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I don't have time! But keep me in the loop: Co-designing requirements for a learning analytics cockpit with teachers

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Abstract

Background: Teacher dashboards can help secondary school teachers manage online learning activities and inform instructional decisions by visualising information about class learning. However, when designing teacher dashboards, it is not trivial to choose which information to display, because not all of the vast amount of information retrieved from digital learning environments is useful for teaching. Information elicited from formative assessment (FA), though, is a strong predictor for student performance and can be a useful data source for effective teacher dashboards. Especially in the secondary education context, FA and feedback on FA, have been extensively studied and shown to positively affect student learning outcomes. Moreover, secondary teachers struggle to make sense of the information displayed in dashboards and decide on pedagogical actions, such as providing feedback to students.

Objectives: To facilitate the provision of feedback for secondary school teachers via a teacher dashboard, this study identifies requirements for designing a Learning Analytics Cockpit (LA Cockpit), that is, (1) a teacher dashboard that provides teachers with visualisations of results from formative assessment (FA) and (2) a feedback system that supports teachers in providing feedback to students.

Methods: This study was conducted in the context of STEM classes and is based on semi-structured co-design interviews with German secondary school teachers. In these interviews, we first explored challenges teachers encountered in monitoring students' learning and providing feedback. Second, in the ideation phase, teachers were asked to define features an LA Cockpit for FA should have. Finally, in the evaluation phase, we provided teachers with a design template for an LA Cockpit, the LAC_Template, which was built upon our previous work and feedback theory, and asked them to evaluate and

improve it. Further design requirements were derived based on the evaluation of the LAC_Template and teachers' suggestions for improvement.

Results: We derived 16 requirements for designing an LA Cockpit for FA in secondary schools. Findings from the interviews indicated that the feedback system of an LA Cockpit should address teachers' time limitations in giving students individualised feedback. It should therefore be designed to minimise the steps required to deliver feedback. To reduce workload, teachers requested an automated reminder to send feedback, but with the ability to adjust feedback to the learning context. Such a semi-automated feedback system can help teachers support students individually but also underline the importance of actively involving teachers in the feedback loop and giving them control when using such technologies in secondary school practice. A challenge for future teacher dashboard designs could be to find a balance between technology and teacher control that utilises the strengths of both in a beneficial combination.

KEYWORDS

co-design, feedback, formative assessment, K-12, teacher dashboards

1 | INTRODUCTION

Learning analytics (LA) uses learning-related data to understand and improve learning and teaching processes (Greller & Drachsler, 2012). It can provide valuable insights into students' learning performance, progress, and needs, which can inform teachers' instructional decisions and feedback practices (Greller & Drachsler, 2012). Currently, most of the research in LA has focused on implementing and testing large-scale solutions in the context of higher education, whereas research on implementing LA in secondary school practice is still limited (Ifenthaler et al., 2021; Kovanovic et al., 2021; Sousa et al., 2021). Despite this, the increased use of online learning activities via educational technologies in secondary education has raised awareness of the potential benefits of LA in schools (Kovanovic et al., 2021; Molenaar & Knoop-van Campen, 2017), as teachers often struggle to monitor and support active learning among their students online (Damşa & de Lange, 2019). However, teachers can become overwhelmed by the vast amount of information generated during online learning activities. Teacher dashboards, tools that can help teachers manage online learning activities by showing them relevant information, can therefore provide relief in this regard (van Leeuwen et al., 2019). Teacher dashboards are visual displays that can help teachers monitor how students learn and make interventions to improve learning by showing them relevant information about students' learning activities and progress (van Leeuwen et al., 2022).

However, deciding what information to display on dashboards and in which way is a challenge when implementing a teacher dashboard, as teachers seem to struggle to make sense of the information displayed in dashboards and decide on pedagogical actions (Molenaar & Knoop-van Campen, 2019; Molenaar & van Schaik, 2016). To alleviate this struggle, we aim to reduce the amount of information that can be collected and presented in a dashboard by selecting only information elicited from formative assessment (FA), since FA-results represent a strong predictor for student performance (Bulut et al., 2023; Tempelaar et al., 2015). FA is a process of regularly evaluating students' work to guide instruction and provide ongoing feedback to students to support their learning progress (Black & Wiliam, 1998; Van der Kleij et al., 2015). The feedback provided in FA has been extensively studied and shown to positively affect student learning outcomes in the secondary education context (Black & Wiliam, 1998; Bulunuz et al., 2014), as feedback is one of the most important interventions in learning (Hattie & Timperley, 2007). Considering the predictive power of FA data on student achievement (Bulut et al., 2023; Tempelaar et al., 2015) and the high potential of FA to support students (Faber et al., 2017; V. j. Shute & Rahimi, 2017), this study aims to provide a guideline to develop a teacher dashboard that utilises data from FA to provide valuable insights on students' learning to teachers.

Another crucial struggle teachers face when they use dashboards is with translating information from dashboards into pedagogical actions, for instance, in the form of feedback (Damşa & de Lange, 2019; van Leeuwen et al., 2019). In fact, most teacher dashboards are designed to display student information and raise awareness but not to facilitate pedagogical interventions, such as feedback (Jivet et al., 2017; Kaliisa et al., 2023). This underscores the importance of *actionable* dashboard designs that provide teachers with clear guidance on the next steps based on the information presented and enable the provision of feedback.

To address this gap and facilitate secondary school teachers' provision of feedback via teacher dashboards, this study aims to set requirements for designing a Learning Analytics Cockpit (LA Cockpit). An LA Cockpit can be defined as a teacher dashboard that provides teachers with visualisations of results from FA and a feedback system that enables teachers to send feedback to students (Karademir et al., 2022). In our previous study (Karademir et al., 2022), we introduced the concept of an LA Cockpit for higher education settings. In

this paper, we present a requirements analysis study in which we extracted and analysed teachers' requirements for an LA Cockpit for FA in secondary school settings by applying a co-design methodology.

To narrow the scope of our study, this study was conducted in the context of secondary school settings for STEM subjects. We targeted STEM subjects since FA tools have been successfully developed in these subjects (Stanja et al., 2023), indicating positive effects on student learning outcomes in digital environments (Shute & Rahimi, 2017).

To conduct this study, we utilised semi-structured co-design interviews with secondary school teachers. In the first phase of the co-design interviews, we explored the teachers' challenges that an LA Cockpit should address in monitoring students' learning and providing feedback. Then, in the ideation phase, teachers were asked to define features that an LA Cockpit for FA should have. Finally, in the evaluation phase, we provided teachers with an LA Cockpit template (LAC_Template) and asked them to evaluate and improve it. The LAC_Template was built upon our previous work that provided a proof of concept of the LA Cockpit (Karademir et al., 2022) and feedback theory to inform the design of its feedback system. Further design requirements were derived based on teachers' evaluation and suggestions for improving the LAC_Template.

2 | BACKGROUND

2.1 | Formative assessment

Assessment can be defined as the use of instruments and processes for gathering evidence about student learning (Black & Wiliam, 1998). The primary purpose of formative assessment (FA) is to use evidence about learning to make decisions concerning the next steps in the instruction and provide feedback to support students' learning progress. It is often referred to as 'assessment for learning', as it is an approach that uses assessments on a regular basis to support learning (Black & Wiliam, 2009). Several studies from secondary school contexts show that FA, which provides immediate feedback to students during instruction, improves learning outcomes and supports competencies across a range of STEM subjects, including physics, chemistry, biology, mathematics, and computer science (Black & Wiliam, 1998; Lee et al., 2020; V. j. Shute & Rahimi, 2017; Stanja et al., 2023). A study by Bulunuz et al. (2014), for instance, revealed that the integration of FA in extracurricular science instruction led to significant improvements in 8th-grade students in their understanding of physics concepts. FA has not only a significant positive impact on student learning but also student motivation and self-regulation (Black & Wiliam, 2009; Clark, 2012). For instance, a case study by Granberg et al. (2021) applying FA in mathematics with secondary school students reveals a significant effect on students' motivational beliefs involved in self-regulated learning when compared to two control classes.

