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Following the Impact Chain of the LA Cockpit: An Intervention Study Investigating a Teacher Dashboard's Effect on Student Learning

Onur Karademir[1,2], Lena Borgards[3], Daniele Di Mitri[4], Sebastian Strauß[5], Marcus Kubsch[6], Markus Brobeil[7], Adrian Grimm[8], Sebastian Gombert[9], Nikol Rummel[10], Knut Neumann[11] and Hendrik Drachsler[12,13]

Abstract

This paper presents a teacher dashboard intervention study in secondary school practice involving teachers (n = 16) with their classes (n = 22) and students (n = 403). A quasi-experimental treatment-control group design was implemented to compare student learning outcomes between classrooms where teachers did not have access to the dashboard and classrooms where teachers had access to the dashboard. We examined different points in the impact chain of the "LA Cockpit," a teacher dashboard with a feedback system through which teachers can send feedback to their students on student learning. To investigate this impact chain from teacher use of dashboards to student learning, we analyzed 1) teachers' perceived technology acceptance of the LA Cockpit, 2) teacher feedback practices using the LA Cockpit, and 3) student knowledge gains as measured by pre- and post-tests. The analysis of n = 355 feedback messages sent by teachers through the LA Cockpit revealed that the dashboard assists teachers in identifying students facing difficulties and that teachers mostly provided process feedback, which is known to be effective for student learning. For student learning, significantly higher knowledge gains were found in the teacher dashboard condition compared to the control condition.

Notes for Practice

- The evidence that teacher dashboards benefit student learning is insufficient, even though their ultimate goal is to support learning.
- This study examines the effect of a teacher dashboard with an integrated feedback system on 1) teachers' perceived technology acceptance, 2) their feedback practices, and 3) student learning using a quasi-experimental treatment-control group design in an authentic secondary school setting.
- Findings provide evidence that when a teacher dashboard is designed for feedback interventions, it can assist teachers in delivering effective feedback to their learners and enhance student knowledge gains. To facilitate the adoption of dashboards in teachers' daily practice, further empirical research is needed to determine which specific features of teacher dashboards and the educational settings in which they are used positively impact student learning.

Keywords: Teacher dashboards, K–12, intervention study, feedback systems, knowledge gain, authentic educational settings

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Corresponding author [1]Email: o.karademir@dipf.de Address: Institute of Computer Science, Goethe University Frankfurt, Robert-Mayer-Straße 11-15, 60325 Frankfurt, Germany. ORCID iD: https://orcid.org/0000-0002-6985-4202

[2]Address: DIPF – Leibniz Institute for Research and Information in Education, Rostocker Str. 6, 60323 Frankfurt, Germany.

[3]Email: lena.borgards@rub.de Address: Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany. ORCID iD: https://orcid.org/0009-0009-0739-590X

[4]Email: d.dimitri@dipf.de Address: Leibniz Institute for Research and Information in Education, Rostocker Str. 6, 60323 Frankfurt, Germany. ORCID iD: https://orcid.org/0000-0002-9331-6893

[5]Email: sebastian.strauss@rub.de Address: Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany. ORCID iD: https://orcid.org/0000-0002-0647-1132

[6]Email: m.kubsch@fu-berlin.de Address: Freie Universität Berlin, Kaiserswerther Str. 16-18, 14195 Berlin, Germany. ORCID iD: https://orcid.org/0000-0001-5497-8336

[7]Email: brobeil@econ.uni-frankfurt.de Address: Goethe University Frankfurt, Theodor-W.-Adorno-Platz 4, 60323 Frankfurt, Germany. ORCID iD: https://orcid.org/0009-0000-7128-4352

[8]Email: grimm@leibniz-ipn.de Address: Leibniz Institute for Science and Mathematics Education, Olshausenstraße 62, 24118 Kiel, Germany. ORCID iD: https://orcid.org/0000-0003-2701-3349
[9]Email: s.gombert@dipf.de Address: DIPF – Leibniz Institute for Research and Information in Education, Rostocker Str. 6, 60323 Frankfurt, Germany. ORCID iD: https://orcid.org/0000-0001-5598-9547
[10]Email: nikol.rummel@rub.de Address: Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany. ORCID iD: https://orcid.org/0000-0002-3187-5534
[11]Email: neumann@leibniz-ipn.de Address: Leibniz Institute for Science and Mathematics Education, Olshausenstraße 62, 24118 Kiel, Germany. ORCID iD: https://orcid.org/0000-0002-4391-7308
[12]Email: drachsler@em.uni-frankfurt.de Address: Institute of Computer Science, Goethe University Frankfurt, Robert-Mayer-Straße 11-15, 60325 Frankfurt, Germany. ORCID iD: https://orcid.org/0000-0001-8407-5314
[13]Email: h.drachsler@dipf.de Address: Leibniz Institute for Research and Information in Education, Rostocker Str. 6, 60323 Frankfurt, Germany. ORCID iD: https://orcid.org/0000-0001-8407-5314

1. Introduction

Observing and assessing student performance in the classroom is a key responsibility of teachers (Schrader & Helmke, 2001). Teachers, hence, need the skills to monitor student actions (Broadfoot et al., 2002) and make appropriate decisions on how to support student learning (Hoth et al., 2016). Although monitoring and decision-making are essential skills for teachers, putting these skills into practice can be challenging (Hoth et al., 2016), especially with class sizes of 20 students or more (Ngoc Anh et al., 2019). One way to mitigate this challenge is the use of teacher dashboards. Teacher dashboards are visual displays that show teachers relevant information about student learning activities and progress. These tools can help teachers enhance their practices by informing their interventions, decision-making, and learning design (van Leeuwen et al., 2022; Wise & Jung, 2019).

Research on teacher dashboards has predominantly focused on its influence on teaching-related aspects (Kaliisa et al., 2023; van Leeuwen et al., 2022). This includes examining teacher perspectives on usability (Rienties et al., 2018; van Leeuwen, 2019), their awareness and sense-making of student activities (Campos et al., 2021; Molenaar & Knoop-van Campen, 2019; van Leeuwen et al., 2019), and the subsequent actions they undertake to impact learning (Knoop-van Campen et al., 2023). However, the effect of teacher dashboards on teaching practices and on resulting student learning has rarely been empirically examined (Motz et al., 2023). While teacher dashboards primarily have been found to assist teachers (Knoop-van Campen et al., 2023; Molenaar & Knoop-van Campen, 2019), their ultimate purpose is to understand and optimize learning in order to benefit students (Siemens & Long, 2011). However, only a limited number of studies have gone beyond analyzing teacher actions to trace the causal chain, examining the effects of teacher dashboards on student learning (van Leeuwen et al., 2022).

