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Data-based instruction in mathematics among teachers using an adaptive learning environment

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Abstract

This study aligns with the global trend of employing data-based decision-making (DBDM) to inform instructional planning in mathematics education. Over the past decades, the approach of utilizing data to inform teaching decisions and optimize learning materials has gained traction, particularly in mathematics instruction. This research explores how mathematics teachers make instructional decisions based on assessment data from an adaptive learning system (*Adaptive: Fractions my way* by Center for Educational Technology, 2025) for teaching fractions in the 4th and 5th grades. The study involved five experienced mathematics teachers, each with over 15 years of teaching experience and at least three years of experience using the adaptive system. Through interviews and non-participant observations, the study identified three innovative types of decision-making pathways: the *partial direct pathway*, which covers only some milestones; the *full direct pathway*, which follows all milestones sequentially; and the *iterative pathway*, which involves revisiting previous milestones for additional information. The iterative pathway demonstrated optimal data utilization, whereas the direct pathways showed more basic use of the data. This study offers valuable insights for policymakers in mathematics education and developers of digital learning environments, emphasizing the potential of adaptive systems to enhance teachers' DBDM processes.

Keywords: data-based decision-making, adaptive learning systems, decision-making pathways, formative assessment

INTRODUCTION

Formative assessment (FA) is defined as the use of evidence on the learner's classroom knowledge, understanding, and achievements that is obtained *during* the learning process. Such evidence can guide teachers, learners, and peers in deciding on the next steps to advance and improve teaching and learning (Kyaruzi et al., 2018) and creating "enabling situations" during learning. FA may occur during classroom discussions, individual instruction, or as a result of evidence obtained from student output. It invites teacher and peer feedback on learning and products, thus generating insights (Brooks et al., 2021). **Figure 1** illustrates the conceptual framework of the assessment process.

Despite the well-established potential of FA to support students' learning, its systematic integration into data-driven teaching practices remains limited. There is a lack of empirical studies exploring how FA is applied by mathematics teachers within adaptive learning environments, where real-time data could theoretically enhance both formative processes and instructional responsiveness. This study addresses this gap by examining how teachers utilize FA within a data-based decision-making (DBDM) framework, supported by the adaptive platform "Fractions my way".

The premise of this study is that the effective use of FA is closely intertwined with DBDM, as both rely on systematically collected classroom data to inform instructional choices. FA generates immediate, actionable evidence of student understanding, which

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Contribution to the literature

- This study investigates how experienced mathematics teachers make instructional decisions based on real time assessment data from an adaptive learning environment for teaching fractions.
- The analysis identified three distinct decision making pathways that reflect different levels of data engagement and pedagogical responsiveness.
- The findings highlight the potential of adaptive systems to enhance teachers' data based decision making and to support more informed and reflective instructional practices.

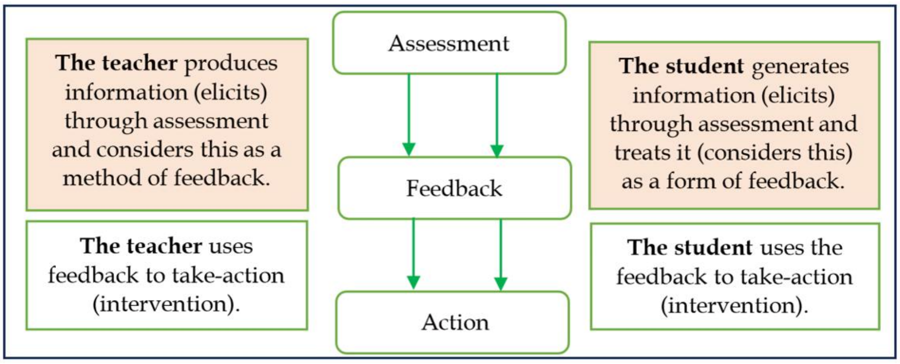

Figure 1. Conceptual framework of FA (Kippers et al., 2018)

can be interpreted and acted upon using DBDM strategies (Hershkovitz & Alexandron, 2020; Visscher, 2021). Teachers receive data and information from an activity or assessment following which they must formulate decisions about how to act, a process that begins with identifying an event and deciding whether or not it requires their intervention and planning an appropriate response (Schildkamp et al., 2017).

Recent decades have evidenced the development of the DBDM approach for planning education, which aims to improve teaching and optimally tailor learning materials, particularly in mathematics education (Cai et al., 2020; Janssen et al., 2017). DBDM is defined as a process in which teachers, administrators, and team members systematically collect and analyze school and student data and then, based on analysis of that data, make various decisions to support student learning. These decisions may include actions such as identifying teaching needs, setting goals, adapting instruction, modifying curricula, evaluating the effectiveness of programs, and improving school policies (Van Geel et al., 2016).

The goal of DBDM is to systematically maximize the achievements of all students and individuals by explicitly focusing on the assessment and analysis of student performance data. Research has shown that when used correctly, this can improve student outcomes. However, for teachers to utilize data effectively, they need the necessary knowledge and skills to analyze and interpret it (Hebbecker et al., 2022). Effective DBDM requires accurate and high-quality data accumulated from various educational and school sources (Kippers et al., 2018). To improve teachers' skills in making data-based decisions, they must be provided with supportive learning systems and trained through professional development frameworks to utilize and extract insights from data to inform their teaching decisions (Mandinach & Schildkamp, 2021; Visscher, 2021).

DBDM involves setting goals and determining a strategy for achieving them. The expected outcome is improved student learning. The use of DBDM will be based on the teacher's learning sources, professional development, and teaching experience, but, in general, the DBDM model follows the following procedure (see **Figure 2**):

1. Attention: The teacher, enabled by the adaptive learning platform's dashboard, which presents real-time evaluation data, notices and identifies an "event" that draws their attention (e.g., assessment data).
2. Interpretation: The teacher examines feedback data displayed in the dashboard and then characterizes, interprets, and analyzes it by topics, activities, and students at different time points (before, during, and after the lesson).
3. Response: The teacher focuses on identifying thinking and learning patterns, which will lead to informed strategies regarding whether intervention is needed or not.

In the current study, we assumed that the model is applicable to teaching individuals, groups, or entire classes.

