JOURNAL OF LEARNING ANALYTICS

Volume 12(2), 279-292. https://doi.org/10.18608/jla.2025.8493

Primary School Teacher Perspectives on Effective Dashboard Use in the Classroom: Skills, Knowledge, and Contextual Conditions

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Abstract

Adaptive learning technologies (ALTs) provide teachers with student data in teacher dashboards (TDs). However, there is substantial variation in dashboard use among teachers, and many find it difficult to draw conclusions based on student data. Teachers' skills, knowledge, and contextual conditions are believed to be essential in effective dashboard use. In this study, 26 primary school teachers using dashboards daily were interviewed about their perspectives on the skills, knowledge, and contextual conditions needed to facilitate dashboard use. Results indicated that teachers require a combination of skills, knowledge, and contextual conditions to make well-informed decisions while using a dashboard, emphasizing data literacy skills and pedagogical knowledge. In addition, teachers addressed other competencies, such as skills and knowledge related to the ALT curriculum and general computer proficiency. Also, contextual conditions at the school and technology level were found to be necessary. Based on these results, we propose various factors to explain teacher dashboard use.

Notes for Practice

- Adaptive learning technologies (ALTs) with learning analytics (LA) visualize real-time student data for teachers in a teacher dashboard (TD), and teachers can use this data to adjust their lessons and contribute to student learning.
- This study identifies teacher perspectives on the skills and knowledge needed, and contextual conditions supporting TD use in primary education.
- Teachers emphasize the importance of data literacy skills and pedagogical knowledge, and supporting contextual conditions for using TDs.

Keywords: Teacher dashboards, primary education, adaptive learning technologies, teacher perspectives

Submitted: 12/06/2024 — **Accepted:** 22/01/2025 — **Published:** 14/04/2025

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1. Introduction

Teacher dashboards provide teachers with insight into student performance (Bodily et al., 2018; Jivet et al., 2018; van Leeuwen et al., 2019). Such insights are enabled when students practise in an adaptive learning technology (ALT) that collects real-time performance data through learning analytics (LA) and forwards it to the dashboard for immediate visualization (Mavroudi et al., 2016; Sarıyalçınkaya et al., 2021). In primary education, these teacher dashboards (TDs) can be used to monitor student progress, identify at-risk students, and inform data-driven decisions (Holstein et al., 2017; Verbert et al., 2014). Despite the potential of TDs, research indicates that effectiveness largely depends on their implementation (Michaeli et al., 2020), but the conclusions on the use of TDs is fragmented across research in primary, secondary, and higher education. However, a

considerable variation among primary school teachers in dashboard usage is found (Molenaar & Knoop-van Campen, 2019), which is currently unexplored. Earlier research shows that many teachers find it difficult to work with real-time data (van den Bosch et al., 2017). Complex teacher characteristics, such as skills and knowledge, might explain the variation among teachers, but it is unclear what skills and knowledge influence teacher dashboard use. There are many contextual conditions, besides skills and knowledge, that influence primary school teachers' ability to use technology in their education (Granger et al., 2002; Vatanartiran & Karadeniz, 2015). However, comprehensive research on the conditions influencing effective TD use is lacking, and research into the use of dashboards within actual classroom settings, incorporating the perspectives of teachers who use these systems daily, is scarce. It has been shown that teacher perspectives on the use and implementation of technology are valuable (van Leeuwen et al., 2023), but little research has been carried out on these perspectives on TDs. This explorative study, therefore, examined teacher perspectives on the skills, knowledge, and contextual conditions needed for effective TD use. We investigate teacher needs by interviewing teachers who use their adaptive learning technologies (ALTs) and dashboards in their daily educational practice.

2. Background

2.1. ALTs and Teacher Dashboards: From Information to Action

ALTs are increasingly being adopted in the Netherlands, with 40% of primary schools using them (Karssen et al., 2023). In ALTs, LA focuses on adaptively providing content to create effective and adaptive learning opportunities (Mavroudi et al., 2016; Sarıyalçınkaya et al., 2021). Within ALTs, LA captures and analyzes student learning performance, providing valuable insights to better understand and enhance educational processes (Molenaar, 2022; Schwendimann et al., 2017; van Leeuwen & Rummel, 2020). Students use personal devices, such as Chromebooks or tablets, to engage with assignments aligned with the curriculum. The ALT, supported by AI, adjusts the difficulty of assignments based on student learning outcomes (Molenaar, 2022). Teachers also use ALTs to deliver language and math lessons tailored to individual learning goals, utilizing educational content from the ALT curriculum, including physical instructional materials and textbooks.

One of the most significant benefits of these ALTs is that they provide teachers with insights into real-time student data visualized on the teacher's device through a TD (Bodily et al., 2018; Jivet et al., 2018). It is important to note that a TD does not necessarily need to be linked to an ALT in every situation. However, when ALTs are employed, the dashboard is the primary tool for visualizing this real-time student data. In this study, the term "teacher dashboards" specifically refers to those integrated with ALTs. Teachers can oversee the number of assignments completed by students on these dashboards, noting how many are correct and how much time students have spent on them. Based on this information, they can choose how to respond to students during lessons, adjust their instruction, and provide targeted support to individual students.

Outside of the lesson, teachers can also adjust the difficulty adaptation level of assignments based on the data from the dashboard and use this information to evaluate their teaching effectiveness. This insight into student data is vital for teachers (Schildkamp & Kuiper, 2010), and the information on student skills, progress, and assignments enables them to make informed pedagogical decisions and provide feedback to students (Holstein et al., 2017). Earlier research concluded that teachers who use student data to adjust their teaching tend to have higher levels of student achievement (Poortman & Schildkamp, 2016).