To address this research gap, this paper presents a quasi-experimental study that investigates the effect of a teacher dashboard on the feedback practices of secondary school teachers and, eventually, on student learning. To investigate this impact chain from the use of the LA Cockpit—a teacher dashboard with a feedback system—over teacher feedback practices to student learning in terms of knowledge gain, we analyzed 1) teachers' perceived technology acceptance of the LA Cockpit, 2) teacher feedback practices using the LA Cockpit, and 3) student knowledge gains measured by pre- and post-tests.

2. Background and Related Work

2.1. Teacher Dashboards

Monitoring and assessing individual student learning in the classroom is challenging (Lodge et al., 2018; Ngoc Anh et al., 2019). Here, teacher dashboards can help monitor student performance and progress, which the teacher can then utilize to tailor teaching to student needs (Greller & Drachsler, 2012; Verbert et al., 2013). Teacher dashboards serve as visual displays, providing teachers with learning-related information about students, allowing teachers to obtain information that has not yet been available to them through their traditional monitoring (Xhakaj et al., 2017). However, studies have shown that teachers often struggle to interpret the information from a dashboard and derive adequate pedagogical actions, for instance, in the form of feedback (Sergis & Sampson, 2017; van Leeuwen et al., 2019). One reason for this difficulty in deriving interventions from dashboards is that the vast majority of teacher dashboards are designed to display student data and increase awareness rather than to support instructional interventions like feedback (Jivet et al., 2017; Kaliisa et al., 2023), despite the primary objective to encourage teachers to take action and improve student learning (Verbert et al., 2013).

2.2. The Impact of Teacher Dashboards

The ultimate goal of teacher dashboards is to support student learning (Banihashem et al., 2022). However, a teacher dashboard does not immediately support student learning processes. Instead, the dashboard is meant to inform teacher actions. Teacher actions, in turn, should then affect student learning (van Leeuwen et al., 2022). Before teachers can derive appropriate actions from the information in a dashboard, they need to accept the dashboard as a helpful tool (Rienties et al., 2018). Therefore, a dashboard needs to be accepted as a technology by the target group to be able to positively impact teacher practices and, subsequently, student learning (Rienties et al., 2018).

According to Xhakaj et al. (2017), the impact of teacher dashboards could be causally linked to the provision of monitoring support to teachers through information about student performance and the subsequent pedagogical actions based on this interpreted information by teachers, which should finally support student learning. In this study, we extended this causal chain by adding the element of teachers' technology acceptance of a dashboard as a prerequisite for the effective use of dashboards by teachers. The current study, therefore, examines an impact chain starting from 1) teacher dashboard technology acceptance to 2) teacher monitoring and their pedagogical actions in the form of feedback to 3) the effect on learning. In this impact chain of teacher dashboards on student learning, feedback can be considered *the* central element.

Feedback is crucial for learning (Butler & Winne, 1995) because it serves as a source of information for the learners' own regulation of learning (Magill, 1994). It has one of the strongest effects on student learning (Hattie, 2012; Wisniewski et al., 2020) and can be considered a core element of successful instructional practices (Lipnevich & Panadero, 2021). Following the feedback model of Hattie and Timperley (2007), feedback should inform about intended learning goals and related criteria of performance (Feed Up), as well as informing about the learning progress (Feed Back) and how to further improve the learning performance (Feed Forward). Feedback can address different levels: Task-related feedback establishes a basis for students to initiate self-regulation and engage in the learning process. Process-related and metacognitive feedback are particularly effective in promoting learning (Hattie & Timperley, 2007), as they aid students in self-regulation and the development of learning strategies (Hattie, 2012). Personal feedback, however, offers limited information pertinent to furthering engagement in the learning process (Hattie & Timperley, 2007).

So far, several studies have examined the relationship between the use of teacher dashboards and the resulting impact on teacher feedback practices (Kaliisa et al., 2023; van Leeuwen et al., 2022). Molenaar and Knoop-van Campen (2017) found that pedagogical actions initiated by teachers are primarily directed to low-ability students, whereas actions taken after consulting a dashboard target middle- and high-ability students. In subsequent studies, they further found that teachers who frequently consulted dashboards activated more diverse pedagogical knowledge compared to teachers with low dashboard usage. Additionally, dashboard usage led to the provision of more feedback, particularly task- and process-related feedback (Knoop-van Campen & Molenaar, 2020; Molenaar & Knoop-van Campen, 2019).

According to Knoop-van Campen et al. (2023), dashboard-prompted feedback promotes the equal provision of different feedback types among all performance levels. Without using teacher dashboards, teachers provide more task-related and less process-related feedback to low-performing students compared to high-performing students. Teachers thus aim their pedagogical actions with the support of teacher dashboards to a greater extent at students with an intermediate or higher performance level. Teacher dashboards, therefore, seem to aid teachers in the provision of effective feedback to their students to support learning.

While existing studies investigated the usability of teacher dashboards and their impact on teacher feedback practices, few studies have empirically investigated the indirect effects of teacher dashboards on student learning (van Leeuwen et al., 2022). The two studies analyzing the impact of teacher dashboards on student learning (Martinez-Maldonado et al., 2015; Xhakaj et al., 2017) present contrasting findings. Martinez-Maldonado et al. (2015) observed enhanced student learning when teacher interventions were informed by a dashboard with alerts. Conversely, the study by Xhakaj et al. (2017) employing a quasi-experimental treatment-control group design with the treatment condition using a teacher dashboard for preparing lesson plans, revealed no positive effects on student learning.

Beyond the impact of teacher dashboards, Motz et al. (2023) highlighted the need for more empirical research on the impact of LA interventions on learning outcomes in general. They advocate for the deployment of experimental LA interventions in authentic educational settings within existing learning environments. These measures could enable progress toward optimizing student learning environments.

2.3. Research Questions

The present study addresses this need for systematic research by investigating the efficacy of teacher dashboards for teachers as well as for students in an authentic educational context. In an intervention study with a quasi-experimental design, we investigated the impact chain of the LA Cockpit, that is, how the use of a teacher dashboard affects teacher feedback practises and, subsequently, impacts student learning outcomes. To trace the impact chain between using the LA Cockpit and supporting the learning process, the following research questions (RQs) will be considered:

RQ1: What is the perceived usefulness and ease of use of the LA Cockpit?

RQ2: How does the use of the LA Cockpit inform teacher feedback practices? What information triggers feedback to students? Which types of feedback are sent to students across different performance levels?

RQ3: What is the impact of utilizing the LA Cockpit on student learning in terms of knowledge gain in comparison to students whose teachers do not have access to the LA Cockpit?

3. Methods

The present study was conducted as an intervention study with a quasi-experimental treatment-control group design with 22 classes from German secondary schools. The legal and ethical obligations associated with conducting a field study in German schools were met. Ethical approval was obtained, and the data was collected in compliance with the General Data Protection Regulation. Additionally, an application was submitted to and approved by the Ministry of Education responsible for data collection. All participating teachers and the parents of all participating students provided written informed consent before voluntarily taking part in the study. Furthermore, we want to highlight that the current study is conducted in the context of K–12, which is so far an underrepresented application field within the LA community.

