Visual Analytics of Student Learning Behavior on K-12 Mathematics E-learning Platforms

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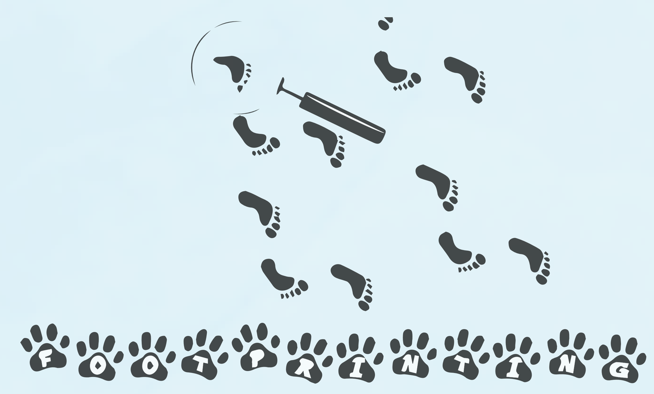
Introduction

Motivations:

- Educational institutions need deep analysis on fine-grained interaction data to understand students' detailed problem-solving patterns and design more reasonable assignments.
- The current data analysis techniques of E-learning platforms are ad-hoc to specific questions or platforms and often not generalizable.



Goals:

- Design visual analytics to support a quick overview of student performance and learning behaviors on E-learning platforms.
- Enable detailed exploration of problem-solving patterns on each question and provide guidance to help educators design assignments and optimize teaching methods.

Overall Performance Analytics

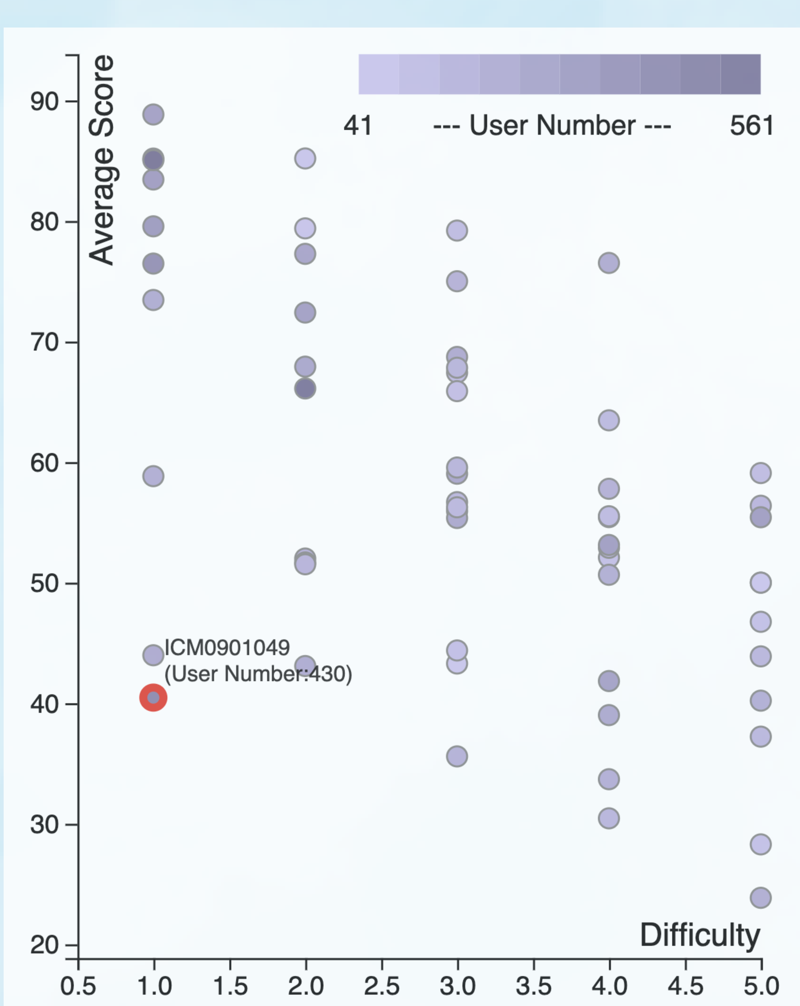


Figure 1 Overview of student performances on questions of different difficulty levels.