Van Leeuwen et al. (2019) illustrated in the Teacher Dashboard Use model how a teacher can transition from overviewing the information to taking action. In this model, they distinguished three stages that teachers go through when using dashboard data. The first stage is awareness, where the teacher knows data is available in the dashboard. The second stage is interpretation, in which the teacher makes sense of the information by understanding (visual) data and asking questions. Some dashboards provide warnings, which the teacher still needs to interpret (van Leeuwen & Rummel, 2020). The last stage is enactment, where the interpretation is translated into (pedagogical) action. This could be action towards a student or the whole class; for example, giving feedback. Alternatively, a teacher can decide not to do anything, which is a response in itself. With the increasing use of ALTs in primary education, teachers access and use real-time student data more easily and more efficiently than without this technology, and research shows that TDs support teachers in making informed decisions towards student needs (Holstein et al., 2017).

Despite the potential of TDs to support teachers with data-driven decision-making, prior research into the use of TDs in primary (Molenaar & Knoop-van Campen, 2019) and higher education (Herodotou et al., 2019) indicates considerable variation in the use of data from dashboards. Studies have shown that teachers interpret and prioritize the same data differently when using dashboards (van Leeuwen et al., 2019), indicating that teachers have diverse competencies in translating information into effective (pedagogical) actions (Herodotou et al., 2019; Molenaar & Knoop-van Campen, 2019). Additionally, research on teachers' visual literacy skills has shown that while they often find and read (visual) data, interpreting and translating it into action is challenging for most (van den Bosch et al., 2017). Moreover, variation among teachers can also be found in their actions when working with a TD (Knoop-van Campen & Molenaar, 2020). Because teachers find the translation of data into information and action difficult, it hinders the efficient use of TDs, limiting the ability to leverage and

analyze student data effectively. Comprehending what is needed to use a TD effectively is essential for providing the best possible support to teachers in using these tools and understanding variations between teachers.

2.2. Teacher Skills and Knowledge in Relation to Dashboard Use

The Modelling Competence as a Continuum framework by Blömeke et al. (2015) shows the importance of (situation-specific) skills as underlying characteristics of observatory behaviour. Indeed, various studies have established the significance of teacher skills and knowledge for effectively integrating technology into their daily teaching (Hughes, 2005; Foulger et al., 2017). Teachers with technological skills and knowledge are better positioned to navigate digital tools, platforms, and applications, enabling them to create engaging learning environments (Foulger et al., 2017). By leveraging their skills and knowledge, teachers can more seamlessly integrate technology into their teaching practices, thus fostering student engagement, motivation, and achievement (Rashid & Asghar, 2016).

When considering how data is translated into actions in educational settings, also known as teachers' diagnostic thinking, the DiaCom framework by Loibl et al. (2020) offers a comprehensive overview of the factors that influence teachers' diagnostic judgments when analyzing data during teaching. This model demonstrates the intricate interplay of factors that affect teacher decisions when interpreting this data. It highlights factors such as teachers' personal attributes, knowledge, and skills, and the impact of those on diagnostic thinking and translating information into behaviour. This is why it is expected that teacher skills and knowledge might play a role in using TDs.

Earlier research in primary education tried to explain the variation in TD use with two case studies (van Leeuwen et al., 2021), which showed that the basic characteristics of teachers, such as age, gender, motivation, and teaching experience, were not directly related to dashboard use. The researchers hypothesized that other factors, such as teacher skills and knowledge, might be directly associated with dashboard use. Based on this research and the DiaCom framework by Loibl et al. (2020), it seems reasonable to expect that skills and knowledge influence the use of TDs.

Studies that have explicitly investigated the skills and knowledge for dashboard use found that it is necessary to have skills that integrate actions with pedagogical and didactic expertise (Aleven et al., 2017; van Leeuwen et al., 2021). This encompasses understanding variations in metacognitive and social skills, and grasping group dynamics and individual student behaviour. Moreover, it involves the ability to engage with the data generated by these systems, including the accurate interpretation of data and the translation into actionable insights (Keuning & van Geel, 2021; van Leeuwen et al., 2021). Previous studies suggest that pedagogical knowledge and data literacy may influence the use of dashboards and could, therefore, explain the variation among teachers (van Leeuwen et al., 2021).

2.3. Pedagogical Knowledge

In general, teachers use pedagogical knowledge in a specific context for different learners and constantly make decisions leading to pedagogical actions (Gudmondsdottir & Shulman, 1987). Pedagogical knowledge necessitates understanding cognitive, social, and developmental learning theories and how they are relevant to students in the classroom. Several sources (Tamir, 1988; Voss et al., 2011; Stronge, 2018) delineate generic pedagogical knowledge into different aspects, covering domain-general pedagogical principles (e.g., understanding child development), teaching methods, classroom management (e.g., the ability to manage and differentiate among various student groups), and assessment.

Throughout the day, teachers constantly observe student behaviour to take pedagogical actions, a concept known as "teacher noticing" (König et al., 2022). They identify what is significant in a lesson situation and draw on their pedagogical knowledge to determine their course of action. The TD can assist them in this process of noticing by providing insights into what is important about a lesson; for example, by giving warnings. As a result, teachers are enabled to have their pedagogical knowledge readily available and to act upon it. Given that teachers base their decisions on pedagogical knowledge, it is essential to investigate how pedagogical knowledge is connected to TD use. A study by Molenaar and Knoop-van Campen (2019) identified six aspects of teachers' specific pedagogical knowledge to translate dashboard information into providing feedback to students. These six aspects were derived from responses provided by teachers in a stimulated recall interview based on teachers' pedagogical actions from the last lesson. On a student level, these aspects included knowledge about the student, the student's progress, and error analysis (the examination of mistakes to ascertain underlying causes). On a class level, they included agreement with the class, class progress, and class characteristics. Exploring teacher perspectives might enable a broader comprehension of pedagogical knowledge and could help support effective dashboard use.

2.4. Data Literacy

Teacher dashboards provide a predominantly visual overview of collected student data. Data literacy, namely the ability to convert data into actionable insights, is recognized as the essential ability to act on information effectively and is expected to play an important role in TD use (van Leeuwen et al., 2021; Schwendimann et al., 2017; Sloan-Lynch & Morse, 2024). Data literacy encompasses a variety of skills (such as visual literacy) and involves the capacity to read, manipulate, analyze, and communicate various types of data (Mandinach & Gummer, 2016). Teachers often find it challenging to make sense of data

presented on a visual TD, which can result in their making the wrong decisions (Khulbe & Tammets, 2023; Pozdniakov et al., 2023).