Due to the increasing use of educational technologies in secondary schools, tools for computer-based FA in digital learning environments have been studied and successfully deployed in recent years (Shute & Rahimi, 2017). However, the type of feedback on FA that is most effective is not clear as different studies show opposite results. Shute et al. (2008), for instance, found that students with elaborated (explanatory) feedback outperformed those with simple verification feedback (confirming correctness), while the study of Maier et al. (2016), showed the opposite.

2.2 | Learning analytics and teacher dashboards in schools

Since FA results are a strong predictor of student performance (Bulut et al., 2023; Tempelaar et al., 2015), using this data in Learning Analytics applications such as teacher dashboards can support teachers in gaining valuable insights into student learning (Kippers et al., 2018). Learning Analytics is the collection, analysis and reporting of learning-related data with the goal to understand and optimise learning (Siemens, 2013). Although LA systems are more common in higher education than in schools (Ifenthaler et al., 2021; Sousa et al., 2021), there is a growing number of studies examining the potential benefits of LA in primary and secondary education (Kovanovic et al., 2021; Molenaar & Knoop-van Campen, 2017). While many LA applications in high schools aim to predict student dropout or learning outcomes (Sousa et al., 2021), recent LA research suggests other purposes, such as providing feedback (Pardo et al., 2019; Tsai et al., 2021) or offering dashboards to support teacher decision-making (Molenaar & Knoop-van Campen, 2019). So far, the most prominent form of LA that supports teachers' decision-making is teacher dashboards, which can be defined as "*visual displays that provide information about students' activities and progress on the task at hand.*" (van Leeuwen, et al., 2022, p. 3).

A dashboard can support teachers in monitoring their students' learning progress and making informed decisions about interventions to optimise learning outcomes (Bodily & Verbert, 2017; van Leeuwen et al., 2022). For several FA tools employed in digital learning environments, teacher dashboards were designed and their effects on teaching and learning have been examined in recent years (Kaliisa et al., 2023). For example, Xhakaj et al. (2017) found that their teacher dashboard developed for an intelligent tutoring system (ITS) improved teachers' knowledge of their students, affecting lesson preparation, but student learning did not increase as a result. A study by Molenaar and Knoop-van Campen (2019) examining how school teachers interpret dashboards indicated that teacher dashboards lead to greater activation of pedagogical knowledge in teachers and that dashboard use leads teachers to provide students with more diverse feedback. Furthermore, Holstein et al. (2019) involved K-12 teachers in the development of an AI-supported mixed-reality classroom orchestration tool, introducing a variety of prototyping methods showing how non-technical stakeholders can participate in designing a complex LA system.

Teacher dashboards can inform teachers' decision-making and are a means to provide feedback to students based on insights the dashboard provides (van Leeuwen et al., 2021). Yet, their designs tend to

focus more on sensemaking rather than teachers' action-taking or the distribution of feedback (Kaliisa et al., 2023), even though the ultimate goal of dashboards is to support teachers to take action (Verbert et al., 2013). Furthermore, the data presented on dashboards is not always *actionable*, meaning that it may not be clear to teachers what actions they should take next after viewing a dashboard (Molenaar & Knoop-van Campen, 2018). A literature review by Kaliisa et al. (2023) has shown that most teacher dashboards are designed to raise teacher awareness but provide limited actionable insights that enable pedagogical actions. Such pedagogical actions that teachers can take when facing a dashboard include adapting the learning design and learning materials, planning lessons or providing feedback (Kaliisa et al., 2023). One way to make teacher dashboards more *actionable* is through the concept of an LA Cockpit that incorporates a feedback system that facilitates teachers' provision of feedback to their students through dashboards (Karademir et al., 2022). According to Wise and Jung (2019), when integrating the use of LA into teaching practices, "*the gap from interesting to actionable is the most important to bridge*" (p. 1). Therefore, an LA Cockpit aims to bridge this gap by providing a dashboard with an integrated feedback system where teachers can take action by sending feedback to students through the dashboard.

2.3 | Integrating feedback systems in LA dashboards

Feedback has one of the most powerful influences on student learning (Hattie & Timperley, 2007) and aims to "*reduce discrepancies between current understandings/performance and a desired goal*" (Hattie and Timperley, 2007, p. 6). The feedback model of Hattie and Timperley (2007) is one of the most widely recognised feedback models in school contexts (Wisniewski et al., 2020). According to their model, effective feedback should answer three questions: (1) *FeedUp—Where am I going?* Answers to this question inform students about what their learning goals are. (2) *FeedBack—How am I going?* Answers to this question inform students what they have or have not accomplished so far. (3) *FeedForward—Where to next?* Answers to this question inform students what actions to take next to progress towards their learning goals.

Furthermore, positive feedback, which refers to students' achievements and corrective feedback, which refers to their knowledge gaps can both be beneficial in supporting student learning. Positive feedback can increase intrinsic motivation but may lack specific guidance for improvement (Deci, 1971; Deci et al., 1999), while corrective feedback can enhance performance (Boehler et al., 2006; Rogers et al., 2012) but may cause unpleasant emotions (Lim et al., 2021).

FA is particularly effective when students receive feedback (Wiliam, 2010). This effect is higher when the feedback is given in a formal way, such as written feedback rather than informal verbal feedback (Lee et al., 2020). However, many of the teacher dashboards used in FA settings that we found in the literature focus on informal verbal feedback given during the lesson after consulting the dashboard (e.g., Dourado et al., 2021; Knoop-van Campen et al., 2021) or on the analogue adaptation of the lesson plan and instructions (e.g., Kaliisa et al., 2023; van Leeuwen et al., 2019; Xhakaj et al., 2017). These tools do not have features to provide written feedback to students via interactions with the dashboard. One exception is the LAViEW tool, a teacher dashboard for college instructors with a built-in email widget allowing the teacher to send personalised feedback to selected groups of students clustered by their scores (Majumdar et al., 2019).

Moreover, Pinheiro et al. (2021) argued that most feedback systems are designed for students only, neglecting the role of the teachers and hardly letting them participate in the feedback process. The proposed concept of an LA Cockpit (Karademir et al., 2022) used in this study aims to actively engage teachers in the feedback process by providing a teacher dashboard with an integrated feedback system that the teacher orchestrates.

3 | METHOD

3.1 | Study design

This study aims to gather requirements for designing an LA Cockpit, a teacher dashboard with a feedback system (Karademir et al., 2022), tailored for the context of FA in secondary schools. Recognising that the lack of teacher involvement in the design of LA tools is a reason for their limited impact on teachers' daily practice (Dollinger et al., 2019; Martinez-Maldonado et al., 2020), we involved teachers in this study. We therefore applied a co-design methodology to set the criteria for an LA Cockpit for FA in secondary schools guided by the following research questions:

> **RQ1.** Which challenges of secondary school teachers should a teacher dashboard address in FA settings to monitor students' learning progress and provide feedback to students?
>
> **RQ2.** What are the requirements for a secondary school teacher dashboard designed to successfully monitor the learning progress in FA?
>
> **RQ3.** What are the requirements for a feedback system to be integrated into a teacher dashboard that facilitates the provision of personalised feedback in secondary school FA settings?

