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TiTela: Enhancing Teacher Inquiry with Fine-Grained E-book Logs

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Abstract: While data-driven educational practices are increasingly required in K-12, teachers often struggle to bridge the gap between learning analytics (LA) data and instructional improvement due to insufficient data literacy and heavy workloads. To address this, we developed TiTela, a system based on Teacher Inquiry (TI) and Teaching and Learning Analytics (TLA) frameworks utilizing fine-grained e-book log data. This paper presents functional refinements of TiTela based on a formative evaluation with high school teachers. Results led to essential improvements, including a shift from real-time monitoring to post-lesson analysis reports and an architectural change from a material-based to a question-based approach. These enhancements facilitate more effective evidence-based reflection, allowing teachers to correlate student reactions directly with their instructional intentions.

Keywords: data-driven, teaching and learning analytics, teacher inquiry, e-book

1. Introduction

In recent years, it is argued that teachers need to acquire data literacy skills to effectively integrate collected data into their data-driven educational practice K-12 environments (Khulbe & Tammets, 2023). According to Mandinach and Gummer (2016), data literacy, especially in the context of teaching, is defined as the "ability to transform information into actionable instructional knowledge and practices". Data-driven educational practices enable teachers to ground their actions in evidence rather than intuition, allowing for a more objective observation of students' learning behaviors (Khulbe & Tammets, 2023).

Learning Analytics (LA) is crucial for realizing data-driven educational practices and mitigating challenges related to teachers' data literacy (Khulbe & Tammets, 2023). Among various educational data, research utilizing fine-grained learning logs from digital teaching material systems is actively being conducted (Shimada et al., 2018; Ogata et al., 2015). The data utilized in this context, including markers, handwritten memos, and page transitions, are captured as time-series information; consequently, they are regarded as highly granular data within the field of LA research (Yamada et al., 2024a).

The aim of this paper is to present the functions implemented based on a formative evaluation of our system, which was developed to support data-driven educational practices for high school teachers using B-QUBE, a digital teaching material delivery and management system provided by our university (Yamada et al., 2024b).

2. Theoretical Background

The analysis results of LA are visualized using tools such as Learning Analytics Dashboards (LAD) and utilized for teachers' instruction or students' learning behaviors (Yamada et al., 2024 October). Previous studies have also conducted research using LADs to collect and analyze students' e-book usage behavior data (such as page dwell time and operation history) and provide feedback on the results to teachers. For instance, Shimada et al. (2018) developed a real-time dashboard for immediate instructional adjustments, while Ogata et al.

(2024) created a tool to visualize reading processes, such as markers and reading speed, to assist in planning subsequent educational activities.

However, considering teacher's limited proficiency in data literacy (Sergis & Sampson, 2017) and their heavy workloads in K-12 environments in Japan (Ogata et al., 2024), this descriptive nature of LADs leads to a situation where connecting data to instructional improvement depends on the individual agency of teachers. Consequently, achieving the final goal of data-driven instructional practice based on insights gathered and analyzed through the LA process is considered extremely difficult. In fact, it has been pointed out that traditional Learning Analytics (LA) often overlooks the instructional context, such as how a lesson is designed and executed, even though these factors are primary drivers of student learning outcomes. (Sergis & Sampson, 2017).

To address these limitations of LA, Sergis and Sampson (2017) proposed another analytics concept, Teaching and Learning Analytics (TLA), which is presented as a concept creating a synergy between Teaching Analytics (TA) and Learning Analytics (LA); in this framework, learner data (evidence) collected and analyzed by LA is directly mapped to the constituent elements of educational design analyzed and defined by TA (Sergis & Sampson, 2017). Furthermore, TLA functions as a framework to holistically support Teacher Inquiry, defined as a process in which "teachers identify questions for investigation in their practice and then design a process for collecting evidence about student learning that informs their subsequent educational designs" (Avramides et al., 2015; Sergis & Sampson, 2017).