The Data Literacy for Teachers (DLFT) framework categorizes 67 general teacher skills for working with data, organized into five phases (Mandinach & Gummer, 2016). The first phase involves "identifying problems and framing questions," emphasizing the need for teachers to articulate practical problems, understand the student context, engage stakeholders, and respect student privacy. The second phase, "use data," requires teachers to identify, understand, select, and utilize data sources. Moving to the third phase, "transform data into information," teachers interpret data, analyze patterns, possess statistical knowledge, synthesize diverse data, and summarize information. The fourth phase, "transform information into decisions," uses the information to determine instructional steps, monitor performance, diagnose needs, and make necessary adjustments. The final phase, "evaluate outcomes," involves assessment, comparing performance before and after decisions, monitoring changes, and considering iterative decision cycles. These phases align with the awareness, interpretation, and enactment phases earlier proposed in the Teacher Dashboard Use model by van Leeuwen et al. (2019). However, there is little knowledge about the relationship between teachers' data literacy and their dashboard use (Schwendimann et al., 2017).

Teacher perspectives on data literacy can highlight the skills and competencies essential for using dashboards and areas requiring additional support or training (Dunlap & Piro, 2016) and can guide professional development. This can enhance the effectiveness of TDs by ensuring that teachers possess the requisite skills to use these dashboards and make well-informed decisions.

2.5. Contextual Conditions in Relation to TD Use

The ability of teachers to use technology relies on various contextual conditions, as emphasized by widely recognized research on technology use in education (Granger et al., 2002; Vatanartiran & Karadeniz, 2015). For example, contextual conditions like teacher training, infrastructure, and collaborative learning are important for implementing technology in education (Spiteri & Chang Rundgren, 2020). When useful contextual conditions are lacking, teachers are likely to face challenges with technology implementation. However, these contextual conditions are mostly related to general technologies in education rather than focusing specifically on dashboard use. Despite acknowledging the significance of these conditions, it is not clear if and which contextual conditions influence the effective use of TDs. Knowledge about whether these relevant conditions are important adds value to streamlining the implementation of dashboards. Teacher perspectives on these contextual conditions will, therefore, give more insight into what they think is needed to use TDs effectively.

2.6. Aim of This Study

The growing adoption of ALTs has enhanced accessibility to student data for teachers in TDs. However, research indicates significant variability in TD use in primary and higher education, but the factors influencing this variability and the specific requirements needed to support teachers with using dashboards effectively still need to be clarified. Based on various earlier studies, the suggestion is to investigate teacher skills, knowledge, and contextual conditions to further explain variations in dashboard usage. This explorative study, therefore, investigated this gap by looking into the perceptions of teachers who use these systems daily regarding the skills, knowledge, and supporting contextual conditions needed when using TDs. The research question is: What are teachers' perspectives on skills, knowledge, and contextual conditions needed for using TDs?

3. Methods

3.1. Participants

Participants were recruited through the social and digital (professional) network (LinkedIn) of the first author, where the call for participants was shared by other educational professionals, utilizing a convenient sample approach. The condition for participation was that the participant was a primary school teacher and that the school where they worked used an ALT and TD during their mathematics lessons. Participation was voluntary, and the participants were informed that they could withdraw from the study at any time without any consequences. All participants provided written informed consent. The study was conducted following the ethical guidelines set by the ICLON institutional research ethics committee (IREC_ICLON 2022-09). The participants were 26 primary education teachers (18 females, 8 males) from nine primary schools. Their age varied from 21 to 59 years ($M = 36.7$, $SD = 11.2$), and teaching experience ranged from one to 37 years ($M = 13.6$, $SD = 10.4$). Participants taught classes ranging from Grade 2 (7 years old) to Grade 6 (12 years old). They used different types of TDs, see Figure 1 for an example of a TD. Of the participants, 69.2% used a dashboard from Snappet, and 30.8% used a Gynzy or Bingel/Prowise dashboard.

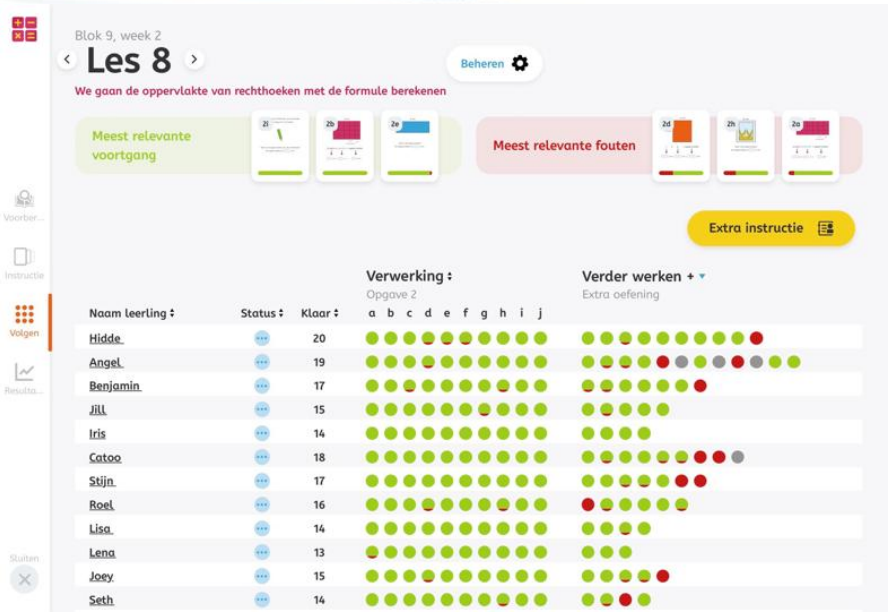

Figure 1. Screenshot of a TD within the ALT "Snappet" from one of the participating teachers (used with permission).