To answer these research questions, we first contextualised the study in the scope of STEM (Science, technology, engineering, and mathematics) education and conducted semi-structured co-design interviews with ten secondary school STEM teachers.

3.2 | Context of the study

This study was performed in the context of a digital instructional physics unit to be integrated into physics classrooms. The FA is based

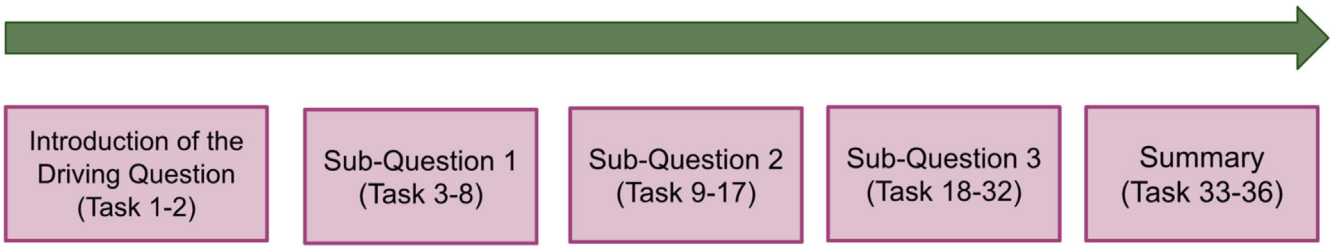

FIGURE 1 The structure of the FA as a part of a technology-based instructional unit in physics classrooms. The FA is divided into a driving and three sub-driving questions containing 36 tasks in total.

on this unit. Following project-based pedagogy (Krajcik & Shin, 2014), the unit starts with a driving question on energy-related phenomena that motivates the lessons (e.g., 'Why do laptops sometimes overheat?'). This is divided into three sub-driving questions that require students to engage in scientific practices. At the end of the FA, the answers to the sub-driving questions are brought together to answer and reflect on the original driving question. The structure of the FA is shown in Figure 1. The FA was based on 36 tasks as Moodle quizzes and should be completed sequentially by 7th and 8th-grade students (aged between 13 and 15) in physics class throughout 5–6 weeks, with each student using a tablet or laptop. These 36 tasks are closed question formats like multiple choice, cloze (which can be scored automatically by Moodle), and text questions that students answer with free text. The free-text answers are scored automatically using an NLP model developed by Gombert et al. (2022), which was trained with previous student responses from the same learning environment. The model has an F1-score of over 90% in evaluating whether a free text response is correct or incorrect and which concepts are used in the responses. Using evidence-centred design, the 36 tasks were linked in advance by a team of physics didactics experts to learning goals that describe the energy concepts addressed in each task (Kubsch et al., 2022). For example, a learning goal for energy transformation is defined as follows: *Students identify the transformation of energy between two different forms of energy*. Thus, if students correctly complete a task, their score for each learning goal linked to that task increases.

3.3 | LA cockpit design template (LAC_Template)

To establish the requirements for an LA Cockpit for FA in secondary school settings, we conducted co-design interviews with secondary school teachers. To facilitate the co-design interviews we developed the LAC_Template. It is a design suggestion used in the interviews to help the teachers define the requirements. We based the design of the LAC_Template on the concept of the LA Cockpit, defined in a pre-study as a teacher dashboard with an integrated feedback system that enables teachers to send feedback to students (Karademir et al., 2022). The pre-study piloted this concept by implementing an LA Cockpit for FA in higher education and received positive results when evaluating it with instructors in terms of its usefulness and usability. Together with an interdisciplinary team of researchers with technical, pedagogical, and domain-specific expertise, we created a LAC_Template with the whiteboard and sketching tool Miro.[1]

The LAC_Template consists of five widgets which are divided into four views with visualisations (the class progress overview, goal view, task view and distribution view) and a feedback system. It is intended to be used as follows: Teachers can view the dashboard visualisations to draw insights from them and identify students who need feedback. They can select an individual or group of students to send them personalised feedback messages by clicking on their data visualisations. Teachers can then write feedback to their students with the help of a feedback system suggesting editable feedback texts based on a template. After sending the feedback, teachers can automate already sent feedback for upcoming scenarios when similar feedback conditions are met in future.

3.3.1 | Dashboard visualisations

Class progress overview

To provide teachers with a quick overview, the *class progress overview* displays the scores of each learning goal for the whole class (see Figure 2).

Goal view

By clicking on "details", teachers access the *goal view*, which aims to provide an overview of each student's performance on the learning goals covered in the assessments (see Figure 3).

Task view

This *view* allows teachers to track each student's performance on each task (see Figure 4).

Distribution view

The *distribution view* shows students' total scores in a bar chart (see Figure 5, left) and students' scores in each learning goal in a multi-bar chart (see Figure 5, right). This view shows how many students are doing well or poorly overall or in specific learning goals to help teachers find groups of students who need extra support or topics where most students struggle.

[1] https://miro.com/

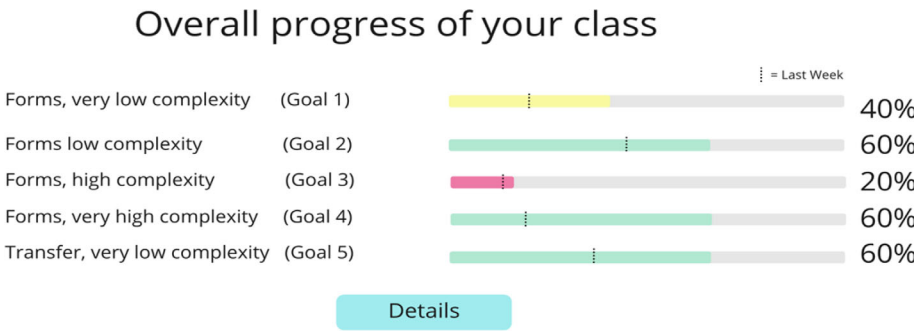

FIGURE 2 The class progress overview of the LAC_Template visualises progress bars displaying the scores of each learning goal for the whole class.

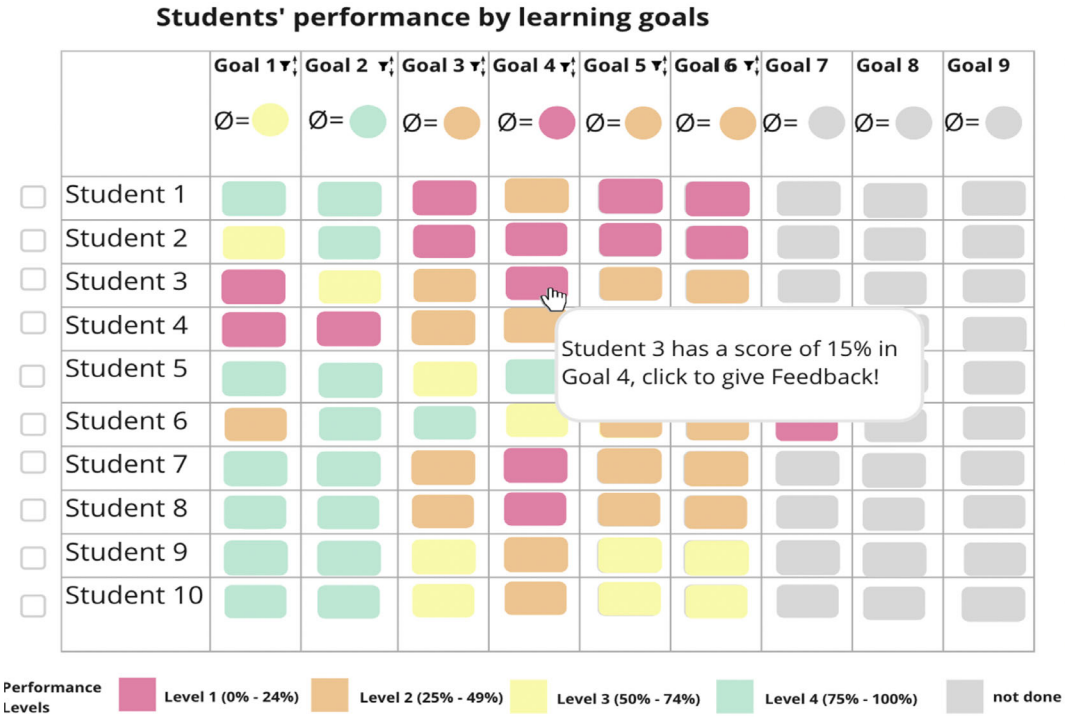

FIGURE 3 The goal view displays students' performance on various learning goals covered in the assessments. The coloured cells of the table indicate the students' performance levels for each learning goal based on their scores (in %) in the formative assessment. Teachers can send personalised feedback for a specific learning goal to an individual student by clicking the corresponding cell.

