

Supporting Teacher Reflection with Multimodal Learning Analytics: An Exploratory Classroom Study with Reflecto

Kexin Yang^{1,2[0000-0002-8132-0166]} Yiliu Pan^{3[0009-0001-9134-1825]} Conrad Borchers^{1,4[0000-0003-3437-8979]}

Nikol Rummel^{5[0000-0002-3187-5534]} Vincent Aleven^{1[0000-0002-1581-6657]}

¹ Carnegie Mellon University, Pittsburgh, PA, USA

² University of Pennsylvania, Philadelphia, PA, USA

³ University of California, Irvine, Irvine, CA, USA,

⁴ Vanderbilt University, Nashville, TN, USA,

⁵ Ruhr-Universität Bochum, TN, USA

kexiny@cs.cmu.edu, mandyp2@uci.edu, c.borchers@vanderbilt.edu,
nikol.rummel@rub.de, aleven@cs.cmu.edu

Abstract. Although substantial research has investigated how analytics-based tools can support teachers, an important question remains: how can learning analytics support teacher *reflection*, a fundamental mechanism for professional development? To address this question, we co-designed with teachers and developed Reflecto, a teacher-facing tool that supports hypothesis-driven reflection and exploration of *multimodal* learning analytics (MMLA). We conducted an exploratory field study in six middle school mathematics classes with two teachers over two weeks to explore the reflection processes, supported by Reflecto. By coding and analyzing transcripts of teachers' reflection sessions, we found that Reflecto confirms, validates, and extends educators' knowledge and insights about their students and their classroom teaching. Our findings suggest the feasibility of a tool-supported process of hypothesis-driven exploration of MMLA and that MMLAs can spur useful reflection by teachers on their classroom practices.

Keywords: Multimodal Learning Analytics, Intelligent Tutoring Systems, Teacher Reflection, Classroom Research

1 Introduction and Motivation

Improving educational practice through reflection is an important focus of teacher professional development [13]. Prior work suggests that reflection can scaffold teachers' critical thinking, provide a source of knowledge construction in teaching, and promote self-regulation [9]. Despite its importance, engaging in frequent and effective reflection remains challenging. These challenges have motivated growing interest in leveraging learning and teaching analytics to support data-driven reflection.

In recent years, multimodal learning analytics (MMLA) have shown promise to enrich the understanding of educational contexts by integrating data from digital and physical learning environments, including physiological, behavioral, and environmental cues [7]. Powered by AI models and data mining techniques, MMLA has been providing educators with important novel insights into teaching and learning [4,11]. As intelligent tutoring systems (ITS) are increasingly used in classrooms, generating rich interaction log data [5], there is an open question about how teachers actually use multimodal evidence

(specifically, log data and teacher position) for reflection to translate analytic insights into instructional practice. Previous research has shown that teachers' positioning and proximity to students can influence engagement, motivation, disruptive behavior, and self-efficacy [10]. TeamSlides, an MMLA-based reflection tool, uses indoor positioning and wireless microphones to provide visualizations that support teacher-guided reflection in clinical settings. Teachers valued its ability to provide evidence for discussing teamwork, collaboration, and communication strategies [8]. Similarly, EduSense [1] collects multimodal audio and video data from higher-education classrooms (e.g., hand raises and body poses) and integrates it into a real-time system that supports reflective teaching practice. Given the nascent stage of MMLA applications, most studies have been done in the lab and empirical evidence from authentic K-12 deployments remains limited [12]. Additionally, many MMLA efforts emphasize analytic innovation, while fewer systems support educators' sensemaking and decision-making in ways that align with teachers' routines and constraints [3,13].

Motivated by this need, we co-designed and developed Reflecto, a teacher-facing tool that supports open-ended reflection by integrating ITS logs with moment-by-moment teacher position data. We conducted an exploratory field study in six middle school mathematics classes with two teachers over two weeks. As a first deployment of Reflecto in authentic classrooms, we aimed to gain an initial understanding of whether and how Reflecto might support useful teacher reflection. Accordingly, this study focuses on assessing the feasibility of Reflecto for supporting reflection on teaching and learning.

