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# Visualizing Knowledge-Based Learning Logs to Support Multi-Perspective K-12 Math Instruction

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**Abstract:** Conventional learning analytics (LA) systems often rely on test scores and behavioral logs, providing limited support for understanding learners from multiple pedagogical perspectives, which are essential for personalized instruction. Recognizing the need for more accessible and beneficial LA tools for K-12 teachers, we developed a visualization dashboard based on the Open Knowledge and Learner Model (OKLM) that integrates diverse learning data into a unified structure to enable flexible, multi-perspective interpretation of students' learning states. Through interviews with three junior high school mathematics teachers, we explored how the dashboard supports teachers in interpreting learners' states from various pedagogical perspectives. The results suggest that perspectives such as self-awareness and relative positioning were especially helpful for understanding students, and that the system allows flexible interpretation aligned with instructional goals. These findings help realize the potential of OKLM to offer richer insights for personalized instruction in real-world educational contexts.

**Keywords:** Knowledge-aware learning analytics, Dashboard, ICT-supported teaching, K12

## 1. Introduction

Learning Management Systems (LMS) are increasingly used in educational settings to support online learning and have produced large volumes of learner activity logs. These logs form the basis of Learning Analytics (LA), which aims to improve teaching and learning through data-informed insights. Yet, in both educational practice and learning sciences, there is growing consensus that personalized instruction requires a deeper understanding of each learner's state and characteristics (Tomlinson, 2014). Test scores and basic behavioral logs from LMS alone are insufficient. In particular, recent discussions have emphasized the importance of knowledge-aware learning analytics that can make sense of learner actions in the context of their knowledge states—an aspect still underexplored in current LA systems (Chen, 2019).

Takii et al. (2024) proposed the Open Knowledge and Learner Model (OKLM), a framework that maps learning logs to a domain knowledge structure and stores learners' knowledge states in a graph database. As an initial application, they developed an OKLM-based visualization tool for higher education. However, the system primarily allowed instructors to monitor how long each student spent viewing content, which limited its ability to support the kind of multidimensional understanding of learners that is increasingly emphasized in personalized instruction (Tomlinson, 2014). The OKLM's potential to capture various dimensions of learning through structured knowledge mapping had not yet been fully realized in its initial application. To address this limitation and enhance teachers' multifaceted understanding of learners, we developed an advanced OKLM Visualization Dashboard. This development aims to fulfill teachers' needs for more accessible and beneficial LA tools in K-12 settings, as the widespread integration of LA into elementary and secondary school classrooms remains relatively under-researched (Valtonen et al., 2025). The effectiveness was evaluated in a Japanese junior high math setting, specifically aiming to support teachers in interpreting student information from diverse perspectives as a pilot study.

## 2. Theoretical Background and OKLM Visualization Dashboard

### *2.1 OKLM infrastructure*

The OKLM stores learning logs from multiple learning support systems, structured by textbook-based knowledge units. Each learner's activity is recorded in terms of when, to which unit, in what aspect, and to what extent it occurred. These logs are organized as a network of interconnected units based on textbook sequencing, aligned with the Japanese national curriculum guidelines (MEXT, 2017).

A key feature of OKLM is its openness to integration with diverse systems. In this study, we particularly focus on this interoperability, which enables OKLM to flexibly incorporate xAPI-format learning logs from various platforms. This design allows the model to adapt to a wide range of educational settings, from elementary education to advanced learning analytics.

Two systems currently connected to OKLM are the GOAL (Goal-Oriented Active Learner) system and the Peer Help System. GOAL enhances students' self-directed learning (SDL) by encouraging regular reflections on academic activities (Wang et al., 2024). The Peer Help System supports peer-assisted learning by allowing students (help-takers) to post questions. Based on the knowledge states modeled in OKLM, the system recommends appropriate help-givers (Jiang et al., 2024). Help-takers then evaluate the responses they receive. These logs, particularly those related to self-awareness, learning strategies, and collaborativeness, are formatted in xAPI and integrated into the OKLM database.

### *2.2 Theoretical groundings of the dashboard*

To support personalized instruction, recent work has highlighted the value of interpreting learners from multiple pedagogical perspectives. Among these perspectives, self-awareness and metacognition are seen as essential components of self-regulated learning, guiding teachers in feedback design and instructional decision-making (Zimmerman, 2002; Schunk, 2012). Collaborative learning that fosters deeper thinking through peer interaction and learning strategies such as reviewing and self-assessment are also recognized as key factors in improving learning quality (Johnson & Johnson, 1987). From a practical standpoint, teachers also rely on indicators such as learning outcomes to determine instructional priorities (Black & Wiliam, 1998), inter-unit balance to identify disparities in understanding across topics (Squires, 2013), and relative positioning to assess individual performance within the class (Becker & Rosen, 1992).