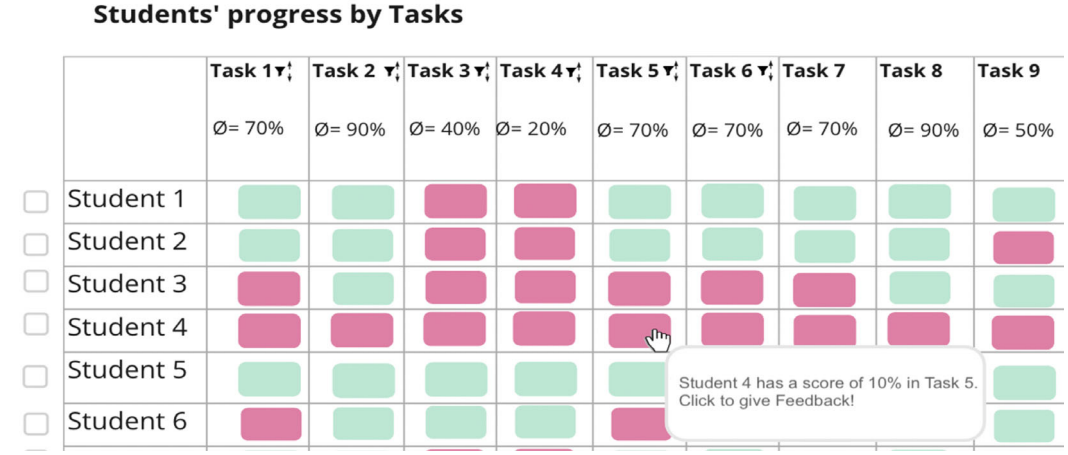

FIGURE 4 The task view. The coloured cells in the table indicate whether the student answered the task correctly (green), incorrectly (red) or whether the task was not yet attempted (grey). Teachers can send personalised feedback to each student by clicking on their corresponding cell.

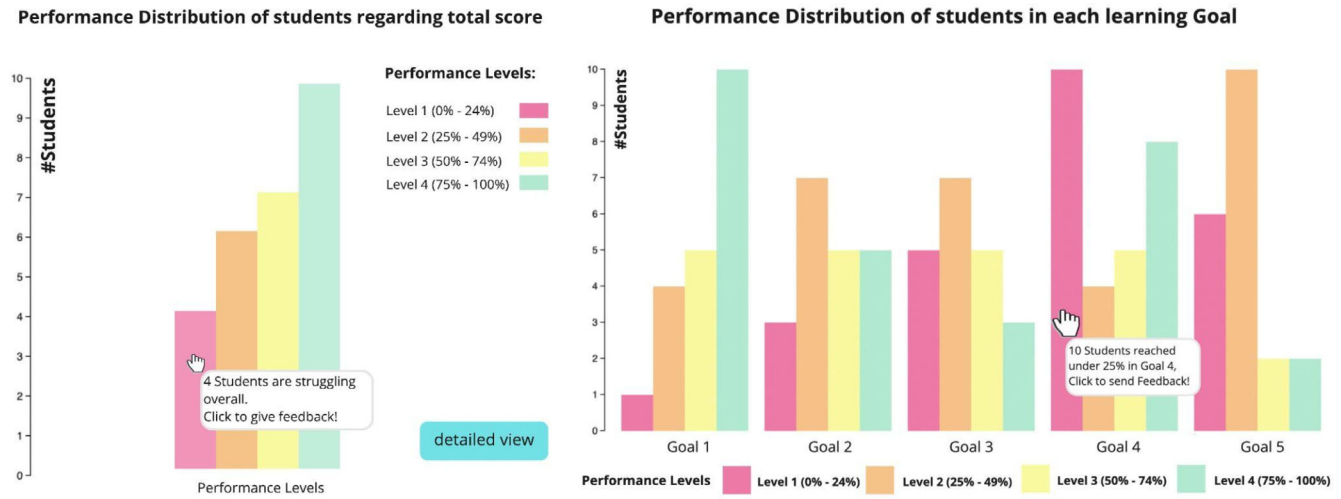

FIGURE 5 The distribution view. The x-axis has score intervals for the four performance levels, the y-axis has the number of students in each interval. By clicking on the bars, teachers can select groups in certain performance levels (for an overall score or a learning goal score) and send them feedback messages. Teachers can click on the bar representing ten students on level 1 (below 25%) in learning goal 4 and send them feedback.

To address possible colour blindness of our study participants, we developed an alternative colour coding in which red, orange, yellow, and green were replaced by different shades of blue, with dark blue indicating a high score and light blue indicating a low score.

3.3.2 | Feedback system

Feedback template

To address the insufficient integration of educational research in the development of feedback tools in online learning environments (Pinheiro et al., 2021), we developed the feedback template. To start using the template, teachers have to select the students to send feedback to. This opens the template and shows pre-filled boilerplate text as feedback suggestions in the input fields (see Figure 6).

To support teachers in creating helpful feedback for students, the template follows the feedback model of Hattie and Timperley (2007) and allows the provision of positive feedback followed by corrective feedback (see Figure 6). The template is structured in a way that positive feedback about the student's achievements in their learning goals should be written first ("What went well?"), followed by corrective feedback addressing weaknesses ("What didn't go so well?"). By starting with positive feedback, the template aims to increase the student's motivation when they receive feedback since positive feedback can increase intrinsic motivation (Deci et al., 1999; Mouratidis et al., 2008).

To make the feedback actionable and be able to provide students with information on how to improve the third input field is labelled "recommendation". This field aims to provide information on the next step the student should take to improve, and it is derived from the question *Where to next?* Recommendations may be, for example, supportive learning materials to fill knowledge gaps or challenging tasks that promote the mastery of learning goals. In the fourth input field, teachers can include other aspects in their feedback and, for instance, ask questions to the students to better understand their situation.

The feedback template furthermore provides suggested boilerplate texts that are based on the selected students' assessment results and can be edited (see Figure 6). With a possible transfer of the presented LAC_Template into a technically functioning application, the system could generate feedback suggestions based on the previous scores of the selected students in a rule-based way. The structure of the feedback template with its four input fields (positive feedback, corrective feedback, recommendations and miscellaneous) is predefined and fixed. However, the suggested texts in the input fields can be freely modified or omitted so that the teacher has a structure based on the feedback theory, but still has the freedom to adapt the feedback to the context if necessary. The fourth input field, labelled "Something else you want to say or ask" (see Figure 6), is intentionally left blank by the system, allowing teachers to input feedback freely. This is to give teachers control and flexibility when creating feedback to ensure that the automatic suggestions do not overly restrict them in the process of providing feedback.