3.1. Sample

The sample consisted of 16 teachers with their 22 classes and 403 students. Teachers were offered two different instructional physics units—“Laptop” and “Solar Cell”—to choose from based on the school’s curriculum. Both units were designed to teach the students about energy in physics education. Three teachers chose the Laptop unit (n_students = 101), and 13 teachers chose the Solar Cell (n_students = 302). The classes included 7th and 8th grade classes. The sample includes only students who completed both the pre-test and the post-test.

Within the two units, seven teachers were provided with the LA Cockpit as a teacher dashboard (treatment condition), and nine teachers were solely teaching the units without the LA Cockpit (control condition). The students were hence subject to one of two conditions as follows: 1) the treatment condition, in which the LA Cockpit was used by the teachers, consisting of 179 students from nine classes guided by seven teachers, and 2) the control condition, where the teachers had no access to the LA Cockpit, consisting of 224 students from 13 classes instructed by nine teachers (see Table 1).

Table 1. Sample Sizes of Students from the Control and Treatment Condition in Both Units

Condition	N	N_Laptop	N_Solar Cell
Control	224	55	169
Treatment	179	46	133
Total with outliers	403	101	302
Total without outliers[1]	393	97	296

3.2. Design and Procedure

Participants were recruited in two different time periods. Data collection for the treatment condition took place between January and June 2023, while data for the control condition was gathered from November 2021 to March 2022. The data collection for both conditions was organized class by class, with each class’s data collection period lasting approximately six weeks. The study design is illustrated in Figure 1. Before the data collection, every teacher in both the treatment and control conditions underwent a 60-minute training session on how to implement the physics units in their classes. Teachers in the treatment condition received an additional 30-minute training on how to use the LA Cockpit during the units. After the pre-test, teachers and their students began working in class through a technology-enhanced instructional physics unit with embedded formative assessment. The total duration of the units was four 90-minute lessons. The treatment condition teachers used the LA Cockpit throughout the unit as part of their instruction, enabling them to provide feedback to their students. After the first, second, and third lessons, LA Cockpit sessions were conducted with the teachers. Teachers were asked about the insights they could derive from the LA Cockpit and were asked to use the tool to provide feedback to their students. Subsequently, a post-test was conducted for the treatment and control conditions.

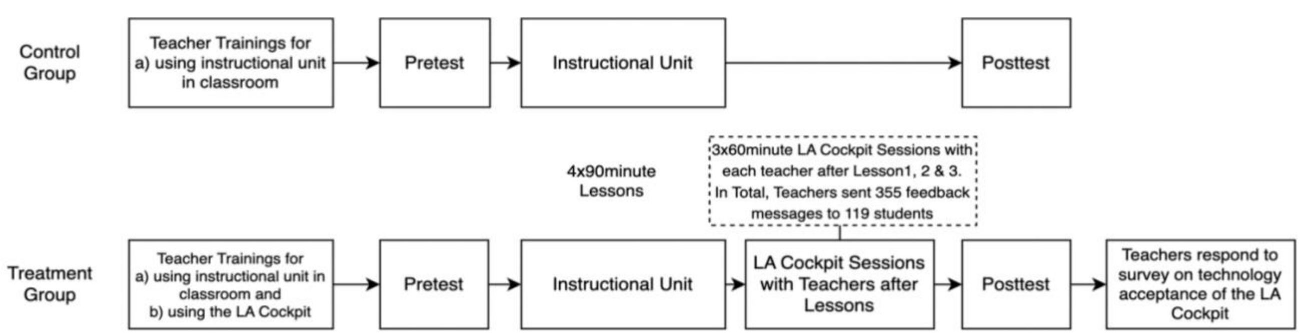

Figure 1. Study procedure.

[1] See Section 3.5 Data Analysis for explanation.

3.3. Materials

Instructional Unit. The two instructional units consisted of two technology-enhanced instructional physics units on the topic of energy. Teachers chose one of the units, and students worked on the chosen unit on laptops or tablets that we provided. One unit focused on solar cells and the question of how solar cells should be placed on a house to convert as much energy as possible. The other unit focused on the question of why laptops sometimes get hot. Both units followed a project-based pedagogy (Krajcik & Shin, 2014). The units were accompanied by a formative assessment implemented in Moodle, which included 36 instructional tasks that students worked through. Tasks with a closed-question format were scored automatically by Moodle, and the free-text answers were scored automatically using a natural language processing model developed by Gombert et al. (2023). Using evidence-centred design, the 36 tasks were linked to learning goals in advance by a team of physics education experts; the learning goals describe the energy concepts addressed in each task (Kubsch et al., 2022).

LA Cockpit. The LA Cockpit is 1) a teacher dashboard that provides teachers with visualizations of results from formative assessment and 2) a feedback system that supports teachers in providing feedback to students. A previous co-design study was conducted with secondary school teachers (Karademir et al., 2024) to define the requirements for the LA Cockpit, which was implemented in this study. The LA Cockpit sourced its data from student responses to the formative assessment conducted within the instructional units. The tool has multiple views and a feedback system with which teachers can send feedback to their students: The *Class Overview* provides a summary of the overall class performance by displaying the distribution of students across four performance levels. The *Task View* allows teachers to track each student's performance on each task (Figure 2). The *Learning Goal View* shows each student's results on the learning goals covered in the formative assessments within the units. To address possible colour blindness, teachers could switch to an alternative, inclusive colour coding. The LA Cockpit is intended to be used as follows: Teachers can view the dashboard visualizations to draw insights from them and identify students who need feedback. Teachers then can select an individual or group of students based on their performance to send them personalized feedback messages by clicking on their data visualizations.