3.2. Procedure and Measurements

Participants were interviewed and completed a survey about their age, teaching experience, ALT experience, and dashboard use.[1] The interview questions (Appendix B) focused on their dashboard use, including how they use data before, during, and after the lesson and any challenges encountered during that time. The purpose of the interviews was to gather in-depth information about the participants' perspectives on the required skills, knowledge, and contextual conditions because, as was already noted, it is still an open question as to how different factors influence effective TD use. Research suggests that skills, knowledge and contextual factors could play an important role in this. The structured interview consisted of 18 standardized questions and took approximately 30 minutes. The interview questions were developed by the authors to address the research question.

Three questions focused on participant use of the dashboard. Eight questions concerned teacher perceptions of using the dashboard (e.g., "What are the specific reasons you use the TD?"). Four questions concerned perspectives on the important skills and knowledge (e.g., "What types of skills and knowledge are, in your opinion, important when working with a TD?"). Three questions concerned perspectives on contextual conditions (e.g., "Are there factors that, in your opinion, influence or support the effective use of the dashboard?"). According to the interview protocol, follow-up questions were asked to clarify answers.

3.3. Analysis

Interviews were transcribed, and segments were identified for coding. Depending on the content-relatedness of the response, the length of the coded segments varied from one sentence to multiple sentences. The fragments were coded in ATLAS.ti 23.0.1 for Mac.

To analyze the data, a partly grounded theory method was used (e.g., Boeije, 2010). The transcripts of the interviews were initially reviewed and coded in three stages. First, an open coding approach was employed in the analysis stage, where labels and codes were derived directly from the collected data. Segments could be double-coded based on content appropriateness. While some codes were informed by the study's theoretical framework, such as generic pedagogical knowledge (Tamir, 1988; Voss et al., 2011; Stronge, 2018), specific pedagogical knowledge (Molenaar & Knoop-van Campen, 2019), and data literacy (Mandinach & Gummer, 2016), a significant portion of the coding process was grounded in the emergent meaning present in the data itself (see Appendix A for an overview, explanation, and example of the codes). This resulted in additional codes found within the data relating to other skills and knowledge, as well as contextual conditions mentioned by participants. This bottom-up approach continued until the selected labels and codes fully reflected the data, reaching a point of saturation and arriving at a set of 32 overarching codes and codebook. Second, at this juncture, a second person coded 45 interview fragments to calculate the inter-rater agreement to ensure the consistency of our analysis, which was found to be high ($\alpha = 0.981$) (Krippendorff, 2018). The codes that differed between the author and the second coder were discussed to finalize the definitive

[1]Observation data from a math lesson was collected per participant as a part of the data collection process. However, it was not used for the specific focus of this study, and the interview data is exclusive to this paper.

codes further. Third, there was a phase of integration based on the existing codes. Based on thematic content, the 32 codes (see Appendix A) were divided into four main categories (pedagogical knowledge, data literacy, other skills and knowledge, and contextual conditions). Within pedagogical knowledge, a division was made into "generic" and "specific," and within the theme of contextual conditions, they were divided into "technology-level" and "school-level" codes. We subsequently examined the occurrence of overarching themes within the interview data to compare them systematically. For each theme, we analyzed the frequencies of codes in participant responses to identify patterns among them.

4. Results

Figure 2 shows the overall distribution of coded fragments across the four main categories. Data literacy was mentioned most frequently, followed by pedagogical knowledge (both specific and general), contextual conditions, and other skills and knowledge.

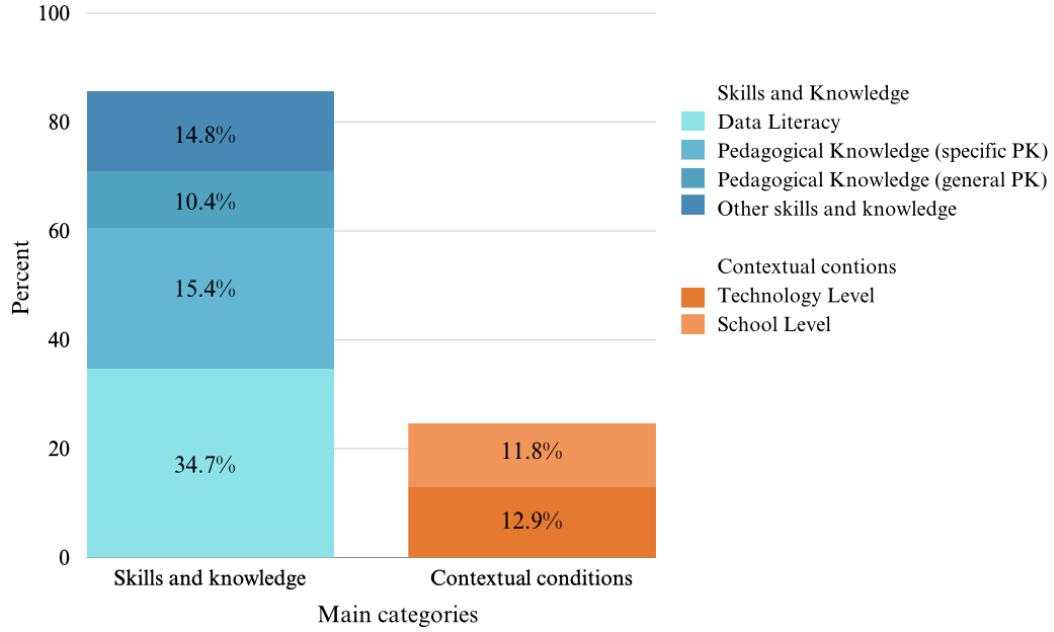

Figure 2. Overview of participant answers related to the main categories, together totalling 100%.
Note: All participants gave answers related to each of these categories.

4.1. Pedagogical Knowledge

Teachers mentioned four aspects of generic pedagogical knowledge and six aspects of specific pedagogical knowledge as important when using TDs (Table 1).