A challenge in the development of feedback systems for student support is the insufficient consideration of the teacher's role. Many systems tend to fully automate feedback, making it difficult for teachers to participate in the feedback process (Pinheiro et al., 2021). Therefore, in our design, we aimed to integrate the teacher's role in the feedback process, even when automation is employed.

Feedback automation

The automation feature is introduced to save teachers time in delivering feedback and still being able to send individualised feedback to as many students as necessary (see Figure 7). This feature aims to automate potentially repetitive situations for feedback so that teachers do not have to resend the same feedback every time an

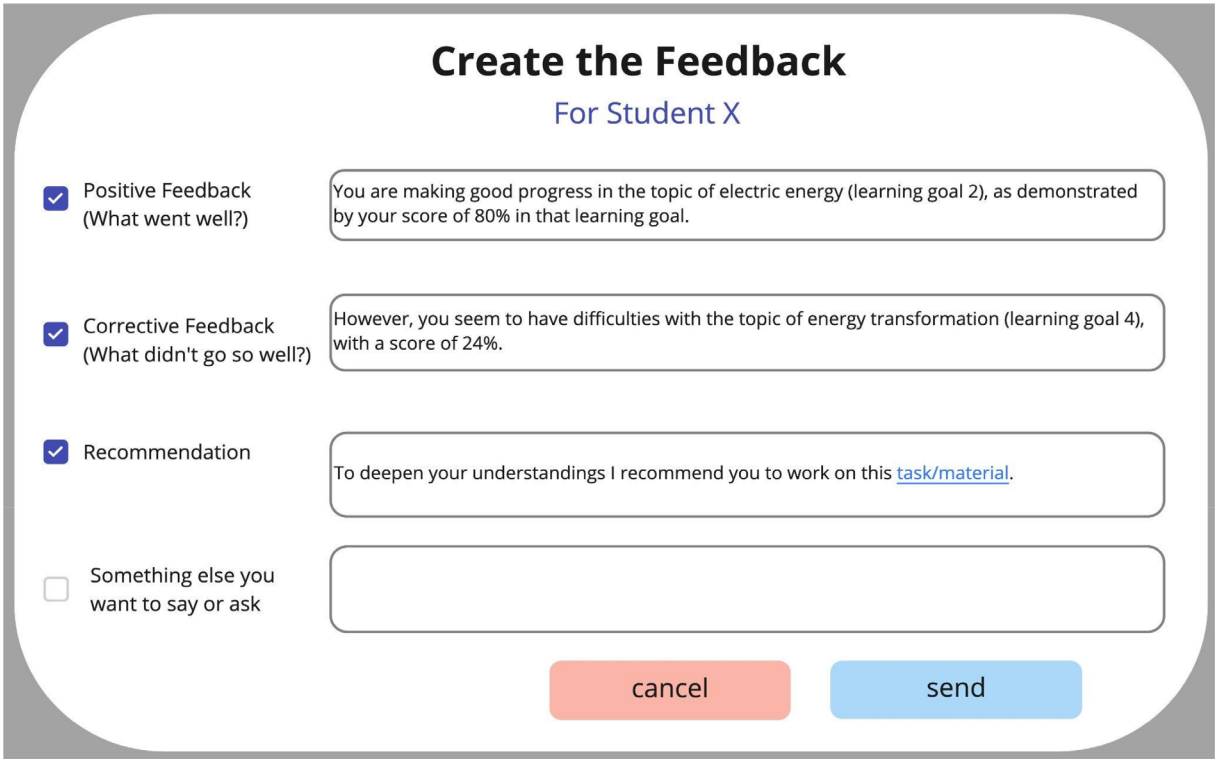

FIGURE 6 The feedback template has four input fields (positive feedback, corrective feedback, recommendations and miscellaneous) and the suggested feedback texts, which are editable.

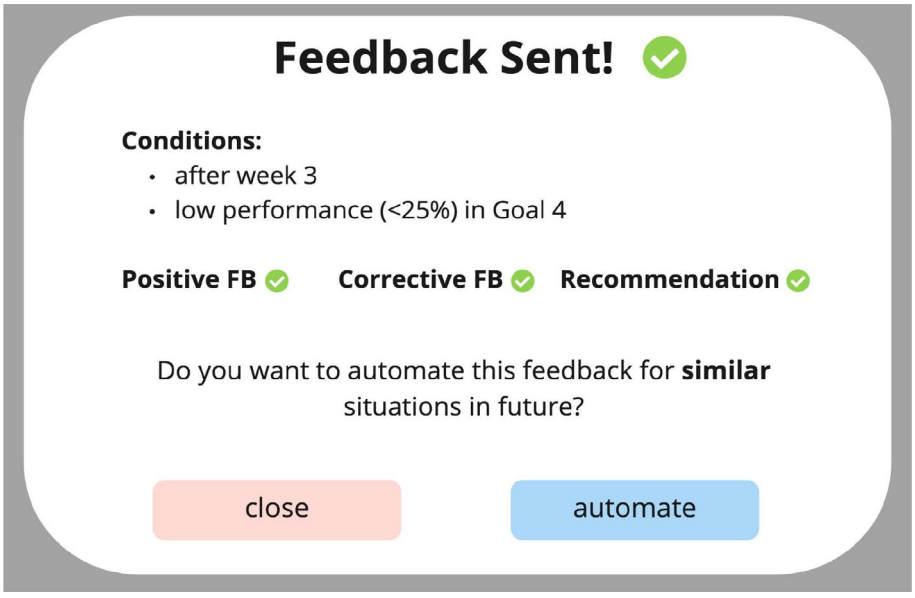

FIGURE 7 Feedback automation popup.

already-known situation reoccurs. After sending a feedback message, teachers can automate that message to be sent to every student who is currently or will be in the future in a similar situation as the current recipients.

They can adjust the messages as needed and review conditions that trigger the feedback, and set the message to be automatically sent to any student in a similar situation in the future. The conditions are based on the selection the teacher makes. If the teacher, for example, selects a group of 4 students who are struggling with a score below 25% in learning goal X and the class is progressed till week 3, the conditions to trigger that feedback message automatically in future would be: *{After Week 3} AND {Score in Learning Goal X < 25%}*. If, in the same week, a teacher selects only one student by clicking on a cell in goal view which represents a student's low