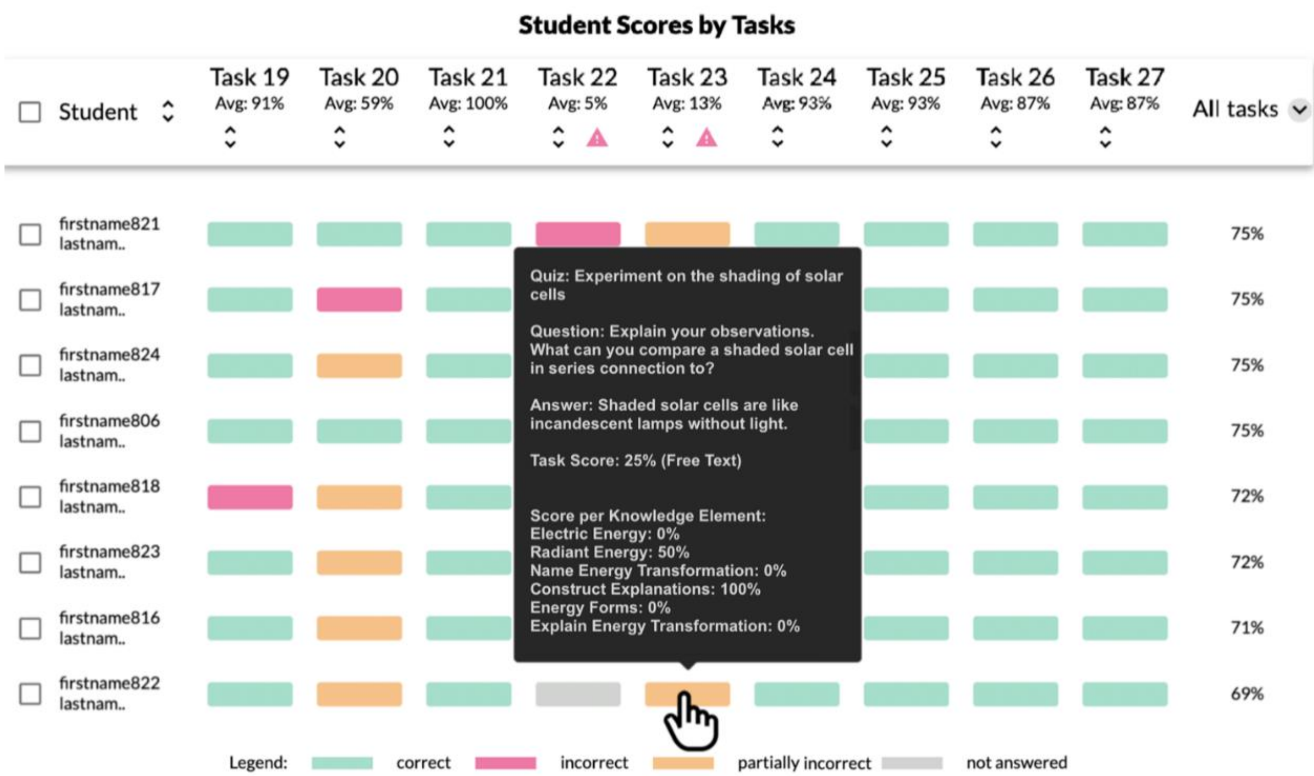

Figure 2. The Task View of the LA Cockpit. Teachers can send personalized feedback to each student by clicking on their corresponding cell or select groups of students to send group feedback.

For instance, in the Task View (Figure 2), when clicking on a cell that visualizes a student's score (e.g., partially incorrect), the feedback template in Figure 3 opens, allowing teachers to refer to the performance in the selected task. The system logged whether feedback was triggered by information that indicates good performance (e.g., when sending feedback by clicking on a green cell) or low performance (e.g., when sending feedback by clicking on an orange or red cell).

When the feedback window opens, teachers can send feedback to their students with the help of a feedback template. The template is structured in such a way that positive feedback about the student's achievements toward their learning goals should be written first ("What went well?"), followed by corrective feedback addressing weaknesses ("What didn't go so well?"). To make the feedback actionable and provide students with *Feed Forward* information (Hattie & Timperley, 2007), the third input field is labelled "recommendation." The feedback template furthermore provides suggested boilerplate texts (that can be edited) based on the selected student's current assessment results in a rule-based way. Feedback, whether to an individual or a group, is always delivered individually through the Moodle environment as a private message with a notification.

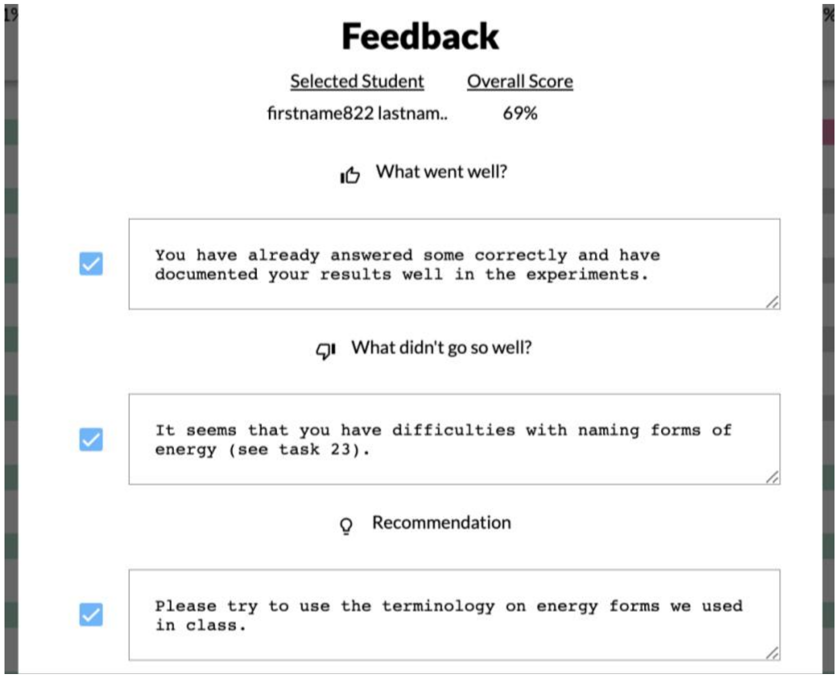

Figure 3. The feedback template consists of four input fields (positive feedback, corrective feedback, recommendations, and miscellaneous) and suggested feedback texts, which are editable.

3.4. Measures

Usefulness and Ease of Use. To measure how teachers perceived the usefulness and ease of use of the LA Cockpit, teachers from the treatment condition answered a survey that included the Technology Acceptance Model (TAM; Davis, 1985) questionnaire. The questionnaire contained a total of 12 items, six of which related to perceived usefulness (PU), such as *"Using this dashboard in my work would allow me to complete tasks faster,"* and the remaining six related to perceived ease of use (PEU), such as *"I would find it easy to learn how to use this dashboard."*

Teaching experience and prior experience. The survey also collected teachers' years of teaching experience and whether they had prior experience using a dashboard.

Feedback purposes and types. To assess the effect of the teacher dashboard on the feedback practices of teachers, the given feedback was classified. Feedback was logged through the implemented feedback system in the teacher dashboard. The feedback was first coded as positive or corrective feedback or as a recommendation to show the intended purpose. Positive feedback praises learners for correctly completing tasks and making progress (Watts, 2007), while corrective feedback addresses students' incorrect task responses and highlights their knowledge gaps (Li, 2010). Feedback as a recommendation serves as *Feed Forward* (Hattie & Timperley, 2007), guiding students on the necessary actions to achieve their learning goals.