Decisions made as a result of this process can lead to enhanced mathematics learning, such as changing teaching strategies, adding instructional hours, supporting specific students, or forming more focused learning groups. Previous studies found a positive link

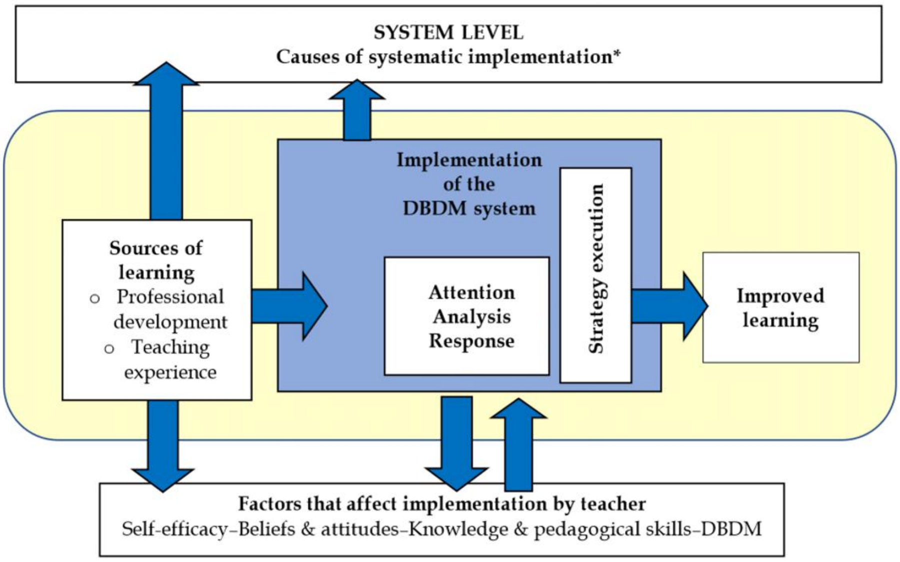

Figure 2. Model illustrating factors related to effective implementation of DBDM for improving mathematics instruction (based on Kearns et al., 2021) (***causes of systematic implementation [macro/meso systematic implementation factors]:** manager's knowledge, content-pedagogical-data-based decision-making, DBDM, culture of data use, professional climate, allocation of time and resources, community involvement)

between implementing DBDM interventions and student achievement in mathematics, regardless of students' background characteristics. The greatest benefits were observed among average-performing students, whose achievements improved significantly post-intervention, rather than among highly gifted or struggling students (Kearns et al., 2021; Van Geel et al., 2016).

The Adaptive Learning Environment: "*Adaptive: Fractions My Way*"

An **adaptive learning environment** is defined as a computerized system that learns a student's approach, identifies challenges and strengths, and tailors the learning path to the student's pace and abilities (Kabudi et al., 2021). Its dashboard provides teachers with real-time data on each student. Proper use of this information can help the teacher save time on lesson planning and grading, leading to more time for personal interaction, discussions and enrichment with students (Barana & Marchisio, 2016).

The current study examines the ***"Adaptive: Fractions my way"*** learning environment for grade 4-grade 5 (hereinafter referred to as "adaptive"). This environment was developed collaboratively by Center for Educational Technology (2025) and Microsoft and is designed to teach, reinforce, and practice fractions for about 30 hours of study. The adaptive platform differentiates between advanced students, who "are allowed" to skip the more basic practice tasks and move on to enrichment tasks, and struggling students, who are provided with more practice tasks and who skip the enrichment tasks. Via the dashboard, which updates every three seconds, the teacher can monitor their students' progress and will "close" chapters and "release" new ones which are based

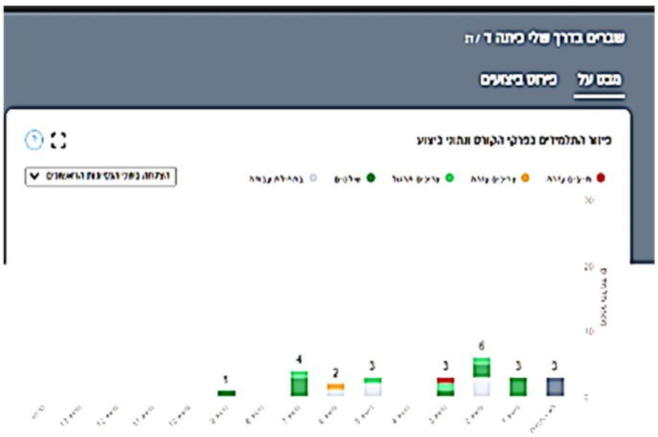

Figure 3. A portion of the teacher's dashboard showing how many students are working on each task (Note: Clicking on any item will give detailed information for that task) (Screenshot from the "My Way" adaptive learning environment) (Reprinted with permission)

on their advancement. At any particular moment, the adaptive dashboard allows the teacher to see

(1) the number of students in each curriculum chapter,

(2) their learning status, and

(3) assessment results.

This information summarizes the class's progress, serving as an evaluation event. Figure 3 and Figure 4 show screenshots from the dashboard.

The screenshot in Figure 4 shows one task where there are different activities. The progress of each student is indicated by color: red–error, orange–about 25% of the answer solved, light green–about 75% of the answer solved, dark green–,completely solved, gray–the computer skipped the question based on its adaptive

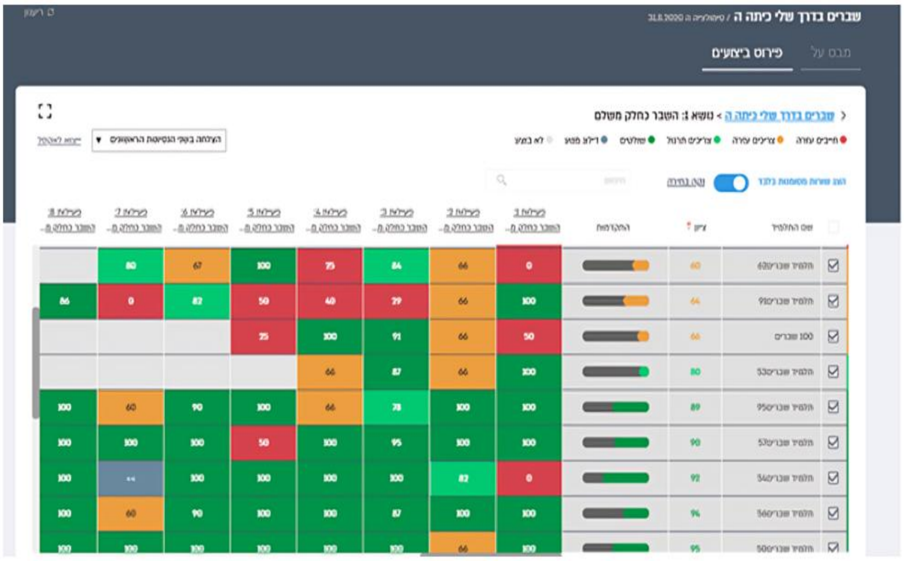

Figure 4. Adaptive system dashboard–Example of an evaluation event (Screenshot from the "My Way" adaptive learning environment) (Reprinted with permission)

capacity either because it considered this task an unnecessary repetition for the student or it considered the question too difficult for that student and removed it from the tasks required. Note that the language is Hebrew, meaning that the direction is from right-to-left (i.e., the list of students is on the right side of the screen).