Table 1. Frequency of Answers Related to Pedagogical Knowledge

	Frequency	%
Generic pedagogical knowledge		
Teaching methods	36	16.1
Classroom management	27	12.1
Domain-general rules of pedagogy	20	9.0
Assessment and evaluation	7	3.1
Specific pedagogical knowledge		
Knowledge of the student	57	25.6
Error analysis	30	13.5
Characteristics of the class	26	11.7
Agreement with the class	11	4.9
Progress of the class	7	3.1
Progress of the student	2	0.9
Total	223	100%

Concerning generic pedagogical knowledge, teachers mentioned *teaching methods* (*N* = 36) the most. Teacher dashboards provide valuable information to teachers about student progress. By combining knowledge of various teaching methods with the data provided by TDs, teachers can better understand areas where students are struggling and which approaches are most effective in enhancing learning outcomes. For example, "The dashboard can provide information, and I want to connect this information effectively when working with the direct instructional model." According to the teachers, skills are required to align the dashboard with these methods and didactical knowledge. The second aspect of generic pedagogical knowledge mentioned by teachers was *classroom management (N* = 27). Teachers indicated that their classroom management is important when working with a TD. They sometimes need to manage different student groups in the classroom at the same time, for example, when students are doing their assignments. They frequently emphasized that it is crucial to have good classroom management skills when doing this and simultaneously monitor the dashboard. Third, *domain-general rules of pedagogy* were also mentioned (*N* = 20). Teachers indicated that they examine dashboard data from a pedagogical perspective. For example, "I know students at this age don't have a lot of concentration. I keep that in mind when looking at their answers over time." *Assessment and evaluation* (*N* = 7) were mentioned the least. One participant said, "Besides the answers given during the lesson on their Chromebook, I check their knowledge with, for example, quizzes."

Within specific pedagogical knowledge, participants mentioned *knowledge of the student* the most (*N* = 57). For example, they mentioned knowledge of student levels, student personalities, and student abilities. Teachers deemed this type of knowledge as essential when enacting a TD to interpret the information about students, as it gives meaning to the student data. Second, *error analysis* was frequently mentioned by participants (*N* = 30). Teachers highlighted that, when analyzing dashboard data, they often examined errors made by students to understand the source or reason behind the mistake. Third, teachers highlighted the *characteristics of the class* (*N* = 26) as crucial (e.g., "This class works very quickly, knowing that helps me interpret the dashboard data more effectively"). Finally, *agreement with the class* (*N* = 11), *progress of the class* (*N* = 7), and *progress of the student* (*N* = 2) were mentioned less frequently.

4.2. Data Literacy

Within the categories of data literacy, the *use of data* was mentioned the most (*N* = 112, Table 2). Most teachers mentioned that using and looking into the data was a skill that they noticed was important when using a TD. One participant said, "I'm developing my skill to really understand when I need to use the data and not to forget that the dashboard is allowing me to see the data."

Table 2. Frequency of Answers Related to Data Literacy

	Frequency	%
Use data	112	21.4
Transform data into information	87	16.6
Transform information into a decision	63	12.0
Evaluate outcomes	20	3.8
Identify problems and practise and frame questions	18	3.4
Total	300	100%

Second, besides the *use of data*, skills related to *transforming data into information* were also mentioned many times (*N* = 87). Teachers expressed the importance of analyzing data to understand it. Teachers emphasized the significance of interpretation, with one summarizing this aspect by stating, "It's all about interpreting what I see; otherwise, I don't know what it means." This is a logical response from teachers, as most dashboards provide information but do not give an interpretation of the data. Third, teachers found *transforming information into a decision* to be an important skill (*N* = 63). A teacher mentioned, "When I have read the information from the dashboard, I have to decide whether or not to act on it. Sometimes, I choose not to act, but that's something I've really had to learn."

Finally, *evaluate outcomes* (*N* = 20) and *identifying the problems and practising and framing questions* were mentioned the least (*N* = 18).

4.3. Other Skills and Knowledge

Five other subcategories of relevant skills and knowledge mentioned by the teachers were identified (Table 3). The knowledge related to the *ALT curriculum* was mentioned the most frequently (*N* = 46). Teachers highlighted the importance of possessing adequate knowledge of the program's curriculum, understanding the incorporation of various learning goals in a student's overview within the dashboard and knowing how to adjust according to these goals across all domains. Examples included connecting students to learning goals and manually adjusting target levels and goals for individual students, as expressed by teachers: "When students have achieved the lesson goal, I sometimes replace it with something else, like practising another lesson's goal."

Table 3. Frequency of Answers Related to Other Skills and Knowledge

	Frequency	%
ALT curriculum knowledge	46	35.9
Computer proficiency	34	26.6
Child-oriented data presentation skills	21	16.4
Understanding artificial intelligence	19	14.8
Adapting to rapid digital changes	8	6.3
Total	128	100%

Second, teachers highlighted skills related to more *general computer proficiency* (*N* = 34). They emphasized that they have to be digitally skilled, implying effective computer operation when working with the TD. This included tasks such as managing sound settings, screen sharing (sometimes on the interactive whiteboard, allowing students to see the dashboard overview), and having the confidence to click. Teachers specifically mentioned the ability to work in various "tabs" within the dashboard, quick typing, and the skill of locating a link within the software.

Third, teachers emphasized the importance of skills and knowledge related to *child-oriented data presentation* (*N* = 21). Some teachers used the dashboard to discuss progress with individual students, necessitating the transformation of observed data into an understandable format for meaningful conversations. This occurred not only during lessons but also in periodic discussions where personal goals were formulated with students for the upcoming period. Teachers noted the challenge of quickly grasping this data themselves, let alone for students. Examples of their responses: "I would like to improve my skills in using the dashboard specifically for lesson closure, providing students with insight into their actions and progress. How can I present this in a way that students can understand, ensuring that they don't draw incorrect conclusions?"

The fourth category of additional skills and knowledge related to the use of TDs concerning *understanding artificial intelligence* (*N* = 19). Teachers wanted to comprehend better how the software makes decisions and to what extent these decisions influence the real-time student data they receive. Notably, teachers had varying responses on this matter. Some teachers mentioned active engagement with this topic and aimed to continue learning about it, as they already possessed some knowledge. Others admitted they knew nothing about the ALT AI but expressed a strong desire to learn more about it.