In a second step, we classified the type of feedback based on the feedback classification system by Knoop-van Campen et al. (2023). Table 2 displays Cohen's kappa scores for the feedback types, along with examples. Task-related feedback refers to the outcome and content of a task assignment, whereas process-related feedback relates to the student's approach to a task and can help to change strategies of task completion. Personal feedback praises the students themselves and does not relate to the characteristics or content of a task. Metacognitive feedback refers to student planning, monitoring, evaluating, or reflecting on their own learning and should further support their metacognitive processes, while social feedback relates to the social skills or co-operative competencies of students and should promote co-operative learning between the students (Hattie, 2012; Knoop-van Campen et al., 2023).

A single feedback message could be assigned to multiple feedback types. The data was coded by two raters. Moderate to perfect interrater agreement was reached (Landis & Koch, 1977). Cohen's kappa was 0.95 for positive feedback, 0.85 for corrective feedback, and 0.91 for recommendation feedback. Regarding the type of feedback, a Cohen's kappa score of 0.7 for task-related feedback, 0.62 for process-related feedback, 0.68 for personal feedback, 0.5 for metacognitive feedback, and

1 for social feedback can be reported. To further ensure the quality of these particular variations and the overall data, disagreements between raters were resolved by discussion until an agreement was reached. The analyses were thus based on a consistent coding of the teacher feedback.

Table 2. Cohen's Kappa Scores and Examples for the Different Feedback Types

Feedback type	Cohen's kappa	Examples
Task-related	0.7	"Your average score on this learning objective is 58%."
Process-related	0.62	"Practise writing texts on a topic in which you use the relevant terminology."
Personal	0.68	"Well done!!"
Metacognitive	0.5	"The only task you didn't work on was the second one. Did you miss it?"
Social	1	"Try to exchange your answers with a classmate before submitting your answer."

Energy Knowledge Gain (pre- and post-test). To measure student knowledge gains before and after the unit, students completed the Energy Concept Assessment, which was developed and validated by Neumann et al. (2013). The assessment tests students' conceptual understanding of energy as a core concept of physics. The pre-test contained 10 items, and the post-test included the same 10 items along with an additional 10 items related to these concepts. The Rasch model (DeMars, 2010) was used to scale the test and compute student ability. The infit of the items was sufficient, between 0.7 and 1.3 (Bond & Fox, 2015). The Weighted Likelihood Estimates (WLEs) for person separation reliability were found to be 0.70.

3.5. Data Analysis

To analyze the impact of the teacher dashboard on student learning in terms of knowledge gain, RQ1 will be addressed by the technology acceptance survey to show how teachers perceive and use the LA Cockpit. To answer RQ2, we analyzed which feedback teachers give to their students. The Kruskal-Wallis-Test is used to investigate the distribution of process-related feedback between students of different performance levels. Also, to investigate how the teacher dashboard affected student learning indirectly (RQ3), the control and treatment conditions in the two physics units were compared in terms of student knowledge gains measured using pre- and post-test scores. Before conducting the analyses for RQ3, we identified and removed 10 outliers, resulting in n = 393 student subjects instead of 403. Outliers were defined as any values falling outside the range of –1.5 times the interquartile range (IQR) to 1.5 x IQR. Subsequently, we conducted t-tests to compare the knowledge gains between the experimental conditions. The interpretation of the effect sizes is based on the work by Cohen (1988), which classifies effects with an effect size of 0.2 as small, effect sizes from 0.5 as medium and effect sizes of 0.8 or higher as strong.

4. Results

4.1. RQ1: What is the perceived usefulness and ease of use of the LA Cockpit?

To assess the usefulness and ease of use of the LA Cockpit, we surveyed seven teachers utilizing the TAM questionnaire (Davis, 1985). None of the surveyed teachers had prior experience using a teacher dashboard in their instruction before our study. Teacher responses to the items resulted in a mean TAM score of 4.95 (*SD* = 1.61), representing the mean of the PU and PEU scores (Davis, 1985). The TAM, PU and PEU scores can range from 1 to 7. The overall mean PEU score was 5.33 (*SD* = 1.93), surpassing the PU score, which averaged 4.57 (*SD* = 1.45) points. Notably, one teacher stood out by rating the dashboard very low, with a PU score of 1.83, PEU score of 2.33, and a TAM score of 2.08.

4.2. RQ2: How does the use of the LA Cockpit inform teacher feedback practices?

Overall, the teachers sent 355 feedback messages to 119 students. Students were provided with feedback between one and eight times during the physics units. Of the 179 students whose teacher could have used the teacher dashboard, 60 students did not receive any feedback at all. Teachers sent 74.37% (n = 264) of the feedback messages to a group of students, whereas 25.63% (n = 91) of feedback messages addressed individual students.

Feedback trigger. Information in the dashboard that indicated success or good performance triggered 38.03% (n = 135) of the feedback messages, while information pointing out errors or difficulties triggered 56.62% (n = 201) of messages. For 5.35% (n = 19) of the feedback, the trigger could not be determined exactly; for example, when a teacher gave students feedback on several tasks without selecting a single task.

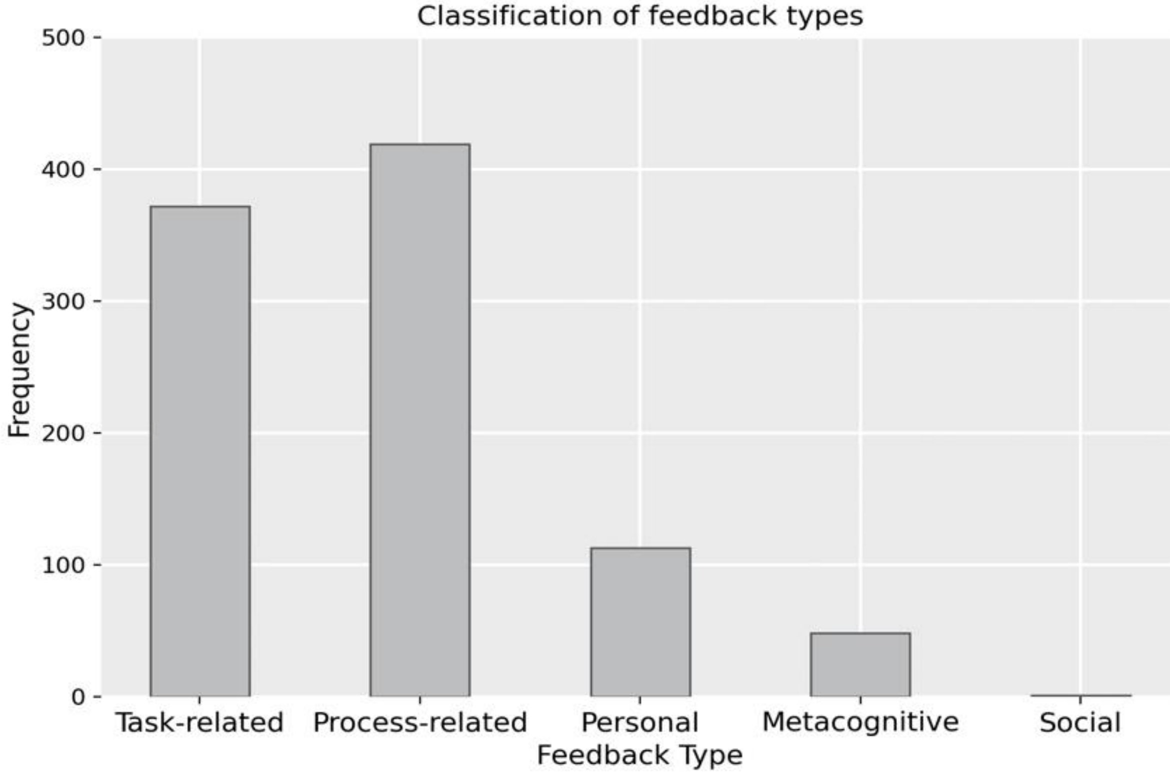

Figure 4. Distribution of the feedback types within the coding of the given feedback.