METHODOLOGY

Research Goals

The current study aimed to examine how teachers utilize data presented in an adaptive learning system, specifically the *Adaptive: Fractions my way* system, to make pedagogical decisions and tailor instruction to students' needs. The study draws on theories of FA and DBDM and proposes a preliminary model to document and map teachers' decision-making processes. The objective was to characterize the pathways of teachers' decision making based on evaluation data presented on the adaptive dashboard and to examine their interpretations, rationales, and considerations for intervention or non-intervention.

Research Question and Procedure

The research question was: What are the pathways that teachers take in their decision-making process when it is based on data from an adaptive learning environment, and what are the teachers' justifications for intervening or not?

To answer this question, five case studies were conducted with experienced elementary mathematics teachers using the *Adaptive: Fractions my way* system. Each case study comprised a series of three lessons on fractions. Data were collected through semi-structured interviews conducted before and after the lessons and non-participant classroom observations. The interviews focused on how teachers interpreted the dashboard data and formulated their pedagogical responses, while the observations captured their actual decision-making processes in the classroom.

Participants

The study involved five elementary-school mathematics teachers who were teaching in the 4th or 5th grades (regular classes, including students with learning disabilities). Participants were selected using convenience sampling (Daniel, 2011). All participants had more than 15 years of experience in teaching mathematics and three years of experience using the "*Adaptive: Fractions my way*" learning system in their mathematics lessons.

Data Processing and Analysis

Data analysis was qualitative. The interviews were transcribed. For each teacher, the interview data were organized in separate Excel spreadsheets, with each interview question analyzed individually. A systematic content analysis (Shkedi, 2011) was conducted to identify how teachers used the adaptive dashboard to make instructional decisions, to characterize the types of decision-making pathways they followed, and to map these pathways in relation to their intervention choices.

The analysis involved dividing the interview into units of meaning, ranging from a single word to several sentences expressing a coherent idea. Recurring keywords and emerging themes were identified across participants. Particular attention was given to the teachers' explanations and interpretations of specific evaluation events identified through the dashboard. In addition, insights from non-participant classroom observations and relevant screenshots of the adaptive dashboard were integrated into the analysis. A flowchart

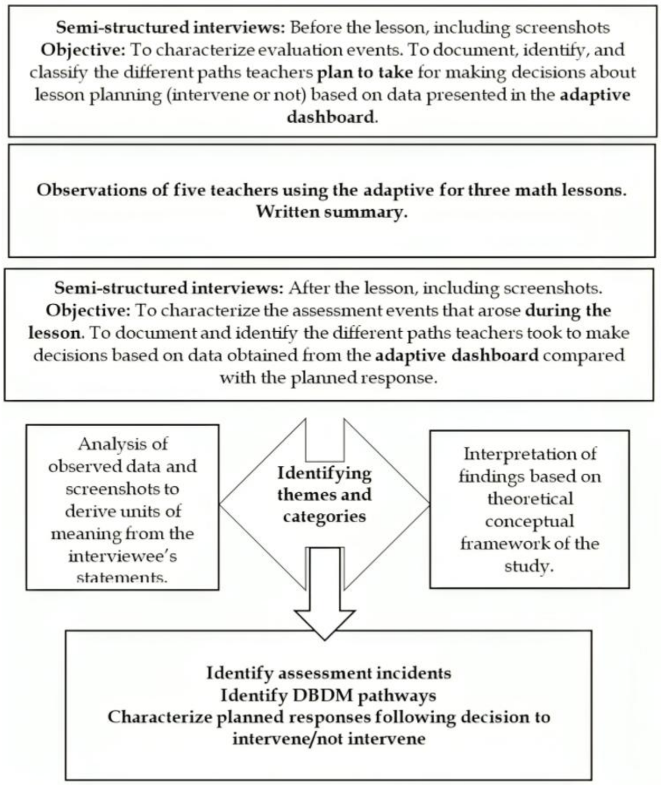

Figure 5. Research design and procedure (Source: Authors' own elaboration)

summarizing the research design, participants, data collection tools, and analytical stages is presented in **Figure 5**.

FINDINGS

The analysis revealed three distinct decision-making pathways that characterize how teachers engaged with data from the adaptive learning system, and the steps taken within each pathway, to inform their instructional decisions. These pathways were defined, in this research, based on teachers' interaction with five milestones in the decision-making process:

(1) viewing the adaptive dashboard,

(2) focused identification,

(3) interpretation,

(4) decision-making, and

(5) response and intervention.

The three pathways that were found are as follows.

Direct Pathway Through Some Milestones and Components

The teacher transitions (steps) from the starting point of the pathway (milestone 1) to the end (milestone 4 and milestone 5) while skipping the other milestones (2 and 3) and their components.

Direct Pathway Through All Milestones and Components

The teacher moves (steps) systematically through all milestones (1 to 5, in order) without skipping any. Simultaneous viewing of dashboard data occurred only within the components of each milestone.

Iterative Pathway Through All Milestones and Components

The teacher starts at milestone 1 and progresses along the milestones but might return to previous milestones (iteration) to gather additional data for decision-making and response. The iterative process involves revisiting the data both between and within milestones, in several steps.

A total of 50 pathways describing evaluation events were documented and analyzed, of which 15 (30%) were selected for in-depth analysis. The section below presents examples of each pathway, accompanied by a visual scheme illustrating the steps taken.

To analyze the different ways in which teachers engaged with dashboard data and made instructional decisions, a general scheme was developed. This scheme integrates theoretical constructs with empirical insights from teacher interviews and serves as a visual framework for comparing decision-making pathways. The scheme is organized around five key milestones:

(1) viewing the dashboard,

(2) focused identification,

(3) interpretation,

(4) decision-making, and

(5) response and intervention.

In **Figure 6**, the scheme is presented using arrows to indicate the teacher's movement between components. The direct arrow (→) indicates a pathway where the teacher examined one component of a milestone and transitioned "ahead" to another component within the same milestone or another; the iterative arrow (↔) indicates a pathway where the teacher simultaneously examines multiple components of a single milestone or across two different milestones (for example, focusing on a specific student [milestone 2] while interpreting data [milestone 3]). In some cases, transitions between different types of reasoning–such as "what," "why," and "how"–are also illustrated.

The scheme was adapted in each case study to reflect the unique sequence of steps followed by the teacher. Following, one representative example of each of the three pathways identified in the study is described, along with its corresponding scheme. Each pathway is labeled (e.g., "P-01"), with numbered "stations" (in red) corresponding to components in the diagram.