2 Reflecto System Design Overview

Reflecto aims to enable a broad range of hypothesis-driven reflections informed by pedagogical trends, rather than imposing preconceived analyses. Developed through a user-centered design process with teachers, Reflecto integrates ITS interaction logs with teacher positioning data collected during classroom instruction. Reflecto supports reflection through three connected components: a Focus Panel, a Class Table, and a Seat Map. **Focus Panel:** Teachers begin reflection by selecting one or more pedagogical trends that represent hypotheses about their instructional practice, such as attending to struggling students, visiting all regions of the classroom, or keeping visits brief. These trends serve as lenses for subsequent exploration of classroom analytics. **Class Table:** The Class Table presents analytics about student learning, behavioral, and teacher visits at the individual student level. Teachers can sort and inspect analytics to examine whether classroom evidence supports or challenges selected pedagogical trends. **Seat Map:** The Seat Map provides a spatiotemporal view of classroom activity by visualizing teacher movement, student analytics, and teacher–student interactions within the classroom layout. This view enables teachers to investigate spatial patterns and classroom dynamics that may not be apparent from tabular analytics alone. Together, these components support a process in which teachers formulate pedagogical hypotheses, explore multimodal evidence, and connect analytic patterns with their classroom knowledge, see [15].

3 Methodology

Participants and Context. Two middle-school mathematics teachers participated in the study. T1 had 20 years of teaching experience and taught three Grade 8 classes (ages 13–14), while T2 had 19 years of experience and taught three Grade 6 classes (ages 11–12). All student names are pseudonyms. The study received institutional ethics approval, and participating teachers provided informed consent. Parents and legal guardians were given the opportunity to opt out of the use of their children’s anonymized data.

Procedure. The study spanned two weeks and was conducted in six mathematics classrooms. During classroom sessions, students worked on algebra-related activities in an ITS, while teacher positioning data were collected using an indoor positioning system. Interleaved with the classroom sessions were seven reflection sessions supported by Reflecto, 3 individual and 4 collaborative with both teachers. During these sessions, teachers explored classroom analytics, reflected on their instructional practices, and discussed potential future actions. The experimenter guided the reflection activities with semi-structured prompts encouraging teachers to examine whether selected pedagogical trends were supported or challenged by classroom data.

Data Collection and Analysis. To understand how teachers engaged in hypothesis-driven reflection, we collected recordings and transcripts of all reflection sessions, as well as semi-structured interviews conducted after the final reflection session. Interviews explored teachers’ experiences using Reflecto, the usefulness of different analytics, and how the reflection process informed their understanding of classroom practice. All reflection sessions were transcribed and qualitatively analyzed. We coded 2,557 sentence-level units using a two-level coding framework that captured (1) **Reflection Actions** (how teachers interacted with Reflecto and explored analytics) and (2) **Cognitive Value** (the interpretations, explanations, and insights generated through reflection) (Table 1). Two researchers independently coded the data and resolved disagreements through discussion. We then conducted affinity diagramming [6] to identify higher-level themes describing how Reflecto supported teachers’ hypothesis-driven reflection.

Table 1. Code Definition and Examples for Teachers’ Cognitive Value and Reflection Gains.

Code	Definition	Example
Confirm Knowledge (<i>N</i> =67)	A teacher affirms that tool-provided data aligns with their prior beliefs or expectations.	<i>“Asa does not surprise me. Asa is the one I had to go back and forth.”</i>
Surprise (<i>N</i> =36)	A teacher states that an aspect of the data is unexpected or contradicts prior beliefs.	<i>“Emily’s (data) surprises me. It’s really high for misuse time and low for accuracy.”</i>
Learn Info (<i>N</i> =59)	A teacher gains new insights about themselves or students, without judging alignment with prior beliefs.	<i>“This class has a lot of high misuse of time.”</i>

Recall Knowledge (N = 309)	A teacher draws upon memories or prior experiences, without referencing tool data.	<i>"Mark is—oh my gosh—, (I recall) he's always sleeping."</i>
Question or Hypothesis (N = 48)	A teacher poses a question or speculates about causes or interpretations of the data.	<i>"My guess would be the kids that are struggling with the words than the actual math." "What defines a misuse of time?"</i>