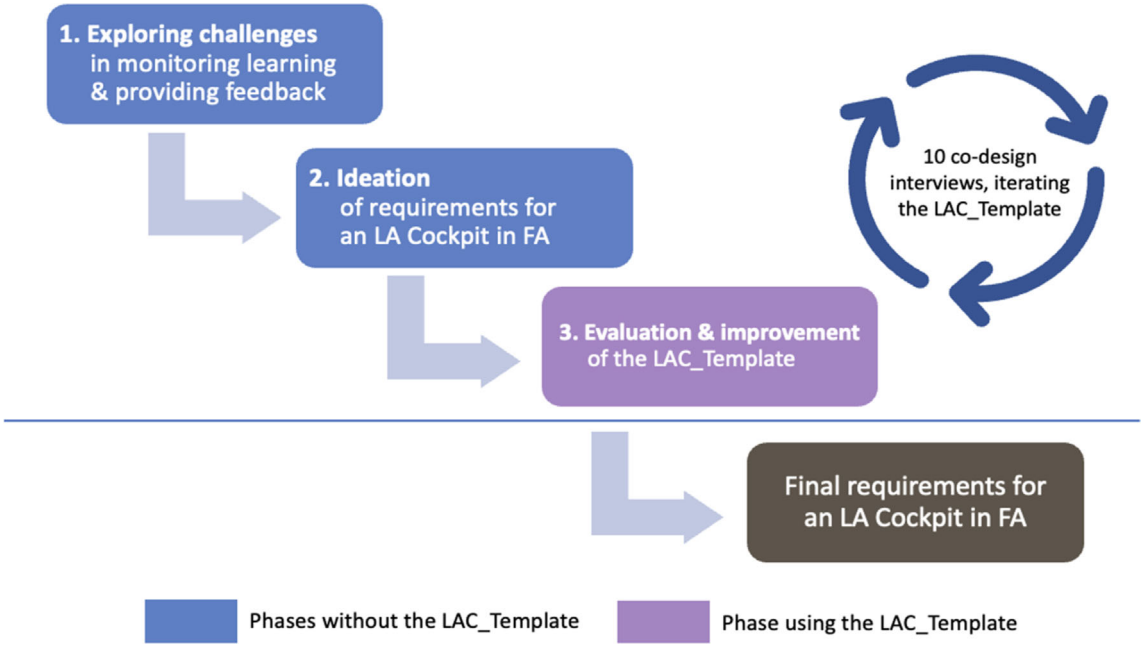

FIGURE 8 The co-design process with teachers to derive requirements for an LA Cockpit. In phases 1 and 2, the LAC_Template was not used to gather teachers' ideas that are not influenced by the LAC_Template. It was then evaluated and refined in phase 3 with the purpose of validating and extracting features for an LA Cockpit. The results from all three phases were then mapped to a list of final requirements.

performance in learning goal Y, then the conditions to automate the feedback message would be *{After Week 3} AND {Score in Learning Goal Y < 25%}*.

3.4 | Procedure and data collection

The interview script followed three phases (see Figure 8). First, teachers were asked about the challenges they faced in monitoring students' learning and providing feedback to students. Next, teachers were introduced to the learning environment of the FA for which an LA Cockpit should be developed and the data that can be gathered from it. Teachers were then asked what information an LA Cockpit should provide them to monitor students' learning progress in the FA and be able to provide feedback effectively. This was done without showing teachers the LAC_Template, in order to obtain authentic requirements from teachers without biassing them towards our own design proposals in the LAC_Template.

In the final phase of the interview, *3. Evaluation and improvement of the LAC_Template*, the LAC_Template described in Section 3.3 was introduced to the teachers. The teachers then evaluated the usefulness and usability of each of the five widgets (including four views and a feedback system) of the LAC_Template and suggested improvements. To do so, they were shown each widget individually and asked to evaluate its usefulness and comprehensibility, and to make suggestions to improve the widget. The LAC_Template was iteratively refined with the help of ideas for improvements. When a second teacher requested an improvement, it was incorporated into the LAC_Template after that interview and the improved version was used in the subsequent interview. The interview questions can be found in the interview protocol in Appendix A.

The interviews took place from May to September 2022, and all teachers were interviewed in a video conference call. One interviewer conducted all ten interviews, which lasted between 1 and 1.5 h each. Nine of the ten teachers have experience teaching students ranging from 5th to 13th grade (approx. 11–18 years old). The participants (four female, and six male) had an average work experience of 7.15 (SD = 6.27) years. Four participants reported having three to ten years of teaching experience, and three participants reported having over ten years of teaching experience. Among the interviewed teachers, the most taught subjects were physics (by seven teachers), mathematics (by six teachers), and computer science (by three teachers), with all teachers teaching multiple subjects. The remaining STEM subjects, biology, chemistry and geography, are each taught by one teacher. Moreover, none of the teachers had experience in using a teacher dashboard.

3.5 | Data analysis

Each interview was audio recorded and then transcribed to a spreadsheet using Whisper,[2] an open-source automatic speech recognition system. The audio files were deleted afterwards. We divided the transcripts into individual statements for each phase of the interviews: (1) the challenges teachers face in monitoring learning and providing feedback to students and the requirements they imply; (2) the

[2] https://openai.com/research/whisper

requirements teachers set for the dashboard without receiving the LAC_Template as a design suggestion from us; (3) finally, the evaluation results of each widget in the suggested LAC_Template in terms of its usefulness and teachers' ideas for improvements.

We coded each statement (Rubin & Rubin, 2011) resulting in 92 unique codes. Infrequent codes which only occurred once were eliminated from the results so that only the codes that occurred in two interviews were included in the results. This leaves us with 25 codes that were further mapped to their three categories corresponding to the three phases of the interview. The results from these three phases were then extracted into a list of final requirements (see Section 4.4).

To verify the trustworthiness of our coding procedure, we conducted an external validation, as per the method described by O'Connor and Gibson (2003). From the pool of 25 codes, we randomly selected 20 codes and retrieved the relevant statements from the teacher interviews. Subsequently, we requested ten external reviewers to associate the randomly arranged statements with the set of codes. Their connections between the statements and codes resulted in a 97% accuracy rate, demonstrating a strong agreement with our coding. This high level of interrater reliability indicates that our coding process is both reliable and valid.

4 | RESULTS

In this section, we present our findings from the co-design interviews. In Section 4.1, we discuss the challenges teachers face in monitoring student learning and providing feedback, labelled as C1, C2, and C3. From these challenges, corresponding requirements are derived, labelled RC1, RC2, and RC3. Moving to Section 4.2, we outline the features for an LA Cockpit that teachers requested during the *ideation* phase without prior exposure to the LAC_Template as a design suggestion. These requirements range from RI1 to RI6. Next, in Section 4.3, we present the outcomes of the evaluation and improvement of the introduced LAC_Template, along with the derived requirements from that phase, which go from RE1 to RE13. Finally, the results from all three phases are summarised into 16 final requirements from RF1 to RF16 in Section 4.4.

4.1 | Challenges in monitoring learning and providing feedback

Following the interviews, we identified three main challenges that teachers face, the biggest challenge being: *C1 Lack of time in manually assessing learning outcomes on a regular basis*, *C2 Lack of technology in assessing learning outcomes*, *C3 Lack of time to provide individual feedback to each student*. This section elaborates on each of the three challenges and presents the requirements they imply (see Table 1).

C1: Lack of time in manually assessing learning outcomes on a regular basis. Seven teachers reported that they have difficulties evaluating the task responses of their students in assignments or assessments due to a lack of time. One teacher stated: "*The main challenge from the teacher's point of view is to monitor the learning progression daily or weekly. It's difficult to do a detailed analysis on where students are currently at*". Another teacher mentioned that their limited time makes it difficult to continuously monitor each of the students. *That is simply not possible in terms of time*. This challenge suggests that the dashboard should provide data on the newest learning statuses of their students.

TABLE 1 Teachers' challenges in terms of monitoring learning and providing feedback.

Challenges	No. of teachers mentioning the challenge	Requirement derived from that challenge
C1 Lack of time in manually assessing learning outcomes on a regular basis	7	RC1 Provide up-to-date data
C2 Lack of technology in assessing learning outcomes	4	RC2 Capability to assess (free-text) responses automatically
C3 Lack of time to provide individual feedback to each student	6	RC3 Feedback system that facilitates the provision of individual feedback

C2: Lack of technology in assessing learning outcomes. Furthermore, four teachers face the challenge of the insufficient use of technology in assessing their students' learning outcomes. One teacher, for example, said: "*The challenge is that many [assignment] results are not automatically available. You need automatic scoring of student answers to see each student's learning status regularly*." Another teacher highlighted a limitation with their LMS, which only checks for exact matches with the sample solution, resulting in spelling errors being marked as incorrect. This may not provide a complete picture of the student's progress, as it doesn't account for small variations in the student's response. Another teacher discussed the limitations of the multiple-choice questions they use in class, stating that this format is limited when assessing whether students have truly understood the topic. They also suggested that free-text questions would be better for assessing student understanding of a topic but also pointed out that this was technically not possible for them.

