

What Insights Are Gained from Students' Trace Data in Homework?

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Abstract: Recent studies have emphasized the importance of formative assessments in improving teaching and learning. This study investigated what insights can be gained from analyzing students' pen-stroke data in homework to support formative assessment (n=37). The results showed that pen-stroke data revealed students' thought processes, including partial understanding and trial-and-error attempts, which were not visible in the final answers. Regarding this result, one mathematics teacher interviewed expressed an interest in using pen-stroke data in the classroom, particularly in specific units. This study concluded that pen-stroke data can enhance formative assessment by offering more profound insights into student learning.

Keywords: Formative Assessment, Data-informed Assessment, Pen-Stroke Data

1. Introduction

Traditionally, the process of confirming the effects of instructional activities has been conducted as a summative assessment. However, recent studies have identified the effectiveness of improving instruction and learning through formative assessments in addition to summative assessments (Black & Wiliam, 2018). In parallel with this movement to focus on students' learning processes, many schools have adopted technological tools, and learning analytics (LA) research has advanced to support teachers' instruction and students' learning using trace data. Indeed, the possibility of using trace data to understand students' knowledge states and applying them to formative assessments has been highlighted (Stanja et al., 2023).

This study analyzed students' pen-stroke data, a type of trace data, and considered whether incorporating trace data would provide new insights for supporting formative assessments. Therefore, the following research questions were established:

RQ: *What insights can pen-stroke data provide that conventional answers written on paper cannot?*

2. Method

2.1 Platform

The Learning and Evidence Analytics Framework (LEAF) comprises four components: a Learning Management System (LMS) for course design, "BookRoll" for delivering digital teaching materials, a Learning Record Store (LRS) for accumulating learning logs, and an LA dashboard called "LogPalette" for analyzing the learning data stored in the LRS (Ogata et al., 2022). The process of using the LEAF system in practice is as follows: (1) Teachers upload digital teaching materials in PDF format using "BookRoll" (2) Students interact with the materials on "BookRoll" by any action (e.g., highlighting, writing notes, and answering quizzes) (3) The students' activity data is stored in the LRS, and teachers can visualize using

“LogPalette” to inform their instruction. In addition, the teacher can check information such as the students’ pen-stroke data (Figure 1[b]), which is described later in Section 2.2.

2.2 Pen-Stroke Data

We used LEAF, as described in Section 2.1, and obtained pen-stroke data (Figure 1[b]) for 37 students collected from the solution of a question (Figure 1[a]) in 8th-grade mathematics in Japan. There were three correct answers to this question. For instance, students must find the midpoints of 1-1 and 1-2, respectively, and draw line segments (Figure 1[c]).

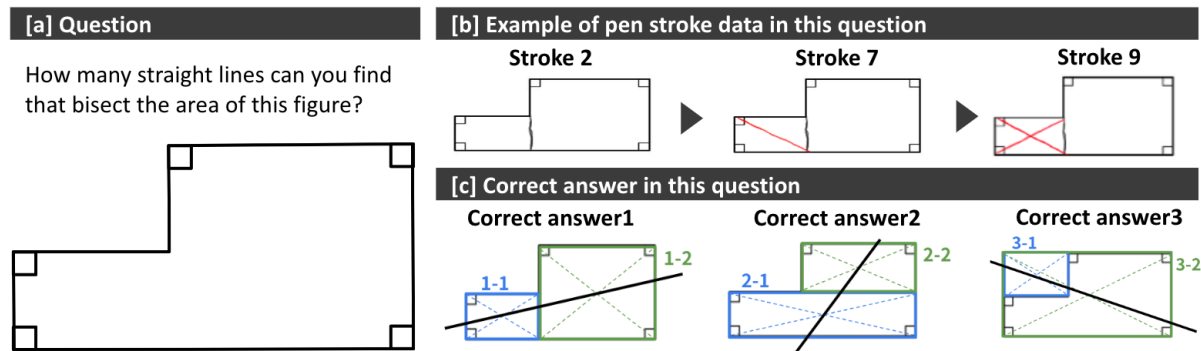


Figure 1. The Question, Collected Pen-Stroke Data, and the Correct Answer

3. Results and Discussion

3.1 Pen-Stroke Data Analytics

For the question described in Figure 1[a], traditional paper-submitted answers only check the final number of line segments. However, pen-stroke data allowed us to trace the student’s entire process, including deletions. We labeled whether each student drew the correct line segment and erased it as well as whether they drew or erased incorrect lines. Figure 2 shows the aggregated results, with the horizontal axis representing the final number of correct answers, and the vertical axis showing the number of students. Using pen-stroke data revealed two new insights into student interpretation, as follows:

New Insight 1: Even if their final answer was incorrect, some students showed understanding during the process by identifying patterns such as 3-1 in Figure 1[c]. This information provides teachers with a detailed view of students’ understanding and trial-and-error attempts, offering valuable feedback for formative assessment.