Feedback types. The coding shows that teachers provided their students mainly with process- and task-related feedback, with a higher proportion of process-related feedback (see Figure 4). Specifically, 43.97% (n = 419) of the feedback sent to students could be classified as process-related feedback, whereas 39.03% (n = 372) was task-related, 11.86% (n = 113) was personal feedback, 5.04% (n = 48) was metacognitive feedback, and 0.1% was social feedback (n = 1).

Feedback distribution among performance levels. Student performance levels were determined based on their scores in the pre-test. The lower performance level included students in the lowest 25% quartile (n = 35). The middle-performance level consisted of the middle 50% of students (n = 61), and the higher performance level was assigned to the top 25% of students (n = 23). Among the students, 30% (15 students) in the low-performance level, 35.8% (34 students) in the medium-performance level, and 32.4% (11 students) in the high-performance level did not receive feedback. A Chi-squared test showed no significant relationship between student performance levels in the pre-test and receiving feedback ($\chi^2(2) = 0.518$, $p = 0.772$). A Kruskal-Wallis test found that teachers provided similar amounts of process-related feedback to low-performing students (M = 3.88, SD = 2.72), medium-performing students (M = 3.69, SD = 2.99), and high-performing students (M = 2.69, SD = 2.26) throughout the unit. Analysis revealed no significant difference in the quantity of process-related feedback between students with different performance levels (h = 2.91, p = 0.233). Further, post-hoc analysis showed no significant differences between high- and medium-performing students (p = 0.539), high- and low-performing students (p = 0.281), or medium- and low-performing students (p = 1) in the quantity of process-related feedback. Looking in detail at the distribution of task-related feedback across different performance levels, low-performing students received an average of 2.68 times (SD = 2.21), medium-performing students received it 3.26 times (SD = 3.09), and high-performing students received it 3.56 times (SD = 1.9). A Kruskal-Wallis test indicated no significant difference in the distribution of task-related feedback between these performance levels (h = 3.342, p = 0.188).

4.3. RQ3: What is the impact of using the LA Cockpit on student learning?

To determine the impact of using the LA Cockpit on student learning, a one-tailed independent sample t-test was performed among both units to compare the knowledge gain of students from the control condition (n = 167 in the Solar Cell Unit; n = 53 in the Laptop Unit) whose teachers had no access to the LA Cockpit and from the treatment condition (n = 129 in the Solar Cell Unit; n = 44 in the Laptop Unit), whose teachers used the dashboard during the instructional physics unit. We conducted one-tailed t-tests, as we hypothesize that the LA Cockpit has a positive impact on student knowledge gains. Figure 5 displays the scores of both the pre-test and post-test, while Table 3 provides the means and standard deviations for both tests as well as the knowledge gains.

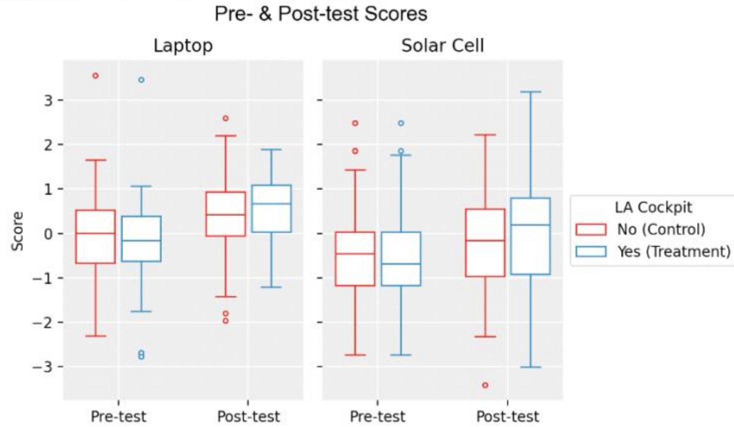

Figure 5. Students' pre- and post-test scores.

Table 3. Pre-Test, Post-Test and Knowledge Gain Means and Standard Deviations (n = 393 students, 10 outliers excluded)

		Pretest		Post-test		Knowledge Gain	
	N	Mean	SD	Mean	SD	Mean	SD
Control Laptop Unit	53	0.13	1.01	0.45	0.95	0.33	0.95
Treatment Laptop Unit	44	–0.27	0.95	0.52	0.70	0.80	0.79
Control Solar Cell Unit	167	–0.48	0.95	–0.17	1.02	0.31	0.91
Treatment Solar Cell Unit	129	–0.53	1.03	0.08	1.08	0.61	0.83

Table 4. One-Tailed T-Test Results with Cohen's d for Student Knowledge Gains

	T-value	df	p	Cohen's d
Laptop Unit	2.62	95	.01	0.53
Solar Cell Unit	2.97	294	.003	0.34

Our analyses revealed a statistically significant difference (t(294)=2.97, p = .003) between the knowledge gain of the control condition (M = 0.31, SD = 0.91) and the treatment condition (M = 0.61, SD = 0.83) of students from the Solar Cell units in favour of the treatment condition (see Figure 6). The effect size, as measured by Cohen's d, was d = 0.34, indicating a small effect (see Table 4). Similarly to the Solar Cell unit, a statistically significant difference (t(95) = 2.62, p = .01) was also observed in the knowledge gain between the control condition (M = 0.33, SD = 0.95) and the treatment condition (M = 0.8, SD = 0.79) within the Laptop unit, favouring the treatment condition (see Figure 6). The effect size, measured by Cohen's d, was d = 0.53, indicating a medium effect (see Table 4).