The last category mentioned was the skill of *adapting to rapid digital changes* (N = 8). Teacher responses related to the digital changes occurring around them, including within the dashboard itself ("It would be nice if some things remained the same. The dashboard changes every time, and that goes too fast. In any case, I sometimes think ICT changes too fast").

4.4. Contextual Conditions

Table 4 shows the frequency of responses for the contextual conditions. Teacher responses could be categorized into two groups: those related to the technology level (TL) and those related to the school level (SL).

Table 4. Frequency of Answers Related to Contextual Conditions

	Frequency	%
Technology level		
Lesson structures within the ALT	38	17.8
Teacher autonomy concerning ALT	26	12.2
Practical operation ALT and TD	23	10.8
TD interface	19	8.8
The connection with other methods in the school	6	2.8
School level		
School vision	31	14.5
Developing with colleagues	25	11.7
Additional training on the ALT/TD	16	7.5
(More) Time	16	7.5
Managing multiple groups	8	3.7
More/other devices	3	1.4
Financial budget	3	1.4
Total	214	100%

In responses regarding the dashboard's technological level (TL), teachers (N = 38) frequently addressed the issue of *lesson structures within the ALT*. As mentioned earlier, teachers can give lessons based on the ALT content. Answers highlighted challenges when the program's predetermined content and learning goals were misaligned, hindering easy access to results. Teachers noted that these challenges impeded the effective use of student data during lessons (e.g., "The various steps I consider necessary to achieve lesson goals are occasionally missing").

Another frequently mentioned factor within the TL was *teacher autonomy concerning adaptive learning technologies* (N = 26). Teachers highlighted the importance of being able to make independent choices within the ALT. For example, "It's nice that there is a guideline, but I want to continue to look critically and be able to adjust the lesson goals if needed."

A third aspect emphasized in teacher responses pertaining to the TL regarding the *practical operation of ALT and TD* (N = 23). Responses addressed issues such as system glitches, incorrect synchronization, or failure to save student responses. Teachers said that these technical challenges impeded their dashboard use. Fourth, in connection with the practical operation of the dashboard, teachers occasionally noted challenges with the interface (N = 19), such as unwanted automatic inclusion of student answers when sharing the dashboard with students while teachers did not want to display answers, for instance, to prevent unwanted comments.

Concerning responses related to school level (SL), teachers highlighted aspects related to the *school vision*, specifically to dashboard use (N = 31). Responses ranged from a lack of a clear vision ("I would understand better how to use the dashboard if we could articulate our thoughts and vision") to a desire to update the existing vision ("Our current vision states usage from Grade 4; I would like to adjust this to a vision of use from Grade 2").

The second aspect within the SL included *development with colleagues* (N = 25), referring to activities such as brainstorming about data interpretation, classroom visits, or engaging in discussions about student data with colleagues. Teachers also expressed the need for *more time* to enhance their proficiency in dashboard use (N = 16) or the need to follow *additional training* (N = 16).

Finally, pertaining to the SL, though mentioned less frequently, aspects including *managing multiple groups*, especially in combination classes (N = 8), the availability of *more or different devices* (N = 3), and having a sufficient *financial budget* (N = 3) were addressed.

5. Discussion

This explorative study examined the perceptions of teachers who use TD systems daily on the skills, knowledge, and contextual conditions needed for effective TD use. The results indicated that teachers require a combination of skills, knowledge, and contextual conditions to make well-informed decisions while using a dashboard, with an emphasis on data literacy skills and pedagogical knowledge. Teachers addressed that several contextual conditions are necessary in addition to these aspects and highlighted other essential skills and knowledge required for effective TD use.

5.1. Teacher Perspectives

First, teachers addressed the skills related to data literacy as the most important. This aligns with earlier findings because within — as well as outside — recent ALT research, data literacy is considered the most needed skill for effectively interpreting and acting upon visual data (Miloradov et al., 2022; Khulbe & Tammets, 2023; Wolff et al., 2016; Pozdniakov et al., 2023). Our analysis showed that this finding is also confirmed from the teacher's perspective, as the teachers in our sample emphasize skills related to using and acting on data rather than framing questions before looking into or evaluating the data. This finding differs from earlier literature (Mandinach & Gummer, 2016), where the five phases of data literacy are considered equally important. The difference could be attributed to the fact that people, in general, are more inclined to talk about acting and the steps to take action than they are to evaluate their actions. Evaluating requires higher-order thinking skills, entails more mental effort, and is less directly related to the practical execution of an action (Forehand, 2010). Another explanation could be that individuals tend to talk more about things they find challenging than things that come easily to them (Kanouse & Hanson, 1987). As we mentioned earlier, teachers struggle with working with and interpreting data (van den Bosch et al., 2017). They may, therefore, discuss the importance of this skill more frequently as they encounter this difficulty often when working with TDs.

Second, regarding pedagogical knowledge, our results show that aspects of both generic and specific pedagogical knowledge are important when using TDs. We found that the *knowledge of the student* aspect was the most frequently mentioned within pedagogical knowledge, similar to earlier research (Molenaar & Knoop-van Campen, 2019). This suggests that teachers consider knowledge about individual students, such as student levels, personalities, and abilities, to be the most essential for effectively using dashboards. However, in contrast to earlier research (Molenaar & Knoop-van Campen, 2019), we found that the *progress of the student* was not considered as important. Only two teachers in our study mentioned its significance. One possible explanation could be that, since the dashboard provides teachers with information on student

progress, they may not have explicitly mentioned the need for knowledge about *progress of the student* themselves, as the dashboard already provides this information. Another reason could be the difference between the earlier study and the current study, as we asked for more general perspectives, whereas the study of Molenaar and Knoop-van Campen was focused on specific classroom events. This prompted teachers to reflect on their overall approach to teaching rather than specific classroom situations.