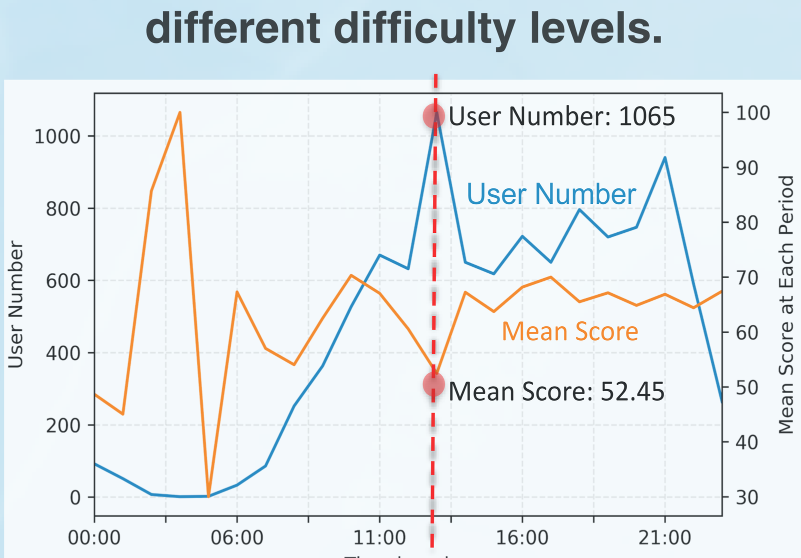


Figure 2 Overall mean scores at different login times during a day.

- The overall status, such as the mean scores, problem difficulty, and user numbers of each question are visualized for analysis.
- Interactions are enabled to help instructors conveniently check the details such as the question ID and the number of students who tried this question.
- Figure 1 shows the correlation between the pre-defined difficulty level and the mean score of each question. It is interesting to find that some questions labeled as "easy" by instructors actually have lower mean scores (highlighted in the dashed rectangle), indicating that their difficulty levels probably need to be re-evaluated.
- Figure 2 reveals the potential effect of the study time on students' performance. It can be seen that a bursting number of students study on the E-learning platform at around lunchtime, but their performance drops there.

Detailed Visual Analytics

Identify thinking patterns – Heat Map

Here is a square on a grid, its area is 4 grid squares.
Move the top right corner to make a new shape which has an area of 6 grid squares.