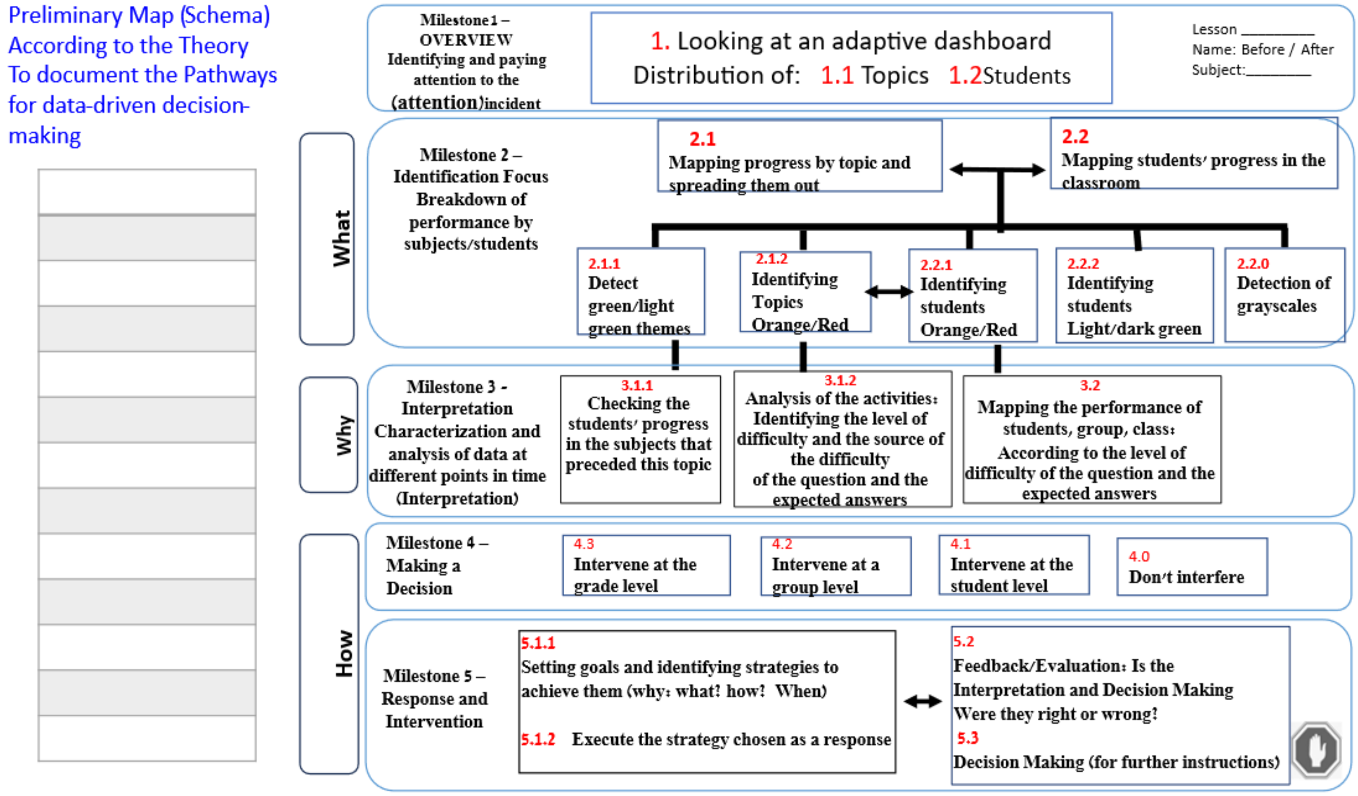

Figure 6. General scheme for documenting DBDM pathways through milestones and components (Source: Authors' own elaboration)

Pathway Type 1. Direct Pathway Through Some Milestones and Components

Decision-making pathway in evaluation event A

Making a decision based on a targeted view of the **adaptive** data related to the learning topic and their distribution.

Before a lesson on "mixed numbers" (whole number and fraction, grade 4), the teacher reviewed the dashboard. The chosen pathway focused solely on topics, leading directly to setting goals and strategies for achieving them. **Figure 7** illustrates the process this teacher underwent.

Step 1. p-01, 1 → 2.1: Here, the evaluation event begins with an observation of the **dashboard**, which provides an overview of the topic and students. This observation leads the teacher to focus on the topics studied and their distribution (2.1): "I saw that most of the girls are already past topic 3–mixed numbers." The focus on the evaluation event is based on the teacher's experience, as she stated, "I haven't taught this concept yet, although they have used fractions greater than 1, but only for identification and representation."

Step 2. p-02, 2.1 → 4.3: The teacher makes an immediate decision (without interpreting the identification, **milestone 3**) based on her experience teaching the topic: "This is a new concept in fractions, so I want to start with it at the beginning of the lesson with a whole-class session."

Pathway 3. p-03, 4.3 → 5.1.1: Following her stated goal, the teacher describes the strategies to achieve it (5.1.1): "I wanted to introduce it to them: for those who don't know it, it's an introduction, and for those who do, it's a review. I'll write the fraction $\frac{8}{6}$ and the mixed number $1\frac{2}{6}$ on the board and ask one of the students to draw the fraction on the board using visual aids."

Characteristics of the Pathway

Focused observation

In this direct pathway, the teacher purposefully examines the curriculum topics and their distribution. She does not utilize components of **milestone 2** (e.g., identifying topics and students via the color codes of green-orange-red-gray) or **milestone 3** (e.g., interpreting and analyzing the data provided by adaptive). Instead, she decides to teach a whole-class session (4.3) based on her experience and understanding of the topic's mathematical importance.

Unique Features

Overview

The adaptive dashboard allows an experienced teacher to skip the detailed analysis typically involved in milestone 2 and milestone 3 ("why") and instead rely on their professional judgement to answer the "what", "why", and "how" questions in an integrated way. This