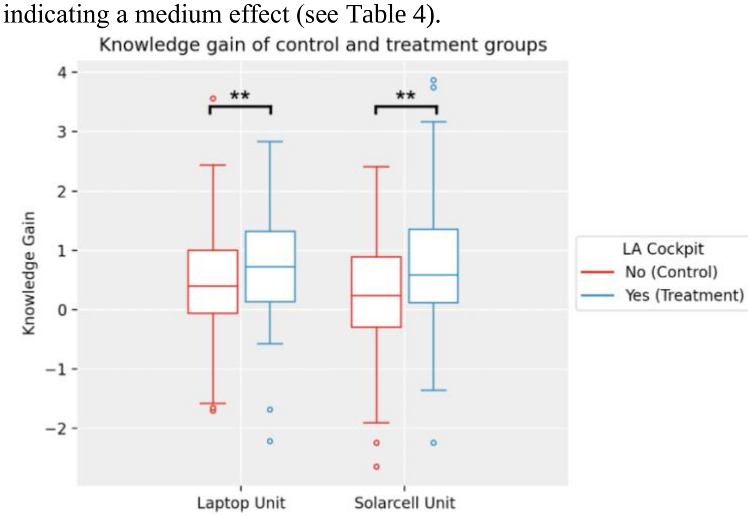

Figure 6. Student knowledge gains.

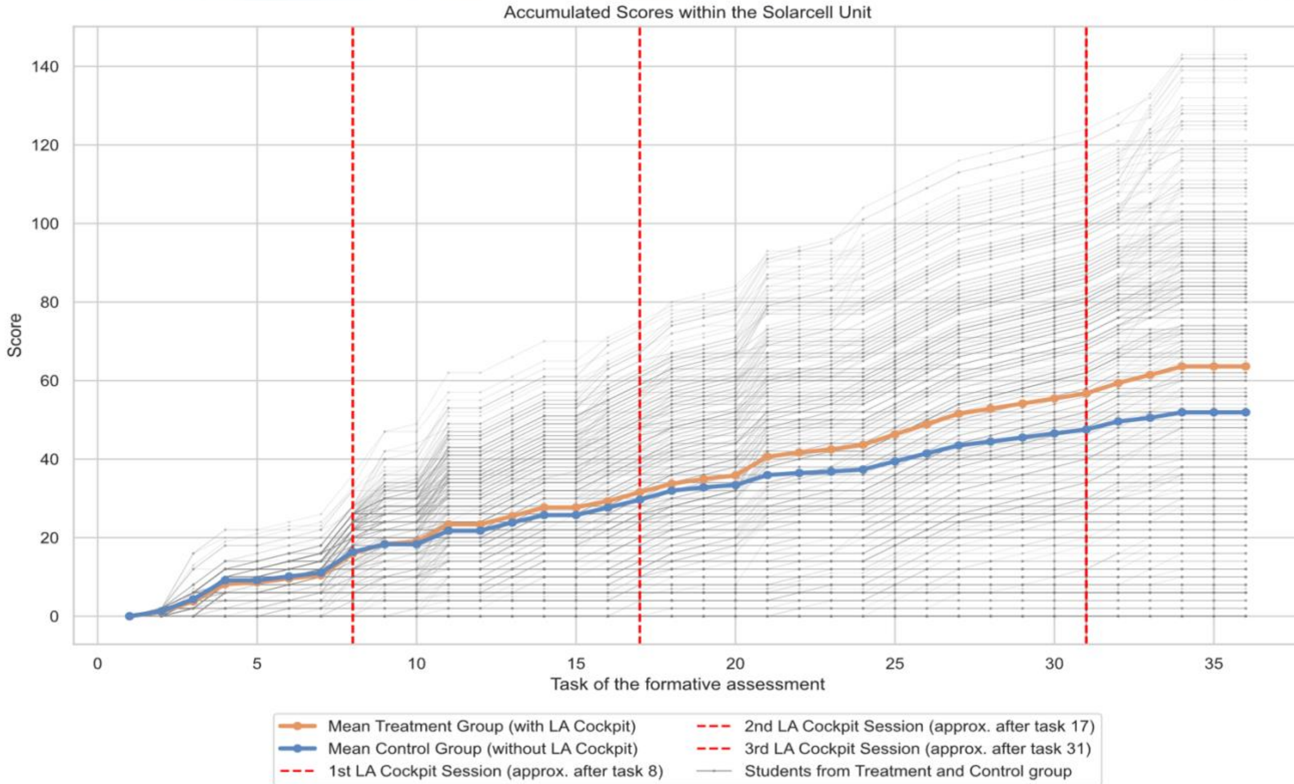

Figure 7. Accumulated scores within Solar Cell unit.

Furthermore, Figure 7 illustrates the cumulative scores of students from the control and treatment conditions in the formative assessment within the Solar Cell units. It presents individual student scores and the means for the control condition (in blue) and the treatment condition (in orange). The formative assessment tasks were unlocked on a lesson-by-lesson basis. The red dashed vertical lines indicate the three LA Cockpit sessions conducted with teachers after the first lesson (after Task 8), after the second lesson (after Task 17), and after the third lesson (after Task 31) of the instructional physics units. At the end of the unit, the mean score of the control condition reached 51.92 (*SD* = 31.29), while the mean score of the treatment condition was 63.61 (*SD* = 39.72).

5. Discussion

Teacher dashboards promise to assist teachers with their instruction and, therefore, improve student learning. While the impact of teacher dashboards on student learning can be identified as the objective of this chain of effects, the effect is rarely supported by empirical evidence from intervention studies. In this study, we conducted a quasi-experiment with a control-treatment group design to examine this impact chain from the usefulness of a teacher dashboard (RQ1) to teacher feedback practises (RQ2) to student knowledge gains (RQ3).

Perceived Technology Acceptance (RQ1). As a requirement for the LA Cockpit to support teachers, it has to be perceived as useful and easy to use. For example, when examining the impact of a teacher dashboard on student learning, Martinez-Maldonado et al. (2015) suggested that the usability of teacher dashboards should be examined to identify the best ways to increase teacher awareness. To assess the perceived technology acceptance, TAM was used. TAM is a popular and valid framework for measuring the acceptance of an information technology system (Al-Emran et al., 2018). It was also applied to evaluate LA systems, for instance, OpenLAIR (Ahmad et al., 2022), where the system was considered as useful and easy to use while receiving a TAM score of 5.17, very similar to that of the LA Cockpit. We therefore argue that the TAM results of the LA Cockpit suggested acceptable values, showing that teachers perceived the teacher dashboard as supportive and simple to use. We reason that a well-accepted LA Cockpit is a prerequisite for supporting teacher feedback practices.

Teacher feedback practices (RQ2). The analysis of teacher feedback practices with the LA Cockpit revealed that the teachers predominantly reacted to data from the LA Cockpit that indicated difficulties. This aligns with the results from Xhakaj et al. (2017), revealing that teachers noticed information about student learning difficulties more often than information about learning successes when facing a dashboard. Teacher dashboards provide teachers with information beyond their own traditional monitoring, enabling them to identify student difficulties that would otherwise go unnoticed, even if teachers are familiar with their class (Knoop-van Campen et al., 2023; Xhakaj et al., 2017).