Based on these perspectives, this study hypothesizes that the OKLM visualization dashboard can support teacher understanding through multiple pedagogical viewpoints. While the dashboard is not explicitly designed to present all perspectives in a structured manner, it is intentionally designed to allow teachers to flexibly interpret students' learning states by leveraging the integrated structure of OKLM along with data from systems such as GOAL and the peer help system. The specific perspectives hypothesized in this study, along with their corresponding data sources and pedagogical implications, are as follows:

- *Learning outcomes*: Teachers can assess student achievement in each unit using objective data such as review tests and periodic test scores.
- *Self-awareness*: Subjective difficulty ratings entered via GOAL allow teachers to identify units students found personally challenging.
- *Metacognition*: By comparing self-assessments (e.g., perceived difficulty) with actual results, the dashboard helps estimate the accuracy of students' self-perceptions.
- *Collaborativeness*: Feedback from help-takers in the Peer Help System provides insights into each student's engagement in peer-supported learning.

- *Relative positioning*: Individual performance is shown alongside class averages, helping teachers gauge each student's standing within the class.
- *Inter-unit balance*: By presenting student data across multiple units, teachers can detect imbalances in students' understanding.
- *Learning strategies*: Combining self-reflection and difficulty ratings enables teachers to infer whether students adopt strategic behaviors, such as reviewing difficult content.

### *2.3 Interface of OKLM Visualization Dashboard*

The following section describes the OKLM Visualization Dashboard proposed in this study. Figure 1 presents an overview of the system interface.

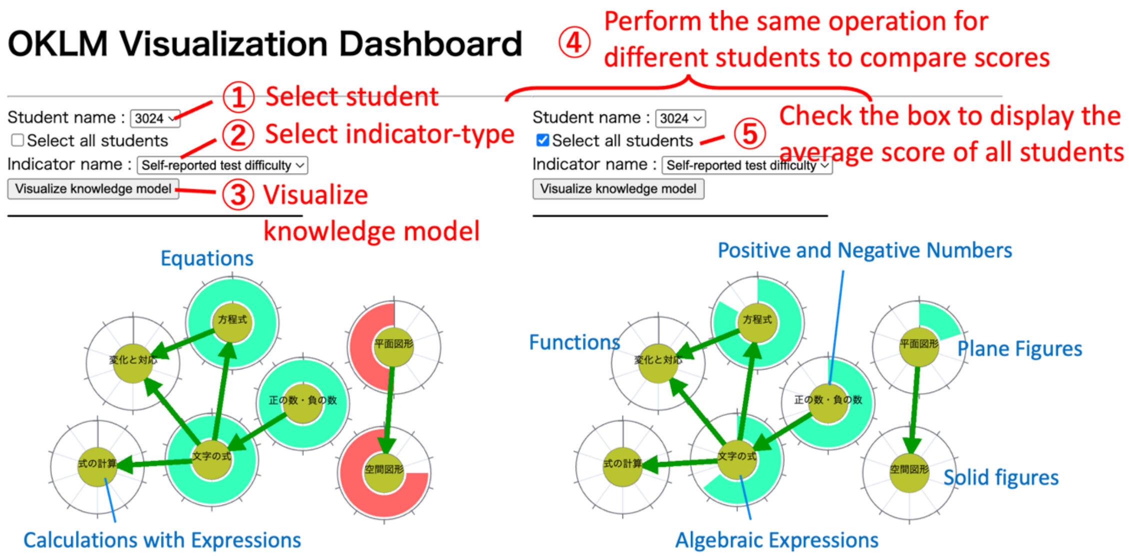

*Figure 1. User Interface of OKLM Visualization Dashboard*

Teachers begin by selecting a learner and an indicator type from the control panel in the upper-left area. The indicator type refers to a node in the OKLM database representing the "to what aspect" dimension of learning activity. Selecting an indicator determines which type of data will be visualized. When the "Visualize Knowledge Model" button is clicked, a network-based visualization appears in the lower panel, reflecting both the knowledge structure and the learner's indicator scores. This view helps teachers interpret the learner's current state and characteristics. The interface also includes a mirrored module on the right, allowing side-by-side comparisons of different indicators. Selecting "all students" displays average scores for the chosen indicator type across the class. By selecting various indicator types and comparing them with the class average, instructors can view each student's knowledge state from multiple perspectives.