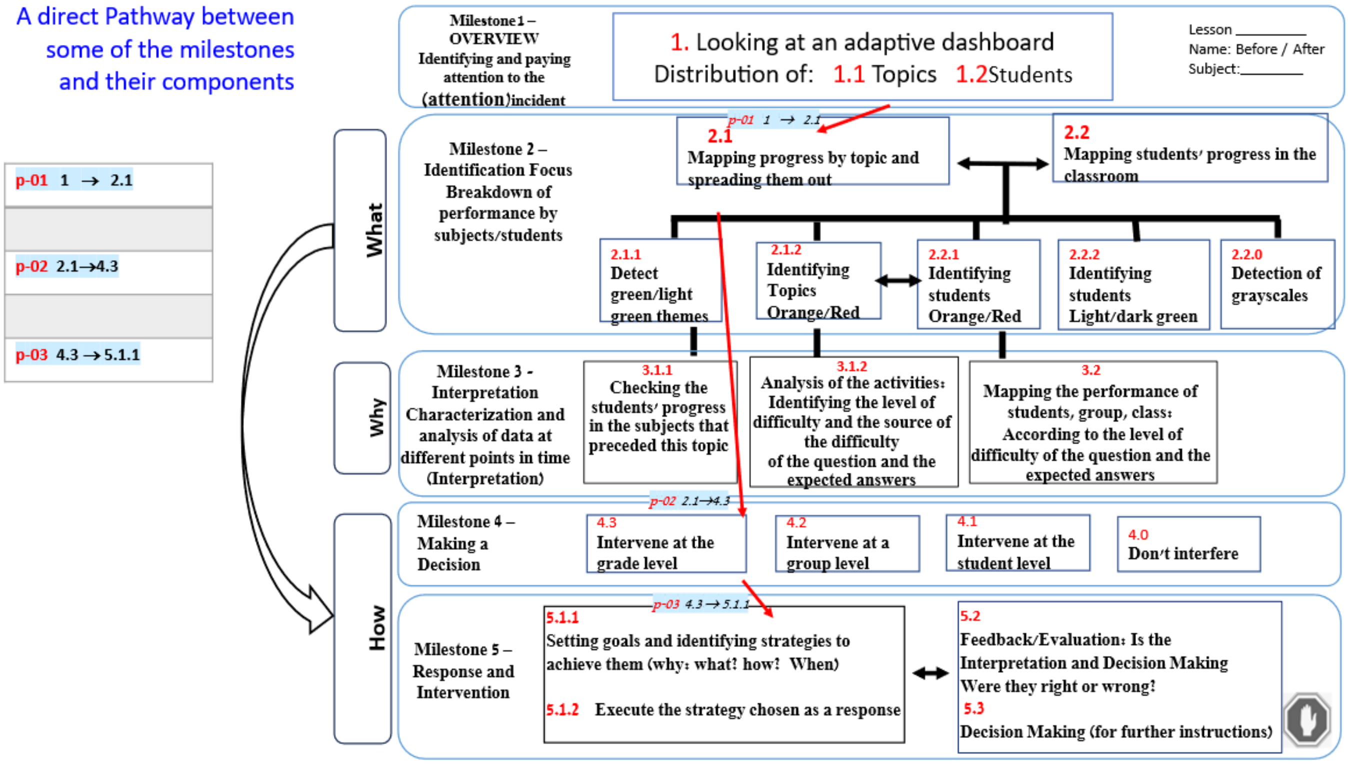

Figure 7. Direct pathway through some milestones and components: Focused on topics only, leading to goal setting and strategies (Source: Authors' own elaboration)

supports a quick, confident decision about whether to intervene and how to structure the instructional response.

Intervention Characteristics

Class-level intervention

The teacher's intervention focuses on the class as a whole, with clear actions ("I want to," "I wanted to introduce it to them"). Her decision reflects a balanced consideration of the topic being taught, the students' knowledge, and the varying success levels within the sequence of activities.

Pathway Type 2. Direct Pathway Through All Milestones and Components

Decision-making pathway in evaluation event B

Making decisions using simultaneous observations of milestone components.

After a lesson on "fractions with different denominators" (grade 4), the teacher reviewed the dashboard. **Figure 8** illustrates the direct pathway that led to a generalized decision about mathematics instruction.

Step 1. p-01, 1 → 2.1 ↔ 2.2: In this pathway, the evaluation event begins with a combined observation of the dashboard, focusing on the topic and students, and continues with mapping progress by topics and their distribution (2.1). This is performed alongside (↔) identifying student progress (2.2): "I reviewed the next topic on the dashboard, which students had already progressed in. Topic 4 was fractions with different denominators."

Step 2. p-02, 2.1 ↔ 2.1.2 → 2.1.1 ↔ 2.1.2 ↔ 2.2.1 ↔ 2.2.2 ↔ 2.2.0: The adaptive system enables the teacher to focus on identifying the students' progress across all the components of milestone 2. For example: "I noticed that all the students who reached activity 7 had mastered this topic well as they showed green or light green (75-100%), meaning that the students could correctly answer the questions, most of which were about identifying what a denominator is and its role. However, from question 8 onward, the system indicated that their statuses were orange, or red, which indicates that the student has not yet mastered the topic or grey, meaning that it was skipped" (see **Figure 9**). Note that down the right side are the names of the students and across the top are the activities in order (recall that Hebrew goes from right to left). Dark and light green indicate that the student has completed the activity satisfactorily. Red and orange indicate that further work is needed. Grey indicates that the system decided that the student does not require further activities for this topic and skipped those activities.

In addition to looking at the general picture of the students, the teacher noticed one student whose performance had declined: "[She] had worked well until activity 8, but in activity 9 and 10 she really fell and I

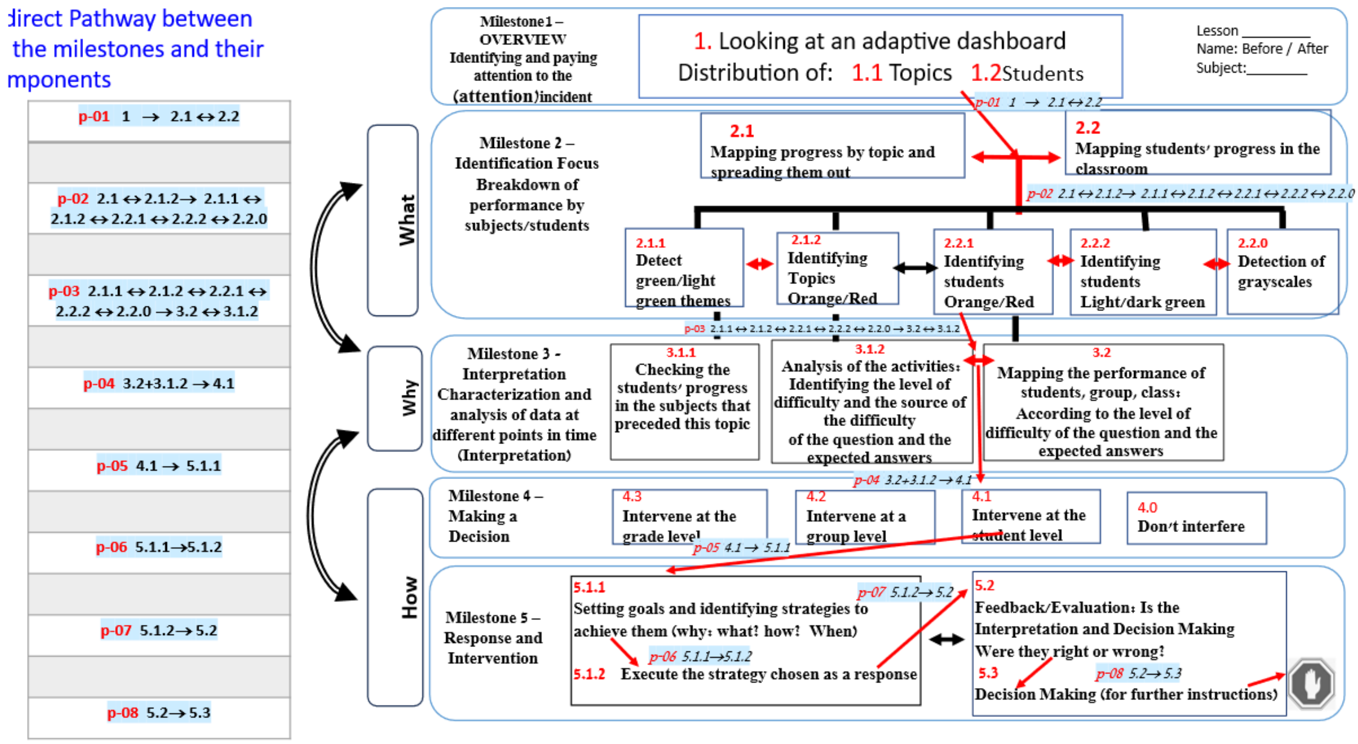

Figure 8. Direct pathway through all milestones and components: Using simultaneous observations of components leading to a generalized decision about mathematics instruction (Source: Authors' own elaboration)

Figure 9. The dashboard showing the progress of the students (Screenshot from the "My Way" adaptive learning environment) (Reprinted with permission)

didn't know why that would be. So, I checked who the student was."