C3: Lack of time to provide individual feedback to each student. Six teachers indicated that due to their limited time resources, they cannot provide individualised feedback to every student in all performance groups. As a result, they focus on giving feedback to weaker rather than stronger students, even though two teachers mentioned that high-performing students should also receive feedback that recognises their efforts. One teacher explained: "*All students, no matter how good or bad they perform, need at least weekly feedback. Unfortunately, there is not enough time for that. I focus most of my time on giving feedback to struggling students*."

Based on the teachers' challenges in monitoring learning and providing feedback, we identified the following requirements of an LA Cockpit for their context:

- *RC1—Provide up-to-date data*, which was derived from *C1—Lack of time in manually assessing learning outcomes on a regular basis*
- *RC2—The capability to assess (free-text) responses automatically*, which was derived from *C2—Lack of technology in assessing learning outcomes* and
- *RC3—A feedback system that facilitates the provision of individual feedback*, which was derived from *C3—Lack of time to provide individual feedback to each student*. This broad requirement is fragmented into more detailed requirements that will be reported in Section 4.4.

4.2 | Ideation

In the ideation phase, requirements were defined when we asked teachers to brainstorm about the features for an LA Cockpit in FA, without showing them the *LAC_Template* as a design suggestion (see Table 2).

RI1: Simple user interface. Starting with a general unspecific criterion, four teachers stressed the importance of *a simple user interface (UI)* that does not contain too many detailed elements at first glance. Since teachers have limited time in their daily work, they need to be able to extract relevant information from the dashboard quickly.

RI2: Problematic learning goals of the whole class. Six teachers found value in viewing the learning goals that the whole class struggles with. They emphasised that this understanding can inform lesson planning and enable the teacher to address these difficulties more effectively in the classroom. One teacher said: "*I would look for the whole class to see which concepts have already been understood and which concepts need to be revisited.*"

RI3: Problematic tasks of the whole class. Furthermore, five educators mentioned that it is essential for an LA Cockpit to identify tasks that the majority of the class did wrong. Two teachers also noted that this information could inform lesson planning and facilitate timely interventions that prevent students from continuing with subsequent errors and misconceptions.

RI4: Each student's progress on the learning goals. In addition to global views on what the class is struggling with, five teachers also requested to monitor individual students' progress on the learning goals. One teacher mentioned that such a view could help with personalised feedback by stating: "*It would be interesting to have a representation of which concepts are less clear to a student. This can allow me to provide personalised feedback to him or her.*"

RI5 Each student's task scores. Additionally, four teachers expressed the need to access individual students' task scores to assess correct and incorrect task completions.

RI6: Struggling students. Five teachers indicated that they need to know which students have a low overall score on their tasks to talk to them personally to understand why they are struggling and to keep their motivation up. A teacher said: "*I need an overview of each student's overall score to see who is struggling. This way I can personally approach these students and help them.*"

TABLE 2 Requirements from phase 2 without providing suggestions.

Requirements from the ideation phase	No. of teachers who requested it
RI1 Simple user interface	4
RI2 Problematic learning goals of the whole class	6
RI3 Problematic tasks of the whole class	5
RI4 Each student's progress on the learning goals	5
RI5 Each student's task scores	4
RI6 Students who struggle	5

4.3 | Requirements derived from evaluation and improvement

In phase 3, teachers were asked for each of the five widgets in the LAC_Template, whether they found it understandable and useful and whether they had ideas for improving the widget. At the end of the interviews, teachers were then asked to choose their favourite widgets, selecting a maximum of three widgets. Table 3 shows how many teachers favoured each widget of the LAC_Template. The three best-rated widgets were the class progress overview and the feedback system, which both were favoured by seven teachers and the goal view was favoured by five teachers.

The LAC_Template was iteratively refined based on teachers' ideas for improvements on any of its five widgets. When a second teacher requested an improvement, it was incorporated into the LAC_Template after that interview and the improved version was used in the subsequent interview. The diagram in Figure 9 illustrates the navigation structure of the final version of the LAC_Template that was continuously refined through the ten co-design interviews with teachers. At the top level is the class progress overview, which displays the scores of the learning goals and tasks for the class as a whole. From there, users can dive deeper and navigate to the goal- or task view to see each student's scores for each goal or task or navigate to the distribution view to see how the students are distributed among the performance groups regarding overall scores or the scores in each learning goal. From any of these three views, teachers can send feedback messages to an individual or a group of students via the feedback system. Finally, they can set an automatic reminder to send the same feedback in similar situations in future.

TABLE 3 Evaluation results of all five widgets of the LAC_Template.

Widget	No. of teachers favouring the widget
Class progress overview	7
Feedback system	7
Goal view	5
Task view	3
Distribution view	2

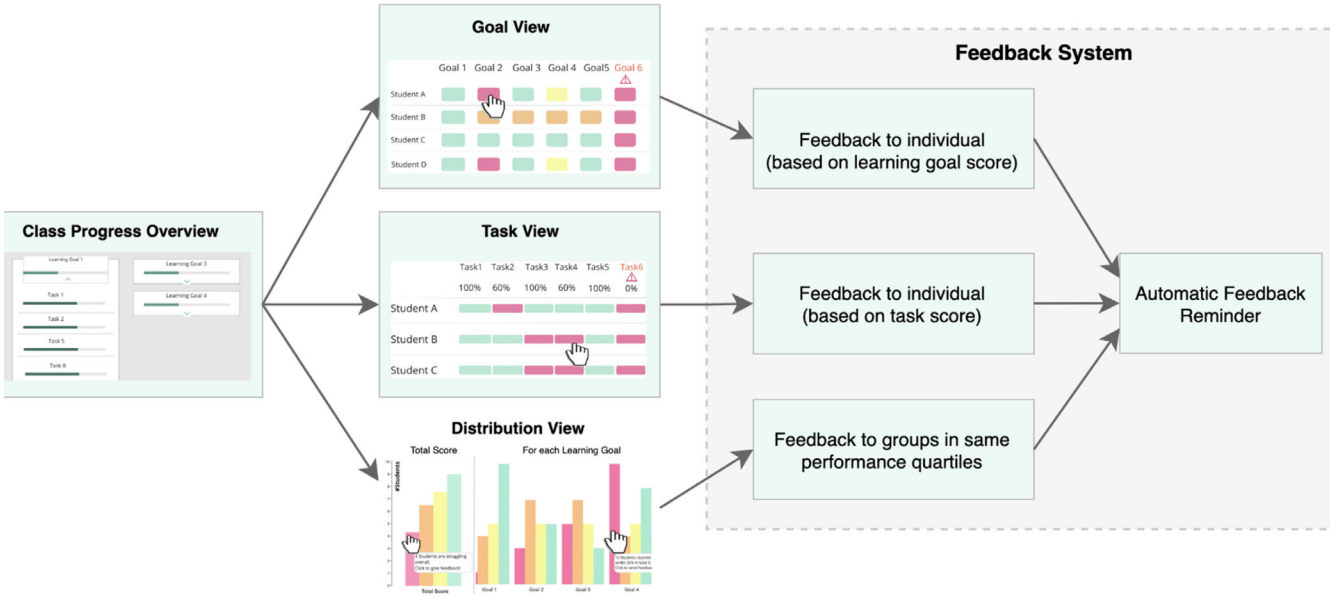

FIGURE 9 The page navigation structure of the final version of the LAC_Template, which was iteratively improved in ten co-design interviews.