Third, for contextual conditions, teachers identified both technology- and school-level factors as essential for effective TD use. Teachers mentioned the ALT program as the most important part of the technology-level factors, which is a logical connection given its interdependence with the TD. The findings regarding school-level factors, such as collaborating with colleagues or teacher training, align with the literature on technology implementation (Tondeur et al., 2008). We also found factors such as the need for more time and finances, which were not all covered in previous research on teachers' technology integration (Spiteri & Chang Rundgren, 2020). These conditions add to our understanding of important prerequisites and conditions for effectively working with a TD. The lack of prior identification of these conditions within the specific use of TDs can be explained because earlier research focused solely on the micro level of TD use (usually studying a specific activity or situation in the classroom), whilst we examined it on a macro level (asking about the deployment of the technology in the whole educational setting). The interconnectedness between micro and macro levels, particularly within educational settings, underscores the necessity of considering both in order to fully comprehend the dynamics at play. This, therefore, explains why it is likely that teachers in this study pointed out previously overlooked contextual conditions.

Finally, teachers also indicated different additional skills and knowledge required for using TDs. Teachers identified skills and knowledge related to the *ALT curriculum* and *general computer proficiency* as particularly important. This aligns with previous studies on teachers' technological competencies, which have shown these skills to be essential (Spiteri & Chang Rundgren, 2020). This study shows that these additional skills and knowledge are specifically relevant when using a dashboard, providing valuable insight into what teachers consider essential when working with these tools.

In general, the novelty of this study lies primarily in its focus on the perspectives of teachers already working with TDs and their views on what is essential for effectively engaging with this innovative technology. An addition to the scientific literature is that earlier research suggested a framework in which basic teacher characteristics might indirectly influence dashboard use via complex teacher characteristics, such as skills and knowledge (van Leeuwen et al., 2021). The results of this study provide support for and align (partly) with the complex teacher characteristics proposed in their suggested framework, showing what teachers who use dashboards find important from their perspective, namely pedagogical knowledge (generic and specific), data literacy, and additional skills and knowledge. Besides skills and knowledge, contextual conditions are influenced within the framework, divided into technology- and school-level aspects.

5.2. Limitations and Future Research

Some limitations can be put forward. First, we acknowledge that achieving a representative sample is challenging in qualitative research (Robinson, 2014). It is possible that teachers unwilling to use or incapable of using a TD were less likely to participate in this study, even though dashboards are available in their schools. Nevertheless, our participants were from various schools and taught different grades, providing a diverse perspective. Future research could look into capturing the perspectives of teachers who are less willing to work with a TD.

Second, the primary focus of our study was to gain more insight into teacher perspectives on the important aspects of effective dashboard use. We did not measure how certain factors directly influence teacher behaviours in the classroom when using the dashboards during the enactment stage of the Teacher Dashboard Use model (van Leeuwen et al., 2019). What teachers mention as needed could be different from their actual behaviour. However, our study provides valuable insights into the perspectives of teachers who use dashboards and highlights the potential complex teacher characteristics proposed in the TD use framework by van Leeuwen et al. (2021), depicting a broader range of factors that may influence the process. This is also a novel approach compared to previous research. For future research, it would be valuable to combine the actual enactment of teacher behaviours when using dashboards with the factors found in this study to truly test these components as an addition to the existing framework. This will offer deeper insight into these factors and how they influence teacher behaviour in the classroom, helping to explain the variation among teachers and allowing the proposed elements of the framework to be measured.

It's worth noting that this study was conducted with a broad perspective in mind, focusing on identifying essential skills, knowledge and contextual conditions. However, it may be important to examine whether different groups of teachers with varying levels of skills and knowledge have different needs, as it is believed that skills influence needs (Rodrigues et al., 2021). While there was no pre-assessment of skills and knowledge or categorization into teachers' skill groups, future research could explore this aspect more broadly by investigating potential differences in responses among groups with varying skill levels. Such research could help us better understand the factors contributing to skill development and identify ways to support individuals in their dashboard use.

5.3. Practical Implications

The insights gained from this study can inform the development of tailored professional development programs designed to enhance teachers' pedagogical knowledge, data literacy, and other skills and knowledge, ultimately improving the effectiveness of ALTs, LA, and TDs. As part of professional development, focusing on the skills and knowledge outlined in this study, particularly data literacy, is important. Data literacy directly links to the skills described in the Data Literacy for Teachers Framework (Mandinach & Gummer, 2016) and can guide teachers' professional development. Several papers put forward that an effective way to support learning these data literacy skills could be by focusing on short interventions wherein essential topics such as data types, scale transformation, and graphic displays are areas that can improve data literacy (Reeves & Honig, 2015; Merk et al., 2020). By thoroughly examining the various phases detailed within the framework and tailoring the approach to meet the unique needs of each individual teacher within these phases, it is possible to ensure a more impactful and successful development process.

The insights from this study can also be informative for school organizations aiming to enhance the effectiveness of TD implementation. With a clear understanding of what teachers prioritize, attention can be directed towards supporting the identified skills and knowledge; for example, by using peer learning, as teachers in this study emphasized the importance of developing skills with colleagues. Addressing contextual conditions as prerequisites, such as having a clear school vision at the school level and organizing lesson structures within the ALT at a technology level, is essential for successful implementation within the school context. It is also recommended to involve these teachers in order to enhance the process of integrating LA and dashboards.

6. Conclusion

This study demonstrated the significance of skills and knowledge in using TDs from the perspectives of teachers who use this technology daily. Teachers acknowledged that data literacy and pedagogical knowledge play an especially important role in using TDs. Furthermore, we showed the importance of contextual conditions at both the technology and school levels. With this study, we propose a direction for understanding TD use that opens up a new avenue of research focusing on teacher skills, knowledge, and contextual conditions when using TDs.

Declaration of Conflicting Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The publication of this article received financial support from Stichting Kennisnet.

Acknowledgments

The authors wish to thank the schools and teachers who participated in this study.