Step 3. p-03, 2.1.1 ↔ 2.1.2 ↔ 2.2.1 ↔ 2.2.2 ↔ 2.2.0 → 3.2 ↔ 3.1.2: To understand the source of the student's difficulty, the teacher observes, in parallel (↔), the different components presented by adaptive: "When I checked what the questions were, it wasn't clear to me why she was having difficulty. They were not questions that needed a high level of understanding. They were quite basic. Despite this, she seemed to not understand the difference between a denominator and a numerator, and which was above and which was below the fraction bar."

Step 4. p-04, 3.2 ↔ 3.1.2 → 4.1: These iterative considerations led the teacher to decide to intervene at the student level (4.1): "I called her to my computer. At first, the student couldn't understand why she was making this mistake."

Pathway 5. p-05, 4.1 → 5.1.1: Since the student seemed to not fully understand where she had gone wrong, the teacher aimed to show her where she erred: "I used colors to show the different parts of the fraction. After a short explanation, she said that now it was clear to her and she understood the difference between the numerator (the colored part) and the "total sum of parts," that is, the denominator."

Step 6. p-06, 5.1.1 → 5.1.2: Later, the teacher described the teaching strategy she used: "I opened the assignments and asked her to solve them while I watched. I immediately saw that she had written the colored parts as the denominator and the total sum of the parts as numerator. I sat down and explained to her, what a denominator is, what a numerator is, and how we write it down as a fraction."

Step 7. p-07, 5.1.2 → 5.2: Her assessment of her decision was backed up by the data provided by adaptive: "It puzzled me that this student managed the first seven activities well, and couldn't understand why, specifically here, she had problems where, in my opinion, there was no reason she should not know the answer. The truth is that I was quite surprised by the student. I know from years that I've been teaching that there are a lot of girls who confuse numerators with denominators. But I was surprised by her."

Step 8. p-08, 5.2 → 5.3: The teacher concluded by describing a general decision she made at the end of the course regarding teaching mathematics: "It strengthened in me the knowledge that there is always a need to check for understanding, even among students who seem to clearly know the subject." This case reflects a whole cycle of formative evaluation where the student receives immediate feedback from the system, and the teacher supplements the feedback to the student by looking at the dashboard.

Characteristics of the Pathway

Systematic review

Adaptive allows the teacher to simultaneously view diverse data about the topics/activities for each student. The analysis and interpretation of this data can strengthen the insights and conclusions the teacher formulated based on extensive experience in the subject and familiarity with the students.

Improved skills

Adaptive contributes to the teacher's professional advancement and teaching skills, as it provides data to corroborate (or not) the accuracy and reliability of their professional knowledge and experience for decision-making. In this case, the teacher re-evaluated her experience in teaching the subject ("I know from the years that I have been teaching that there are many students who confuse numerator and denominator"). But, based on her analysis of the intervention she performed with the individual student in question, she stated that "but I was surprised by her."

Unique Features

Simultaneous observations

The teacher actively engaged with multiple layers of data at once–students, topics, and specific activities–enabling a comprehensive understanding of learning progress and challenges.

Data utilization

By fully utilizing all milestones and their components, the teacher was able not only to make targeted instructional decisions for a specific student, but also to derive broader pedagogical insights. These led her to refine general strategies applicable to other mathematical topics and to reexamine prior assumptions based on her experience.

Intervention Characteristics

Generalized intervention

The teacher can identify and analyze in depth the source of the student's misconception at the student level and take responsibility, as a teacher, for ensuring the specific student's understanding alongside the understanding of all the students (even those supposedly proficient in the material being studied, given her familiarity with them and her teaching experience).

Pathway Type 3. Iterative Pathway Through All Milestones and Components

Decision-making pathway in evaluation event C

Making decisions using iterative observations across and within milestone components: "For those two students, throughout the pathway, it was green/red and ended in gray. I reviewed the gray questions to understand the activities."

After a lesson on "fractions as part of a quantity" (grade 5), the teacher reviewed the dashboard. **Figure 10** illustrates the iterative pathway that led to a group-level