Our analysis showed that teachers provided similar amounts of process-related feedback to students of different performance levels. This is consistent with the findings of Knoop-van Campen et al. (2023), who suggest that teachers with a dashboard intervene equally in the learning of students of all ability levels, in contrast to teachers without a dashboard who focus primarily on low-achieving students.

Further, our results indicate that the LA Cockpit helps teachers provide more process-related feedback than task-related feedback to their students. In classroom settings without teacher dashboard support, teachers typically provide more task-related than process-related feedback, although process-related feedback, along with metacognitive feedback, is most effective as it supports the regulation of students' own learning (Hattie, 2012; Hattie & Timperley, 2007). The predominance of process-related feedback over task-related feedback provided to low-performing students, along with student weaknesses being the main trigger of feedback, could contribute to explaining the indirect impact of teacher dashboards on enhancing the learning of students who might otherwise fall behind. Moreover, there was a small amount of personal feedback, which, according to Hattie (2012), is not conducive to the student learning process. We conclude that the LA Cockpit can help teachers provide more process-related feedback and less personal feedback, indicating its role in assisting teachers in delivering effective feedback to students.

Effect on Learning (RQ3). The third research question focused on the (indirect) effect of teachers' LA Cockpit use on student learning in terms of knowledge gain. Our analyses revealed that students in the treatment condition, whether working on the Laptop or Solar Cell unit, had significantly higher knowledge gains compared to the control condition. The replicability of significantly higher knowledge gains in both units suggests a positive effect of the LA Cockpit on student learning.

van Leeuwen et al. (2022) stressed the scarcity and importance of teacher dashboard studies that investigate student learning since the ultimate goal of teacher dashboards is to impact student learning. While many studies have evaluated teacher dashboard usability and effect on teacher practices, few studies empirically examined their indirect effect on student learning. Martinez-Maldonado et al. (2015) reported that teacher interventions informed by a dashboard with alerts resulted in improved student learning, whereas interventions informed by the system without alerts did not. In addition, the study of Xhakaj et al. (2017), along with this present study, represents one of the few studies on the indirect effects of teacher dashboards on instructional practices and subsequently on student learning that used a quasi-experimental treatment-control group design in the context of secondary schools. While this intervention study indicates a positive impact on student learning, the intervention study conducted by Xhakaj et al. (2017) showed no improvement in student learning, although it did have a positive impact on teacher lesson planning. These contrasting findings from related studies, along with our results, suggest that further empirical research is needed to determine which specific features of teacher dashboards and the educational settings in which they are used positively impact student learning.

5.1. Limitations and Future Research

The results of our study need to be viewed in light of several limitations. Due to the complexity of classroom teaching, our study design did not allow us to isolate the teacher dashboard's influence on student learning from other variables inherent in classroom teaching. Teachers in both conditions were always able to provide oral feedback to students via classroom interactions, but this "off-system" feedback was not recorded or coded. Only the "on-system" feedback sent by the teachers in the treatment condition via the LA Cockpit was recorded and coded in this study. Recording and analyzing the "off-system" feedback, for instance, the oral feedback given via classroom interactions in both conditions, could have provided us with further insights into how the dashboard influences instruction in the classroom. Besides the distribution of the different feedback types among student performance levels that we analyzed in this paper, factors such as the processing of feedback by students (Iraj et al., 2020), the use of the dashboard for classroom activities, or teachers' feedback literacy (Carless & Winstone, 2023) affect the effectiveness of teacher feedback. Future studies should, therefore, investigate the role of these processes in authentic learning contexts that include teacher-facing dashboards. Furthermore, the control condition did not have access to a modified version of the LA Cockpit to test any specific features of it. This precise study design choice—providing the LA Cockpit to the treatment condition and no dashboard to the control condition—was made to examine the general effect of the LA Cockpit as a teacher dashboard since the evidence that teacher dashboards benefit student learning is insufficient (Kaliisa et al., 2023; van Leeuwen et al., 2022). The study aimed to establish treatment effects in general before delving into more nuanced examinations of specific features of teacher dashboards (e.g., Feedback Systems, Alerts).

To better understand how teacher dashboards impact learning, future research should investigate which specific features of teacher dashboards support teaching practices and, subsequently, learning and the educational settings in which they contribute to teaching and student learning. To further examine the potential causal effect of the LA Cockpit on teacher feedback practises, future research could isolate the effect of its feedback system by conducting A/B tests where condition A uses the LA Cockpit without the feedback system and condition B uses the dashboard with the feedback system enabled. Further, the number of occasions where teachers provide their students with feedback and the duration of these occasions should be accounted for when comparing teacher feedback practices. In order to further analyze and optimize the effectiveness of the feedback template of the LA cockpit, future studies should compare the performance of the existing template with other templates. Concerning the technology acceptance of the dashboard evaluated with the TAM survey, the sample of seven teachers must be mentioned, so that the generalizability of the acceptance of the tool by the teachers must be considered. Due to the voluntary nature of experimental studies, participating teachers are likely to have more positive attitudes toward educational technology. This potential selection bias should be considered when interpreting the TAM results. Additionally, as the data collection for control and treatment conditions took place at separate times, it is necessary to consider cohort effects.

6. Conclusion

In this study, we examined three stages of the impact chain of a teacher dashboard: 1) teachers' perceived acceptance of the tool, 2) their feedback practices with it, and 3) the effect on student learning in terms of knowledge gain. Results indicate that teachers perceived the LA Cockpit as useful and used it to send feedback to their students. Furthermore, the analysis of feedback given by teachers using the LA Cockpit revealed that the dashboard assists teachers in identifying students facing difficulties and that teachers mostly provided process-related feedback, which is known to be effective for student learning (Hattie & Timperley, 2007). For student learning, significantly higher knowledge gains were found compared to the control condition, indicating a positive effect of the LA Cockpit teacher dashboard on student learning. This intervention study, conducted in secondary school practice with a treatment-control group design and aligned with curriculum-linked units, using a validated instrument to measure knowledge gain, can make a valuable contribution to LA research.

In summary, these findings provide evidence that a co-designed dashboard (Karademir et al., 2024) can support teachers in providing their learners with effective feedback and enhance student learning. Thus, the LA Cockpit can be considered *practicable* for teachers in the classroom (Viberg & Grönlund, 2023) and can serve the purposes of *"understanding and optimizing learning and the environments in which it occurs"* (Siemens & Long, 2011). This study contributes to expanding the empirical evidence on the effects of LA interventions on student learning. We invite future studies to carefully collect data about the different processes related to the effectiveness of teacher feedback. This is critical considering the necessity for further empirical research on the impact of LA (Motz et al., 2023) and teacher dashboards (van Leeuwen et al., 2022) on student learning.

Declaration of Conflicting Interest

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

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