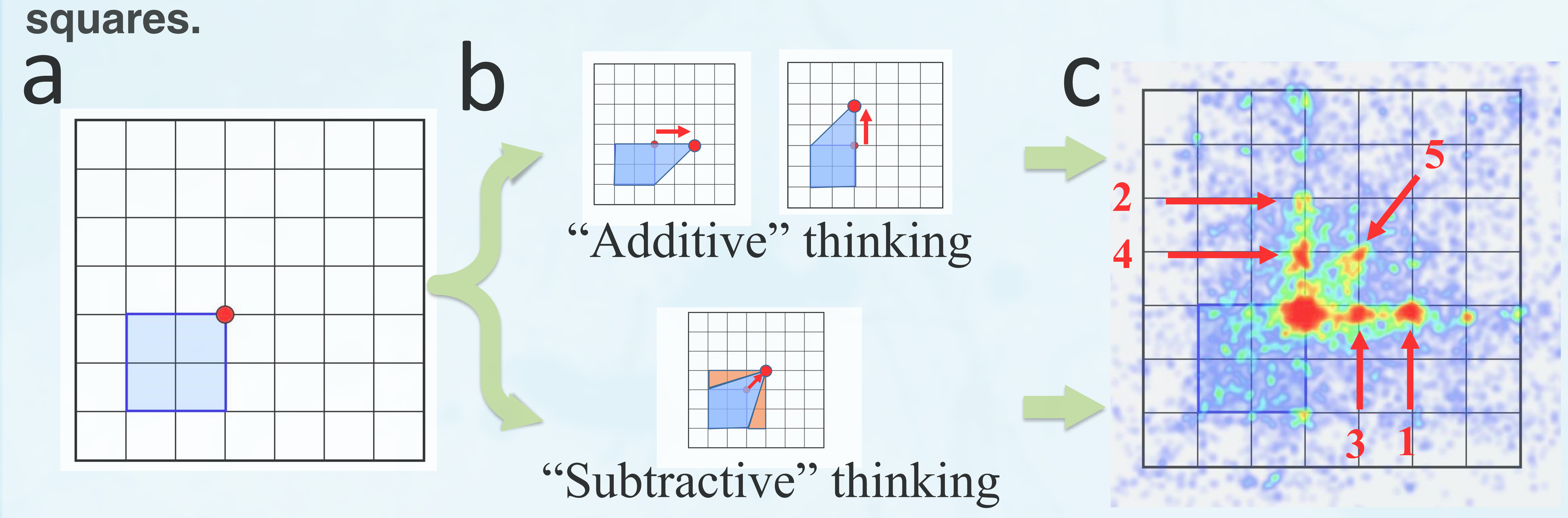


Figure 3 (a) shows an example question. (b) displays two different ways to solve the question. (c) is a heatmap to show the students' mouse movements when solving the problem. From (c), we can see many students solved the question by "additive" thinking and preferred to move the point horizontally (passing Point 3 to Point 1) than vertically (passing Point 4 to Point 2). A considerable portion of students used a "subtractive" way and went for Point 5.

Reveal problem-solving steps – Transition Map

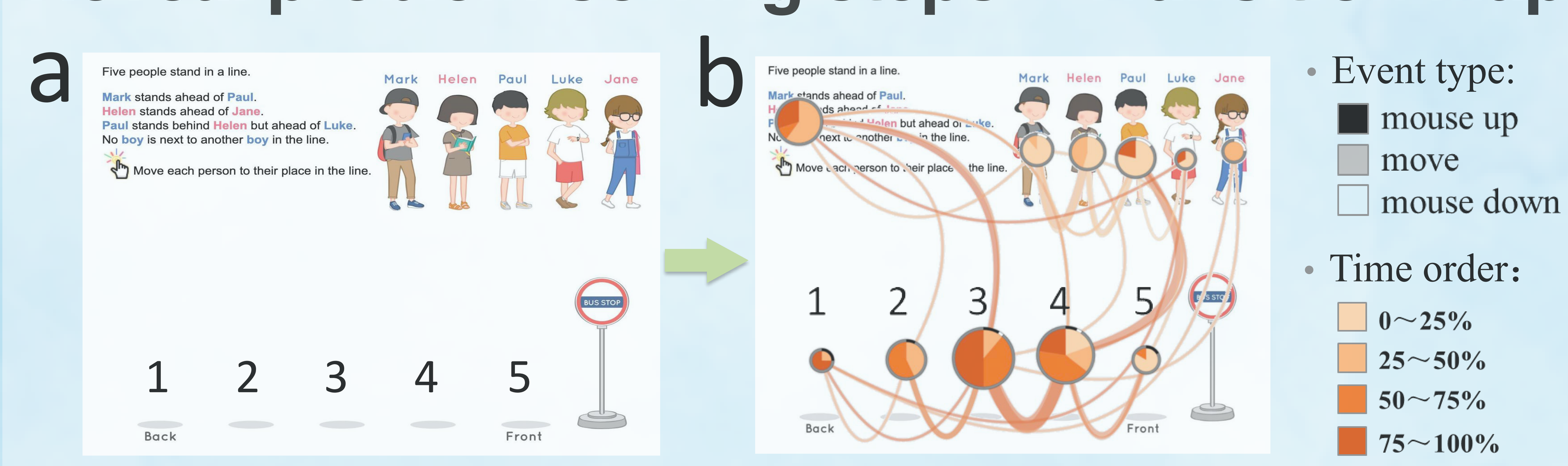


Figure 4 (a) is another example question. (b) is a transition map of the problem-solving steps, where Regions of interest (ROIs) that students mostly interact with are extracted and visualized as pie charts and users' mouse trajectories are represented as arcs connected pie charts. The size of the pie chart is the number of interactions over the ROIs; the color of arcs and sectors represents the time order of actions. From (b), we can see the student solved the problem from Position 5 and 4 (indicated by the large proportion of light orange sectors) and hesitated between Position 3 and 4 at last (indicated by the thick and dark red line in between). Finally, she double checked the problem description before the submission (the dark red arc from Position 3 to the problem description).