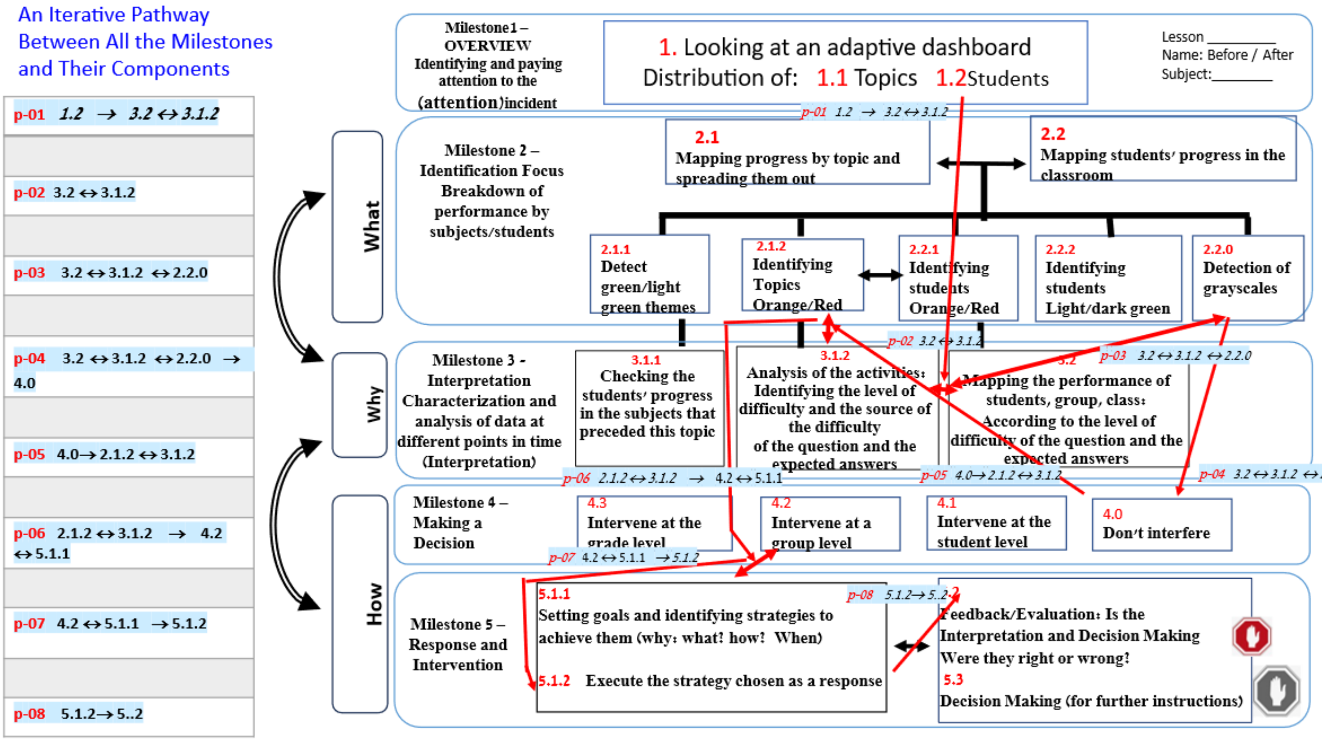

Figure 10. Iterative pathway through all milestones: Combining complex comparisons across topics/activities skipped (gray component), leading to feedback/evaluation of the chosen strategy (Source: Authors' own elaboration)

intervention while setting goals and strategies for achieving them.

Step 1. p-01, 1.2 → 3.2: After the lesson, the teacher uses adaptive to examine an event she had noticed during the lesson: "I opened the dashboard; I don't always have time during the lesson. I was interested in two students, as I wasn't sure they fully understood."

Step 2. p-02, 3.2 ↔ 3.1.2: To explore further, she focuses on these students: "I filtered the two students and reviewed their progress in Topic 1, Fraction as a Part of a Whole, which we had already studied and reviewed during today's lesson."

Step 3. p-03, 3.2 ↔ 3.1.2 ↔ 2.2.0: The teacher incorporated the gray component to support her developing decision: "I saw that for those two students, throughout the pathway, it was green/red and ended in gray (skipped activities). I reviewed these questions to see whether it was worth addressing them since gray typically represents enrichment that the system skipped or possibly that the students skipped because it was difficult for them."

In this case, adaptive allows the teacher to identify, analyze, and interpret the data (**milestone 3**).

Step 4. p-04, 3.2 ↔ 3.1.2 ↔ 2.2.0 → 4.0: By identifying the nature of the skipped activities and interpreting the data displayed by adaptive, the teacher decided not to intervene: "… because it's an enrichment activity."

Step 5. p-05, 4.0 → 2.1.2 ↔ 3.1.2: Using adaptive, the teacher simultaneously observes the orange/red topics (2.1.2) and analyzes the activities (3.1.2) to pinpoint the difficulty level and source of errors. This leads her to decide "to only intervene with the red questions. At the end of the lesson, there were still 10 minutes left, and these questions I consider foundational. Although I had conducted a whole-class review at the beginning of the lesson and worked with a group of students, when I walked around, the questions they asked me raised concerns that they still didn't fully understand what a fraction is or how to identify it."

Step 6. p-06, 2.1.2 ↔ 3.1.2 → 4.2 ↔ 5.1.1: The decision to intervene at group level (4.2) was combined (**↔**) with setting the goal and reasoning for the chosen strategy: "I called those two students over. This topic forms the basis for understanding the continuation of fractions. It was already the end of the lesson, and time was short, but this was critical. It was important for me to hear their responses and ask them clarifying questions to identify the difficulty and help them."

Step 7. p-07, 4.2 ↔ 5.1.1 → 5.1.2: The teacher details the implementation of the intervention (5.1.2): "I called the two students over, opened their activities on my computer, and together, using my guided questions, we solved the problems in the activity. I also asked them to draw the fractions I described."

Step 8. p-08, 5.1.2 → 5.2: The pathway concludes with the teacher's reflection on the intervention she conducted: "The questions I asked and the explanations I gave, combined with asking them to draw the fractions, provided additional practice. The questions and my guidance helped them understand and also clarified for me where they were struggling."

Based on this feedback, the teacher evaluates and justifies her decision: "This reassures me! When there's difficulty, you need to address it directly with the student. The questions sharpened for both them and me that they didn't know and helped me decide how to assist."

Characteristics of the Pathway

Iterative comparisons

This iterative pathway spans all the milestones and components, allowing the teacher to integrate iterative comparisons with skipped topics/activities (gray component) to support decision-making. Throughout the pathway, the teacher optimally utilizes the data provided by adaptive not only for decision-making but also to self-assess and evaluate the strategy implemented.

Unique Features

Two key features distinguish this iterative pathway and were incorporated into the revised scheme for documenting the decision-making process:

Simultaneous use

The teacher navigated across multiple milestones in parallel (↔), particularly identifying areas where students struggled (e.g., orange/red indicators in 2.1.2) while simultaneously analyzing related activities and questions (3.1.2) to uncover the source of their difficulties.

Integrated decision-making

The decision to intervene at the group level (4.2) was closely intertwined (↔) with the formulation of instructional goals and strategies (5.1.1), demonstrating a dynamic interplay between recognizing the need for intervention and planning an appropriate pedagogical response.

Intervention Characteristics

Student-level intervention

The teacher engaged two students in a focused activity using guided questions and visual representations. This approach allowed her to directly address foundational misunderstandings and monitor students' thinking in real time.

Overall, the analysis revealed three distinct pathways that teachers followed when using data from the adaptive learning system to make instructional decisions: a partial direct pathway, a full direct pathway, and an iterative pathway. These pathways differed in the depth of data engagement, the sequence of interaction with dashboard components, and the nature and scope of the resulting interventions. While the partial direct pathway reflected quick, experience-based decision-making with minimal use of the dashboard, the full direct pathway demonstrated a systematic, linear use of all milestones. The iterative pathway was the most dynamic, involving repeated analysis and reflection across milestones, leading to nuanced and responsive instructional decisions. These distinctions form the basis for the discussion that follows.

DISCUSSION

The aim of this study was to identify and characterize the potential that integrating the adaptive system offers to DBDM in elementary school mathematics teaching. Five 4^{th}- or 5^{th}-grade mathematics teachers were interviewed before and after three consecutive lessons using the adaptive platform for teaching fractions. In addition, non-participating observations were conducted in the classroom. The study assumed that the adaptive system collected real-time data during the learning process and task execution. Collecting and continuously analyzing the data allows decision-makers to derive accurate and comprehensive insights into students' successes and difficulties, which help focus their interventions (whether for an individual student, a group, or the entire class), define the intervention's goals, and choose the appropriate strategies to achieve them.

