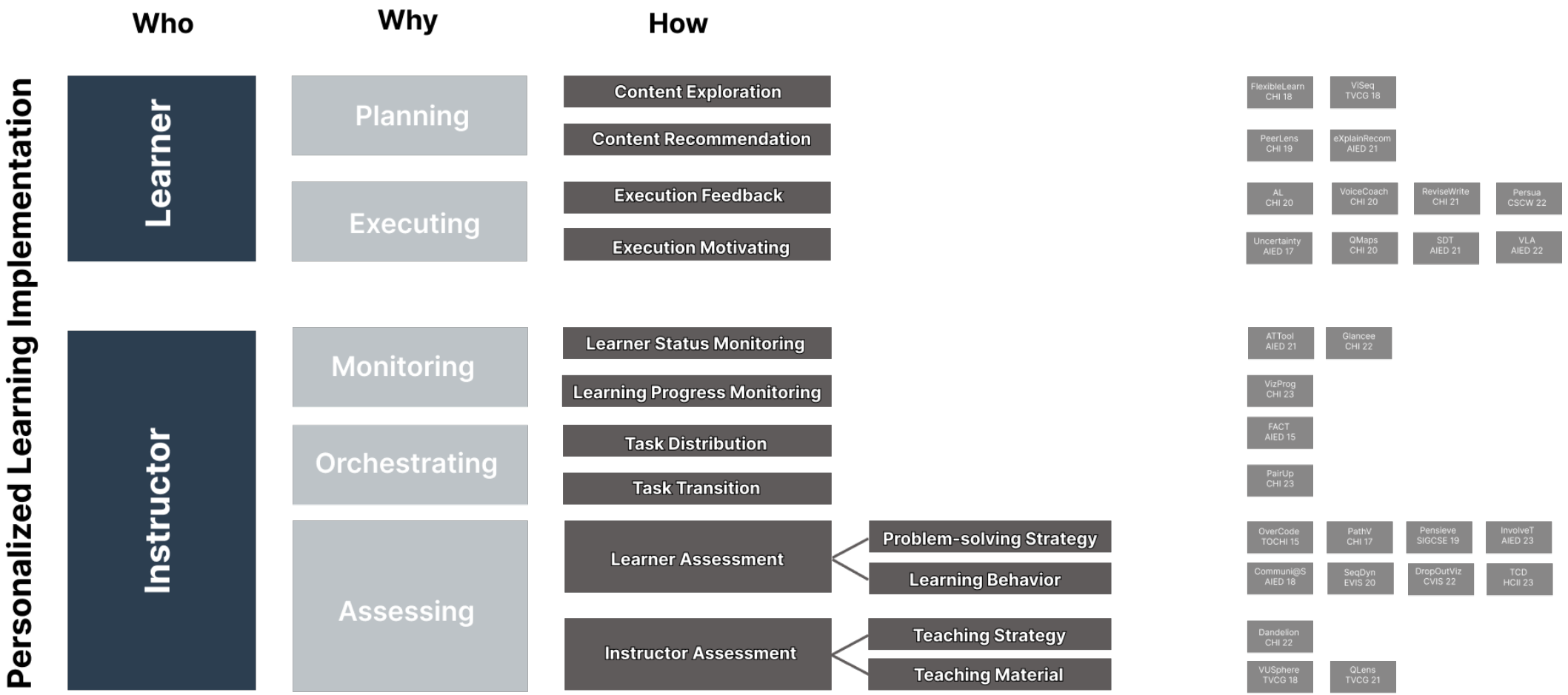
Outline

- Introduction
- Taxonomy
- Future Work
- **Take-home Messages**

Take-home Messages

- The needs for personalized learning in modern education
- Taxonomy: VA for personalized learning execution
  - Who, why, and how we use VA.
- Future Directions
  - Short-term
    - VA for learner's self reflection
  - Long-term directions
    - Operationalize personalized learning theories
    - In depth personal data analytics
    - Learner-centered design principles
    - Advance AI models

Thanks!


Who
Why
How
Personalized Learning Implementation
Learner
Instructor
Planning
Executing
Monitoring
Orchestrating
Assessing
Content Exploration
Content Recommendation
Execution Feedback
Execution Motivating
Learner Status Monitoring
Learning Progress Monitoring
Task Distribution
Task Transition
Learner Assessment
Problem-solving Strategy
Learning Behavior
Instructor Assessment
Teaching Strategy
Teaching Material
FlexibleLearn CHI 18
ViSeq TVCG 18
PeerLens CHI 19
eXplainRecom AIED 21
AL CHI 20
VoiceCoach CHI 20
ReviseWrite CHI 21
Persua CSCW 22
Uncertainty AIED 17
QMaps CHI 20
SDT AIED 21
VLA AIED 22
ATTool AIED 21
Giancee CHI 22
VizProg CHI 23
FACT AIED 15
PairUp CHI 23
OverCode TOCHI 15
PathV CHI 17
Pensieve SIGCSE 19
InvolveT AIED 23
Communi@S AIED 18
SeqDyn EVIS 20
DropOutViz CVIS 22
TCD HCII 23
Dandelion CHI 22
VUSphere TVCG 18
QLens TVCG 21