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Appendix A: Overview, Explanation, and Example of the Codes

Category	Explanation	Example
Pedagogical Knowledge		
Generic PK		
Domain-general rules of pedagogy	Teachers are familiar with pedagogy principles and factors that can impact learning, such as anxiety and attention disorders.	This age group finds it hard to concentrate for longer than 20 minutes.
Teaching methods	Teachers use a range of teaching methods and didactics to meet their student's diverse needs and create the best learning environment for each individual.	I know that for this lesson active learning is the best way to reach this goal.
Classroom management	Teachers are skilled in managing classrooms, ensuring student focus and engagement while overseeing multiple activities simultaneously.	I know that employing clear expectations and behaviour interventions is helping me maintain my classroom management.
Classroom assessment and evaluation	Teachers need to be proficient in both formative and summative assessments to evaluate student progress towards learning objectives.	I know that when I regularly gauge student understanding through quizzes and discussions, it allows me to adjust instruction and support student learning.
Specific PK		
Knowledge of the student	The teachers' awareness of students' knowledge or personal characteristics.	This student is weak in maths but has a high general intelligence.
Error analysis	The analysis of mistakes to determine the reason for these errors.	This student has a wrong conceptualization of double-digit numbers.
Progress of the student	The teachers' knowledge about the students' progress.	This student completed a lot of exercises today.
Characteristics of the class	The teachers' knowledge of the class's characteristics and knowledge.	This class has many dyslexic students.
Agreement with the class	Refers to the agreements that were made with a class.	We respect each other’s opinions.
Progress of the class	Refers to the progress of the class.	The whole class has worked well today.
Data Literacy		
Identify problems and frame questions	Teachers should be able to articulate a problem of practice, understand the context at the student and school level and involve other stakeholders.	Over the next few weeks, I'll investigate whether this student consistently achieves below average scores.
Use data	Teachers should be able to identify, understand, find, locate, select and use different (qualitative and quantitative) data sources.	I am going to check this student’s notes to see if I can find the mistake they are making.
Transform data into information	Teachers should be able to understand how to interpret data, how to use data displays, (basic) statistics, summarize and explain data and assess patterns and trends.	This graph is showing me that the student made a lot of mistakes over and over again.
Transform information into decision	Teachers should be able to determine the next instructional steps, diagnose students' needs and monitor student performance.	This student is making mistakes so I will give him feedback on his task.
Evaluate outcomes	Teachers should be able to re-examine the original question or problem and compare performance pre- and post-decision, monitor student and classroom changes and evaluate.	I have given extra task feedback and see that it is helping him to achieve the learning objective.

Other knowledge and skills		
ALT curriculum knowledge	Knowledge of the curriculum, lesson structure and learning goals within the ALT.	I understand how the learning goals are structured within the educational content of the ALT.
Computer proficiency	The ability to effectively use computers and related technologies for various tasks, including basic operations, software applications, and internet navigation.	I can navigate the computer in a way I need.
Child-oriented data presentation skills	Proficiency in effectively conveying information to children through age-appropriate formats and techniques.	I translate the data for my students in a way that they understand it.
Understanding artificial intelligence	Proficiency in comprehending the principles, applications, and implications of AI technologies.	I understand that AI determines the next task for the student based on patterns.
Adapting to rapid digital changes	Being able to deal with the rapid changes in the digital world.	
Contextual conditions		
Technology level		
Lesson structures within ALT	The way that instructional formats and content within the ALT are organized and coherent to facilitate effective teaching and learning.	The structure of the educational content does not help me with teaching the students the right goal.
Teacher autonomy concerning ALT	The level of independence granted to teachers in using and customizing ALT to their preferences.	I can adjust the pacing of lessons and customize content to suit the diverse needs of my students.
Practical operation	Using the technology without any bugs and errors.	It doesn't help when the technology is frozen or when it takes ages to load the next frame.
TD interface	The user interface designed for teachers to access and manage educational data, resources, and tools within the ALT.	The interface of the dashboard gives me the right data that I need to streamline my workflow.
The connection with other subjects	The incorporation of cross-disciplinary concepts, methodologies, or content from various subjects into the teaching and learning process.	The words students need to read during the maths lessons are harder than they learned during their language lessons.
School level		
School vision	The overarching goals, values, and aspirations that guide the direction and development of the school or educational organization.	In alignment with our vision, we prioritise using the technology every lesson.
Developing with colleagues	Collaborative efforts among educators to enhance their skills, knowledge, and teaching practices through shared learning experiences and mutual support.	We exchange best practices to explore how we can develop the use of this technology.
Additional course or training on ALT/TD	Professional development focusing on enhancing proficiency in ALT/TD.	I would like to enrol in an additional course on ALT/TD.
(more) time	Additional time beyond the standard teacher activities.	I can use more time to delve more deeply into the technology.
Managing multiple groups	Effectively managing and coordinating activities, instruction, or responsibilities for multiple students.	At the same time, I am employing different instructions to the multiple student groups within my classroom.
More/other devices	Additional or other devices.	It would be nice if every student had a Chromebook during the lesson.
Financial budget	Financial budget.	We would like to acquire more money to buy this technology for every classroom.

Appendix B: Interview Questions

1. The questionnaire revealed whether or not you look at the dashboard in preparation for the lesson. Do you make this choice consciously, and why do you choose to do this or not?
2. Are you satisfied with the dashboard used at your school?
3. Do you review the dashboard after you have given the lesson?

8 questions about teachers' perceptions of using the dashboard:

4. What are the specific reasons you use the teacher dashboard?
5. How frequently do you use the dashboard and the adaptive learning technology during a normal schoolweek?
6. How does the information from the dashboard help you in giving your lessons?
7. Which information do you use the most? What do you mostly focus on?
8. At what moments do you use the information from the dashboard during your lessons?
9. Is the use of the dashboard in line with your vision on education?
10. Are you, in your opinion, able to work well with the dashboard?
11. Do you use all the information from the dashboard?

4 questions about skills and knowledge:

12. What types of skills and knowledge, in your opinion, are important when working with a teacher dashboard?
13. Do you need specific skills and knowledge to work with a dashboard?
14. What would you like to develop further to use the dashboard more effectively?
15. Do you find some types of knowledge and skills more important than others for effectively using the dashboard?

3 questions about perspectives on contextual conditions:

16. Are there factors that, in your opinion, influence or support the effective use of the dashboard?
17. Which of these factors help or hinder you in your current situation
18. Do you find certain 'external' factors more important than others for effectively using the dashboard?