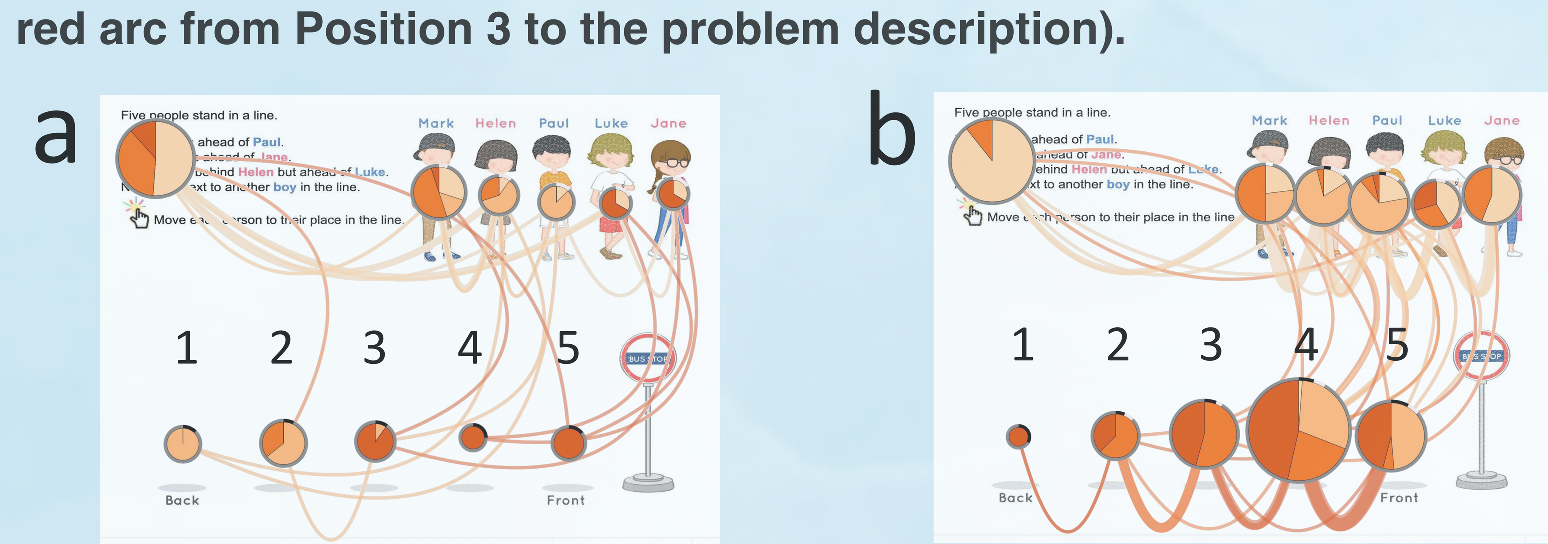


Figure 5 (a) and (b) are the transition maps of student A, B who got incorrect answer and correct answer, respectively. The smaller size of pie charts in (a) indicates that Student A tried fewer times than B did. The color distribution of each pie chart shows that A started to solve the problem from Position 1 while B from 5. In addition, sparse arcs among pie charts in the bottom row in (a) imply that A rarely rearranged the answer. On the contrary, dense and thick arcs in (b) show that B reordered Position 1-5 repeatedly before the submission.

Conclusions

- Built an interactive visual analytics system to analyze math problem-solving behaviors on E-learning platforms.
- Conducted temporal distribution and correlation analytics to explore overall learning performance.
- Proposed novel visualizations to explore the detailed learning behaviors and thinking patterns.

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