Based on these theoretical underpinnings, several previous studies have attempted to embody the TLA framework into digital tools, such as Sergis et al. (2019) who focused on analyzing phase transitions in inquiry-based STEM learning, and Hansen and Wasson (2016) who targeted broad teacher professional development (PD). Concurrently, other Learning Analytics Dashboards (LADs) have utilized e-book logs for classroom settings, but they have primarily focused on real-time orchestration (e.g., Shimada et al., 2018), often leaving the subsequent process of instructional redesign to the teachers' ad-hoc interpretation. Our system, TiTela (a system based on Teacher Inquiry, and Teaching and Learning Analytics), offers critical novelty by bridging the gaps in these two distinct research strands. Specifically, TiTela applies the TLA framework to lecture-based instruction in high school classrooms by directly mapping a teacher's specific "instructional intentions" (e.g., inquiry questions or explanations) to students' "fine-grained reactions" (e.g., markers, memos, and comprehension buttons) on e-books. Furthermore, by shifting the analytical focus from real-time monitoring to post-lesson sense-making and structured reflection, TiTela uniquely supports K-12 teachers in conducting continuous, evidence-based instructional improvements without imposing excessive cognitive load during class.

3. System Development

We began the development of TiTela in July 2025 and conducted a formative evaluation of the prototype with public high school teachers in October to facilitate functional refinement based on the results. To ensure the system aligns with the practical needs of K-12 environments, we actively involved end-users in the design process. Specifically, we conducted semi-structured interviews with four teachers from diverse subject areas (History, Mathematics, English, and Civics) to gather direct feedback on their daily workflows, instructional challenges, and barriers to data utilization. This user involvement crucially informed the subsequent refinement of the system's features and interface to better fit authentic classroom contexts.

In TiTela, functions were designed to align with the six steps of the TI cycle framework: (1) Problem Identification, (2) Develop Inquiry Questions, (3) Educational Design, (4) Deliver Educational Design and Collect Data, (5) Analyze Data, and (6) Reflect on Data (Higuchi et al., 2025). From a technical perspective, TiTela is developed as a Python (Flask)-based web application that interoperates with a digital teaching material delivery system called B-QUBE. The system is technically structured to harvest fine-grained e-book logs from B-QUBE, which include time-stamped records of page transitions, dwell times, text markers, handwritten memos, and comprehension responses (e.g., clicks on "understood" or "not understood"

buttons). To facilitate teachers' sense-making, the user interface of TiTela is designed to synchronize these fine-grained logs with static thumbnails of the teaching materials and dynamic interactive graphs. This allows teachers to visually map students' detailed reactions against their initial instructional designs. In the following sections, we describe the features of the prototype version, the results of the formative evaluation, and the features of the current version of TiTela, which has been improved based on these findings.

The prototype version of the system featured three primary components corresponding to these steps: an inquiry and instructional design setting page (Steps 1–3) designed for recording Inquiry Questions, their pedagogical backgrounds, and the lesson designs intended to answer those questions (Higuchi et al., 2025). However, the formative evaluation revealed that teachers reported ambiguity in the interface, specifically regarding what information should be recorded in each section. To address this, the current version features an improved user interface that clarifies the input requirements. Furthermore, in addition to recording inquiry settings and lesson designs, a "Data Collection Condition Setting" function has been added, enabling the semi-automatic collection of specific datasets defined by the teacher.

Second, a Learning Analytics Dashboard (LAD) page (Steps 4 and 5) was originally designed for the real-time data visualization of fine-grained learning logs, such as page views and comprehension responses, allowing teachers to collect insights during classroom practice. Teachers indicated during the evaluation that monitoring student behaviors and recording insights in real-time is practically difficult given the demands of classroom management. Consequently, the current version has shifted its focus; the UI has been modified to generate analysis reports based on the pre-defined data collection conditions, allowing teachers to review visualized information and record insights more effectively after the session.

Third, the reflection page (Step 6) supports teachers in integrating gathered insights to record final answers to their inquiry questions. Its interface was updated to align with the new reporting features, ensuring a seamless flow from analysis to reflection.