Although the teachers reported using adaptive for decision-making before and after the lessons, minimal use of the dashboard was observed during the lessons. Some teachers explained that this was due to the large class sizes and their preference to address students based on their pre-planned lessons. They admitted that they referred to the dashboard during class only if time permitted and they were available to review it to decide whether intervention was needed for the current or subsequent lesson.

Decision-Making Pathways Identified

To summarize the findings, the study identified three types of decision-making pathways based on adaptive data:

1. **Direct pathway through some milestones and components:**
    a. In this pathway, the data observed on the adaptive dashboard is primarily used for initial identification and focus on the event (that is, the topic being taught).
    b. Decision-making is targeted toward the topics and their coverage, relying on the teacher's practical knowledge, accumulated experience, familiarity with the class's achievements, the curriculum's progress, and the topic's mathematical importance.

   c. The teacher views only some of the milestones and their components and does not utilize the full range of data provided.
   d. This approach allows the teacher to bypass the "why" stage (analysis and interpretation) and immediately respond to "what-why-how" questions, leading directly to a decision whether there is a need for intervention and, if so, its objectives.
2. **Direct pathway across all milestones and components:**
   a. In this pathway, the teacher systematically progresses through all the milestones, from the starting point observing the adaptive dashboard to the concluding decision-making regarding intervention.
   b. Simultaneous observation of all the components in the dashboard (students-topics-activities) allows for focused identification, followed by analysis and interpretation of the data.
   c. This step reinforces the teacher's conclusions and insights based on their professional experience, familiarity with the curriculum, and understanding of their students, thus guiding them toward a data-based decision.
3. **Iterative pathway across all milestones and components:**
   a. This pathway involves iterative and simultaneous observations of adaptive data, both within and between milestones.
   b. Teachers revisit earlier milestones as needed to gather additional data to refine their decisions about the need for intervention and response.
   c. Decision-making is conducted in parallel with giving responses and setting goals and deciding on the strategies to achieve them.
   d. During this pathway, the teacher optimally utilizes the adaptive data not only for decision-making but also to provide self-feedback on past teaching and to evaluate the strategies employed.

As may be recalled, the path to decision-making (milestone 4) and response planning and evaluation (milestone 5) in the adaptive system begins with an overview of the dashboard (milestone 1) and focuses on identifying the assessment event (milestone 2). It then continues characterization and analysis through the interpretation of the data and reasoning whether intervention in the context of the mathematics curriculum is required (milestone 3). In other words, the decision-making pathways in the adaptive environment provide a response to the need to increase the objectivity involved in evaluating achievements (Ayalon & Wilkie, 2021).

Comparison of Findings to Theoretical Frameworks

The findings highlight the critical distinction between direct and iterative pathways, which is expressed in the level of data utilization teachers achieve by observing the adaptive dashboard. **Basic utilization** of direct pathways involves sequentially collecting data at each milestone, leading to formative evaluation. On the other hand, **optimal utilization** uses an iterative pathway that includes a feedback loop: returning to earlier milestones and components multiple times to refine decisions based on additional data. These findings expand upon the theoretical framework of Kippers et al. (2018), adding two additional pathways to the original "direct pathway across all milestones." The three pathways are illustrated in **Figure 11**.

The Role of Teachers' Knowledge and Prior Experience

An analysis of the pathways emphasizes the role of the teacher's experience, knowledge of mathematical pedagogy, and familiarity with students in the decision-making process. For instance, teachers who use the **direct pathway across some milestones and components** tend to base their decision-making on prior experience and familiarity with the curriculum and do not feel the need to analyze or interpret the available data in real time. On the other hand, teachers who use the **direct pathway across all milestones and components** are basing their decision-making on the data provided, and their interpretation and analysis of the data reinforces their practical knowledge. Finally, those teachers who use the **iterative pathway across all milestones and components** are those who use the data to not only plan interventions but also to reassess their experience, evaluate previous decisions, and refine classroom teaching.

Implications for Professional Development

The study underscores the fact that although abundant, high-quality data might be available in real-time for teachers, most teachers lack sufficient knowledge, skills, and motivation to utilize them for formative evaluation to improve their teaching. However, an adaptive system such as the one studied in this paper can provide real-time aggregated data that they can use to make informed decisions. This was also highlighted in a previous study by Lai and Schildkamp (2013). Furthermore, such learning environments in mathematics offer a valuable framework for professional development, helping teachers develop skills to analyze and utilize data to support evidence-based decision-making (Cai et al., 2020; Mandinach & Schildkamp, 2021).

Another implication of teacher education and training in continuing education courses is the development of methods for optimal training using "adaptive" for decision-making in the iterative pathway. For example, the need to look at the entire color scheme displayed on the "adaptive" dashboard (not only red-green, but also gray) and the need to observe all the data during the lessons as a routine (and not just data presented on the overview), in order to get immediate feedback on the instruction they planned for this lesson, as well as the ability to transit between milestones in several multi-directional steps.

Another interesting finding that emerged from the analysis of the decision-making pathways is that a decision-making process that is based on data presented by an adaptive system can not only improve teachers' practical knowledge but may even allow teachers to make decisions that can be generalized for other mathematical topics or even other areas of knowledge. In other words, using adaptive data for decision-making when teaching mathematics can strengthen teachers' abilities and skills in analyzing achievement data, and they can use this data to evaluate and shape their instruction in an informed manner (see also, Barana & Marchisio, 2016). This echoes the process in which FA integrated into the curriculum helps the learner develop authentic problem-solving skills that can be transferred to other subjects (Biton, 2011).

In order for teachers to reach the iterative pathway, several conditions must be met. First, teachers need to develop a conceptual understanding of the decision-making process in adaptive environments, including the importance of revisiting earlier data points and using feedback loops. Second, they must gain technical fluency with the dashboard features to move easily between milestones and interpret nuanced data (e.g., grey indicators, skipped tasks, and progress pacing).

To support this, adaptive learning systems must be integrated into professional development frameworks, not only as technical tools but as catalysts for pedagogical growth. For example, continuing education courses should include practical training sessions in which teachers simulate decision-making scenarios using authentic student data from adaptive environments. These sessions could emphasize how to identify patterns over time, adjust instructional strategies accordingly, and critically reflect on the effectiveness of interventions.

Additionally, mentoring models in which experienced teachers share their iterative decision-making practices could foster a community of practice, reinforcing the transition from basic dashboard use to more refined, iterative FA.

CONCLUSIONS

This study contributes to the global trend of encouraging DBDM in mathematics education. It enriches the existing knowledge about how mathematics teachers can use adaptive assessment data and the pathways that lead them to decide whether to intervene or not at the individual, group, or class level. The findings also suggest that teachers can use the information supplied by the adaptive data to make informed decisions when planning subsequent lessons, whether regarding which topics to focus on or which students or groups of students require additional attention.

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