4 Results

Based on coding results of teachers' reflection session transcripts, and affinity diagramming for sentences under "Learn Info", "Surprise", and "Question", the Reflecto sessions brought new knowledge, information and surprises to teachers. Utterances under "Learn Info" (11.4%) show teachers used Reflecto to **uncover new insights** by noting student metrics such as accuracy or number of visits. Teachers also identified individual- or class-wide patterns across sessions (e.g., change, improvement, decline). For example, *"But she's at 60 (for accuracy) on Monday. On Tuesday, she's at 49. So that declined"* (T2). Teachers also gained more awareness of their own visit patterns and durations: *"Jack, his visits were five, but like under two minutes. So none of them are super long"* (T2). A key form of reflection supported by Reflecto involves teachers generating and evaluating **data-driven hypotheses about patterns in student analytics**. Teachers hypothesized in depth about possible reasons, including content and curriculum, language barriers, and students' emotional and physical states. For example, T1 said: *"My guess would be the kids that are struggling might struggle more with the words than the actual math context"* (T1). Another teacher hypothesized about a student: *"Mary, she doesn't handle stress or anxiety well... Her misuse of time is high, and her accuracy is low... But depending on the day, what's going on outside of math class could really throw her off. And this was also the class we had after dodgeball..."* (T2). For quotes under "Surprises", which contributed 5.7% of total utterances, Reflecto **prompted genuine surprises** in teachers by revealing cases of underperformance among typically strong students, as well as struggling students who exceeded expectations in accuracy, persistence, or task completion. For example: *"Dina, let's see where she is. She had a lot of misused time, which surprises me because she's a hard worker, she's focused. So that was interesting. I felt like that was a high number (shown on Reflecto)... So I'm really surprised by her"* (T2). Affinity diagramming for quotes under "Recall Knowledge" and "Confirm Knowledge", we analyzed how Reflecto helps teachers **recall and validate** their existing understanding of teaching and learning. Most frequently, in reflection, teachers **recalled** classroom events, student traits, and instructional practices, which accounted for 58.9% of total utterances. For example, T2 recalled their visit strategy: *"I feel like when it first starts and they're getting started, I loop around specifically to make sure that I'm close to everybody at some point. That way, if they have a question, they'll ask me when I'm there. And then I sort of navigate around by where the hands go. And then once the hands are*

not going up or down, you can see who looks to maybe be off task or doesn't look as engaged as they should be” (T2). Data-driven metrics in Reflecto (e.g., accuracy, misuse time, problems solved) also informed and confirmed teachers’ prior knowledge of students’ learning behaviors, reinforcing existing pedagogical beliefs, taking up 10.9% of total utterances. For example, “Let’s see. I mean, my accuracy (displayed) probably matches up well with where my kids perform in class for the most part” (T2).

5 Discussion and Conclusion

This exploratory study examined the feasibility of supporting hypothesis-driven teacher reflection, as a first classroom test of a novel multimodal learning analytics (MMLA) tool. Across individual and collaborative reflection sessions, teachers used Reflecto to select pedagogical hypotheses, explore supporting and contradictory evidence, connect analytics with classroom knowledge, and develop explanations for observed classroom patterns. Our findings suggest that, by integrating student learning analytics with teacher position data, Reflecto enabled teachers to examine relationships between instructional actions and classroom outcomes that would otherwise be difficult to reconstruct after instruction. Teachers frequently used the tool to confirm existing understandings of their classrooms, but they also encountered unexpected patterns that prompted further questioning and reflection, consistent with prior work on teacher reflection [13] and human-in-the-loop analytics [2]. A key design feature of Reflecto is that it supports open-ended, hypothesis-driven exploration so that teachers can interpret through their own classroom knowledge. This approach appeared to support productive reflection while preserving teacher agency, aligning with calls for teacher-centered and personalized analytics systems [13]. This study has several limitations. As an exploratory deployment involving two middle-school mathematics teachers over a short period, findings should be interpreted as preliminary and not as evidence of instructional effectiveness. Another limitation is the relatively strong involvement of the experimenter during the reflection sessions. Future work should investigate how hypothesis-driven reflection unfolds across broader educational contexts and explore additional forms of support for teacher sensemaking, including AI-assisted reflection facilitation and richer multimodal data sources.

Overall, our findings provide an initial indication of the feasibility of using MMLA tools to support hypothesis-driven teacher reflection. Reflecto enabled teachers to investigate classroom hypotheses, seek supporting and contradictory evidence, and connect analytic patterns with their professional knowledge. These findings contribute to ongoing efforts to design teacher-centered MMLA systems that support meaningful reflection in authentic classroom settings.

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