Finally, significant architectural changes and additional features were implemented to enhance usability. The system structure shifted from a material-based approach to a question-based approach, meaning that data collection, analysis, and reflection can now be conducted across multiple teaching materials for a single inquiry question. To support this, a "Question List" (Home) page was implemented to verify and manage the visibility of inquiry questions, along with a "Question Details" page where teachers can focus on a specific

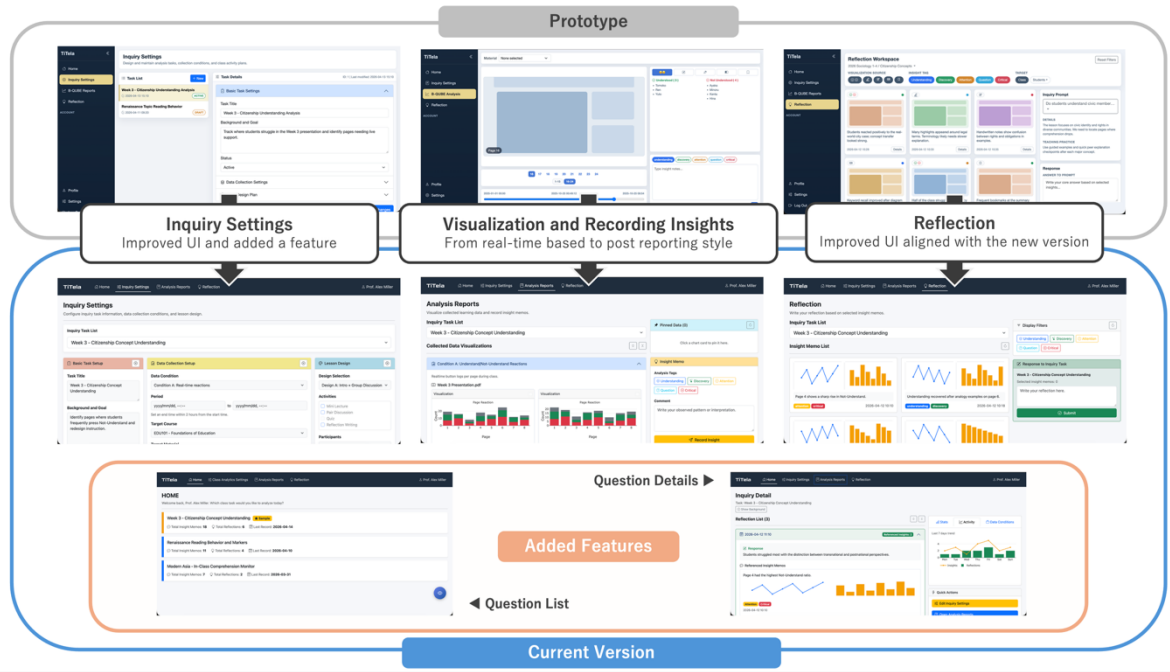

Figure 1. The Examples of User Interfaces of TiTela

inquiry, reviewing the accumulated insights and activity logs associated with that question. Figure 1 illustrates the user interface of prototype version, the current versions, and the added features.

4. Conclusion

In this study, we described the functions implemented based on a formative evaluation of TiTela, a system utilizing fine-grained logs obtained from e-books based on the theories of Teacher Inquiry (TI) and Teaching and Learning Analytics (TLA) to support data-driven educational practices.

When reflecting on educational practices based on data, collecting and interpreting data to verify identified issues is a difficult task requiring high data literacy for many teachers (Mandinach & Gummer, 2016). Furthermore, it has been pointed out that the process of data-informed decision-making requires time for "getting oriented" to the data and applying "focused attention" (Wise & Jung, 2019). From these perspectives, the design functions of TiTela are expected to be useful for data-driven educational practices.

Currently, teachers at the experimental high school are using the improved prototype of the system. Therefore, as future work, we will continue refining the prototype and proceed with designing and conducting an evaluation of the impact of TiTela usage on teachers' instructional practice behaviors and perceptions.

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