New Insight 2: Hidden bottlenecks are also uncovered. For instance, some students found all the correct answers but made mistakes, such as misapplying the definition of a trapezoid. This information helps teachers recognize that even students who answer the question correctly require further review, thus contributing to a formative assessment.

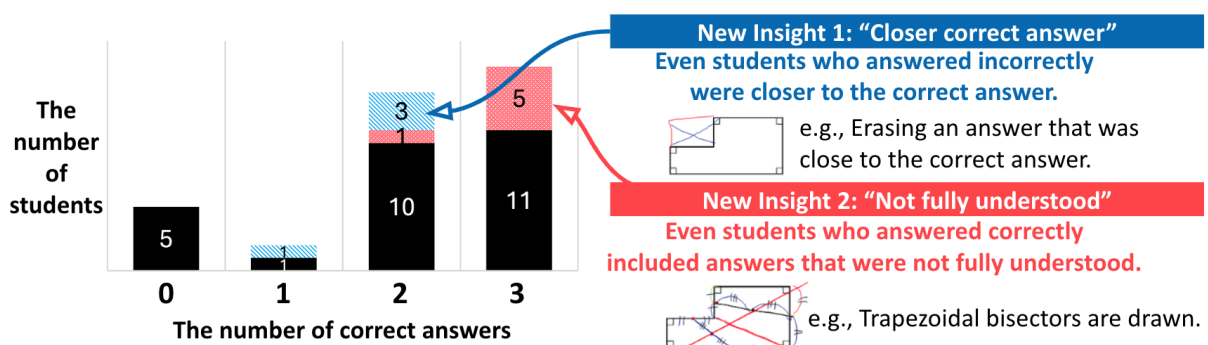


Figure 2. The Results of Aggregating Labeling Using Pen-Stroke Data

3.2 Teacher Interview about Pen-Stroke Data Analytics

We interviewed a mathematics teacher regarding the analysis described in Section 3.1. The content of the interview asked whether the teacher was willing to incorporate this analysis into their class on a 5-point scale. The higher the number, the stronger is the willingness to incorporate.

Regarding the degree to which the teacher can use them, the respondent answered 2-3 for everyday use because “in terms of content, they can be used in the area of figures, but not in the area of equations.” However, if it is used for comparison over time, the answer was 4 because “it can be used to say that in the past, things changed in this way and that many students thought in this way.” In mathematics, which involves many questions, the teacher did not emphasize tracking changes in students’ conceptions for all questions. However, a subject-specific perspective exists. These responses show that trace data can contribute to a formative assessment. However, to utilize trace data to support formative assessments, it is necessary to consider subject-specific characteristics and situations for application.

4. Conclusion and Future Work

This study shows we can gain new insights when analyzing students’ trace data. Using only the traditional paper-submitted answers leads to rough insights, as it can only tell whether the student solved the question. However, as shown in Figure 2, pen-stroke data, as a type of trace data, can provide new insights into learning processes and enable more effective formative assessments by offering teachers a better understanding of students’ learning states. For instance, it is possible to gain insight into whether a student’s understanding is advanced (“Closer correct answer”) or whether they have incorrect knowledge even though they have answered the question correctly (“Not fully understood”). Furthermore, one teacher was interviewed regarding the results of the pen-stroke data analysis. The interviews indicated that it is important not to use trace data in every mathematics class but rather to use it in set units and questions.

Our future research expands the sample size and considers various attributes such as the school stage and teachers. Additionally, since this study took the form of interviews with teachers, the focus was limited to partial formative assessment centered on teachers. We must include students in using trace data to support formative assessment. Their active participation is not just beneficial but essential for the success of this approach. Future research will focus on supporting formative assessments using trace data.

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