## 3. Methodology

To evaluate the utility of the OKLM Visualization Dashboard in a K-12 context, we conducted a semi-structured interview with three mathematics teachers (Teachers A, B, and C) at a Japanese junior high school (School X). All had prior experience using both the GOAL and Peer Help systems and were familiar with the integrated data. Teachers A and B were active subject teachers with 10 and 8 years of experience, respectively; Teacher C, with 25 years of experience, served as vice principal. This study formulates the following research questions:

- RQ1: Can the proposed OKLM Visualization Dashboard help teachers to understand students from proposed perspectives?
- RQ2: Are the insights obtained from proposed perspectives useful for teachers?

## 3.1 *Data Source*

We used log data from 120 first-year students at School X during the 2024 academic year, derived from three sources and stored in the mathematics OKLM database: (1) GOAL, (2) Peer Help System, and (3) periodic test results. From GOAL, we collected four types of data reflecting different aspects of students' engagement with weekly review tests: test scores, perceived difficulty, performance expectations, and the presence of written reflections. From the Peer Help System, we collected ratings given by help-takers to help-givers after receiving assistance on posted problems. These ratings were automatically stored as distinct indicator types in OKLM, allowing teachers to interpret not only learning outcomes but also aspects such as self-awareness, metacognition, and collaborativeness. Periodic test scores, though manually entered, were included as indicators of learning outcomes, anticipating future integration with school management systems. Some indicators, such as perceived difficulty and performance expectations, include negative values. Visual elements like color gradients are employed to support intuitive interpretation by teachers.

## 3.2 *Interview Design*

At the beginning of the interview, a brief explanation of the OKLM Visualization Dashboard was given using real data from four randomly selected first-year students from the 2024 academic year. Teachers then explored the system to familiarize themselves with its features. Afterward, they participated in a semi-structured interview guided by predefined questions.

Following the research questions, the interview consisted of two main sections, each applied to the seven perspectives for interpreting learners' states: Section 1 (RQ1) asked whether each type of information could be interpreted from the dashboard, and Section 2 (RQ2) asked whether it was useful for understanding learners' states or characteristics.

In Section 1 (Q1-Q7), teachers were first asked their agreement with the statement: "Can this dashboard help you interpret information from the seven perspectives?", using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). In Section 2 (Q8 - Q14), they were asked the usefulness of the seven perspectives with the statement: "Is the following information useful in understanding students' states or characteristics?" using the same scale. After each response, teachers were encouraged to explain their reasoning, suggest improvements, and share general impressions. The interviews were recorded and transcribed.

For qualitative analysis, we applied a constant comparative approach (Glaser, 1965), combining deductive coding based on the predefined pedagogical perspectives with inductive coding for additional themes that emerged during analysis.

# 4. Result & Discussion

Figure 2 shows teachers' evaluations of the dashboard: Section 1 results are on the left, and Section 2 on the right.

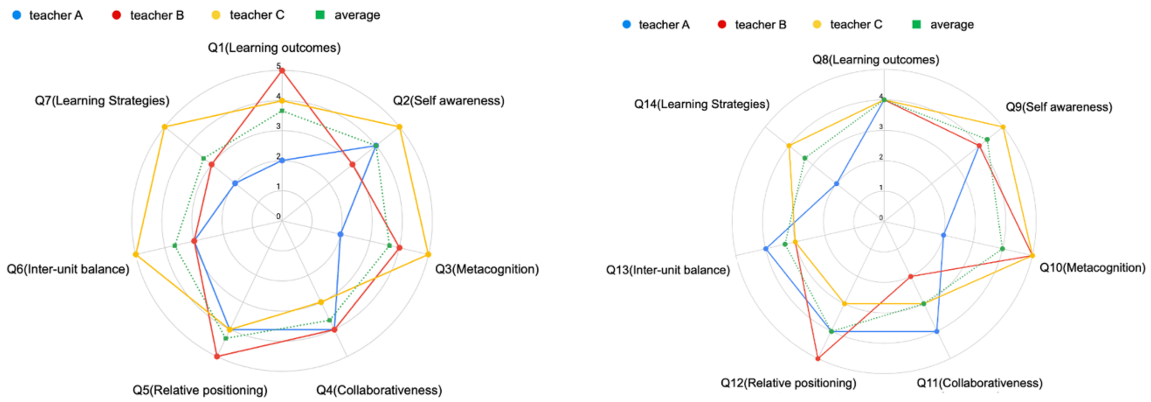


*Figure 2. Likert scale results of Section 1 (Left) and Section 2 (Right)*

In Section 1, only self-awareness and relative positioning received average scores above 4. However, all teachers rated at least three perspectives 4 or higher, indicating that they perceived the dashboard as supporting multi-perspective learner understanding. Interview comments reflected each teacher's instructional stance. Teacher A noted, "It's easy to see which unit students are good at or struggle with," and "I can get a general sense of where each student stands in the class," demonstrating that the dashboard facilitated understanding from the perspectives of self-awareness and relative positioning.

Other perspectives showed more variability. On learning outcomes, Teacher B stated, "I strongly agree with how the learning outcomes for each unit are shown," while Teacher A commented, "Honestly, it's hard to say at this point." Regarding metacognition, Teacher B appreciated "the gap between actual scores and perceived performance," and Teacher C noted, "The way the GOAL scores and questionnaire results are quantified seems potentially useful." In contrast, Teacher A observed, "The gap between students' self-evaluations and their actual performance is hard to grasp—it varies a lot by student." These differences may stem from varying levels of familiarity with the system and individual pedagogical beliefs. Teacher A, who rated several aspects lower, remarked, "It's possible that I haven't fully figured out how to read this graph yet," suggesting that prior experience with similar tools influenced interpretation. This aligns with earlier research showing that teachers' digital literacy and pedagogical beliefs shape how they adopt educational technologies (Ertmer, 2005).

Section 2 showed that learning outcomes, self-awareness, metacognition, and relative positioning again received average scores above 4.0. These perspectives were perceived as relatively useful in understanding students' states. Meanwhile, collaborativeness and inter-unit balance were rated lower. Although collaborative learning is often emphasized in pedagogy (Johnson & Johnson, 1987), the perceived usefulness of collaborativeness varied. Teacher C remarked, "I'm not sure how well this captures collaboration," suggesting a gap between pedagogical ideals and system implementation. Regarding inter-unit balance, Teacher B commented, "I don't think inter-unit balance is that important," showing a lesser focus on cross-unit comparisons. The learning strategies perspective also yielded mixed responses. While teachers acknowledged its value, they pointed out usability concerns. Teacher B said, "I do think it's useful to look at, but it's a lot of work to go through each student individually," implying a need for more intuitive or aggregated visualizations to make such data actionable in classroom contexts.

In summary, for RQ1, the interviews suggested that perspectives such as self-awareness and relative positioning were generally effective in helping teachers interpret students' conditions and characteristics. However, for the other five perspectives, there was considerable variation in perceived interpretability and usefulness. These differences likely reflect individual differences in ICT proficiency and instructional beliefs. Regarding RQ2, the two perspectives found to be informative for RQ1 (self-awareness and relative positioning) were also rated as relatively useful. Learning outcomes and metacognition were additionally seen as potentially helpful, but perceptions varied among teachers in both interpretability and usefulness.

One limitation of this study is the small dataset used: only four first-year junior high school students were included. This restricts the generalizability of the findings. However, teacher A remarked, "I'd like to see cross-grade connections, such as moving from equations to simultaneous equations," highlighting the potential value of more longitudinal or cross-grade data for deepening insight.

## 5. Conclusion & Future Work

This study conducted a pilot investigation into the potential of a knowledge-oriented, cross-activity educational dashboard for supporting teacher decision-making in K-12 contexts. By visualizing learner states through the OKLM, the dashboard enabled teachers to interpret students' conditions from multiple perspectives. The system also demonstrated interoperability with external learning support tools via xAPI, allowing the integration of log data at the level of individual knowledge units. This flexibility suggests feasibility for continued expansion as educational environments evolve.

To further enhance its practical value, the dashboard should expand its capacity to visualize behavioral and non-cognitive information that is typically difficult for teachers to access. For example, data on learning retention, motivation shifts, or post-assessment behavior may enrich teacher understanding beyond traditional performance indicators. As teacher B remarked, "It's helpful to be able to see indicators that we don't usually look at," highlighting the potential of the system to reveal previously unseen learner characteristics. This kind of adaptability is essential for differentiated instruction, as teachers must interpret diverse student profiles to offer personalized support (Tomlinson, 2014)

In terms of future improvement, refining the user interface for more intuitive interpretation remains a priority. Additionally, we aim to introduce automated features such as system-generated task recommendations, especially to support learners who encounter specific conceptual difficulties. These enhancements would help connect dashboard insights more directly to actionable classroom practices.

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