4.3.1 | Widgets for monitoring: Evaluation and requirements

Through the evaluation and improvement of the LAC_Template, we established requirements that either confirmed those generated during the ideation phase (where the LAC_Template was not proposed to teachers) or emerged only during the evaluation of the LAC_Template.

Requirements for monitoring from LAC_Template evaluation that confirm ideation requirements

RE1: Simple user interface. As mentioned as a key criterion by four teachers in the ideation phase (RI1), in the evaluation phase, three teachers also requested *a simple user interface*, after they perceived one or multiple widgets as too cluttered. Based on teachers' suggestions to improve the UI, we fine-tuned the widgets visually by adapting colour coding, and spacing, and reducing "visual noises", and redundant elements in the UI that do not provide additional information. To further enhance the UI, we adapted the wording in the widgets to those that teachers suggested.

RE2: Problematic learning goals of the whole class. The most popular widget, the class progress overview, visualises the goal progress of the entire class and thus also the problematic goals with which the whole class is struggling (see Figure 10, right). Its popularity led to the extraction of *RE2* in the evaluation phase and confirmed the identical requirement of *RI2* from the ideation phase.

RE3: Problematic tasks of the whole class. Likewise, this requirement is derived through the popularity of the class progress overview, which also shows the problematic tasks for the class. RE3 therefore confirms *RI3 to show problematic tasks of the whole class*, from the ideation phase as well.

RE4: Each student's progress in learning goals. Based on the positive evaluation of the third most favoured widget, the goal view (see Figure 3), showing each student's scores in each learning goal, *RE4* was extracted. It confirms RI4, the same requirement extracted in the ideation phase. Four teachers mentioned that the goal view could enable them to see the strengths and weaknesses of each student. Three teachers also reported that the goal view could be valuable to grading students at the end of the semester since it can give teachers profound reasons for the grades. However, three participants also mentioned that the goal view is too detailed and time-consuming, which indicates that the goal view is not suitable for day-to-day use, with one teacher stating.

RE5 Each student's task scores. Based on the positive evaluation of the task view, which displays each student's task scores and was favoured by three teachers, *RE5* was extracted. *It* confirms the identical requirement *RI5*, which was identified in the ideation phase. The task view is seen by two teachers as a means to identify tasks that are poorly designed. According to two teachers as well, the task view provides an opportunity for teachers to detect struggling students and offer them immediate support during lessons. Two teachers, however, also commented that it would take too much time to analyse every single task for every student.

New requirements for monitoring only derived from LAC_Temlpate evaluation

RE6: Show how learning goals and tasks are connected. When facing the initial version of the class progress overview (see Figure 10, left), three teachers mentioned that they would like to see which tasks are linked to the presented learning goals to understand the scores better. We

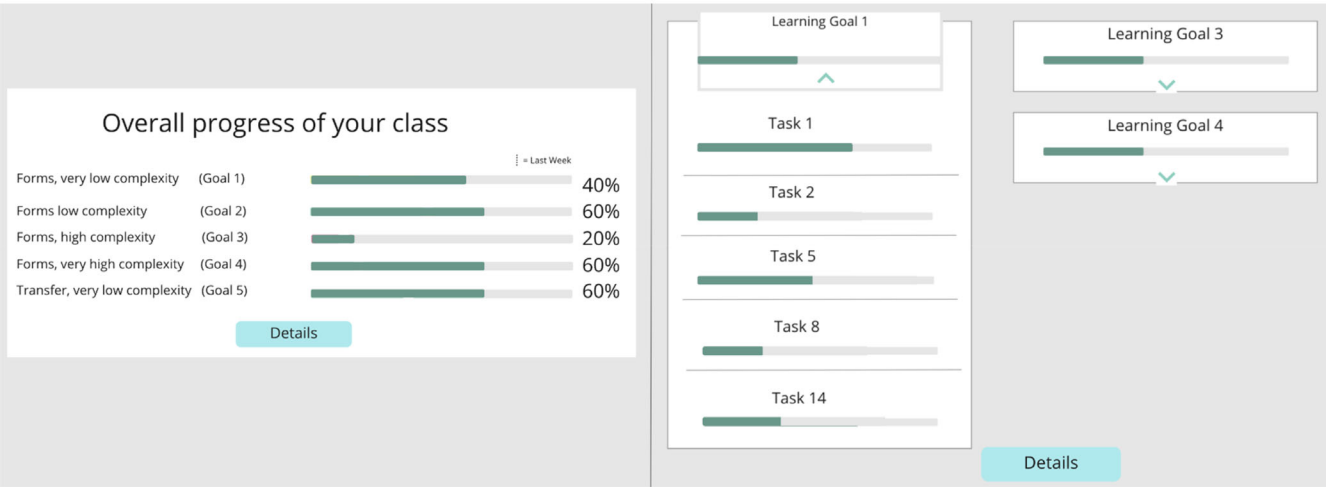

FIGURE 10 The class progress overview from the initial version of the LAC_Template (left) and the improved version improved by the teachers' suggestions (right). It is the starting point of the dashboard and provides the summed score of the whole class in each learning goal and allows users to expand the tasks associated with the goals. By clicking on "details", teachers can dive into details to see the goal- and task view, which display the progress of each student.

therefore enhanced the class progress overview accordingly (see Figure 10, right) and concluded *RE6: Show how learning goals and tasks are connected*.

RE7: Start from class overview & dive into detailed views. Four teachers mentioned that they might not have enough time to use detailed views, such as the goal- or task view, showing individual student results, in their daily teaching practice. After improving the class progress overview, three teachers found it useful for a "quick check" when they do not have much time. They suggested the idea to first start with a rough overview of the class progress and then, only if they have time, to zoom into problematic tasks or into detailed views like the goal- or task view. One teacher said: "*A teacher has many things to do, and it is impossible to have these granular levels of accuracy on each student every single day but these detailed views [goal- and task view] could be useful if the teachers have the free time. If there's no free time, they can use this panorama visualisation [class progress overview]. If they have more time, they can go into detail.*" From this, we can derive *RE7*, to *start from the class overview and dive into detailed views*, which was implemented within the navigation structure of the final LAC_Template version (Figure 9).

RE8: Alerts that highlight problems. Two teachers suggested they would like to receive alerts when a student or the whole class struggles with a certain task or goal. One teacher said, "*it would be nice to get a warning if something is going wrong, so I do not need to read the whole dashboard*". The suggested improvement was therefore incorporated in the task- and goal view of the LAC_Template (Figure 9) so that a red warning icon lights up when the overall score of a student drops below a certain threshold (e.g., below 20%).

The *distribution view*, which displays how students are distributed across four achievement levels, was found unhelpful by four teachers as it did not provide them with sufficient information about individual students. For these reasons, the *distribution view* was excluded from the list of requirements.

4.3.2 | Feedback system: Evaluation & requirements

In the ideation phase, no features for the feedback system were established, as teachers were only asked for requirements for monitoring to enable them to provide feedback in that phase. Since selecting students for feedback by interacting with the visualisations is a novel functionality of our feedback system, we explicitly asked teachers for requirements for the feedback system only after introducing the LAC_Template in the *evaluation & improvement* phase. Besides the class progress overview, the other most favoured widget, also favoured by seven teachers, is the feedback system with its following components: student selection for feedback via interacting with the charts; the feedback template split into positive corrective and recommending feedback; the editable feedback suggestions that relate to the scores of the selected students; and the automation feature. In this section, we present requirements driven only from the stage where the feedback system of the LAC_Template was evaluated and improved.

Feedback system requirements derived from LAC_Template evaluation

RE9: Reduce the steps to create feedback. Three teachers emphasised during the evaluation of the feedback system that the process to create feedback should be as quick and easy as possible because of their limited time resources; as one teacher said: "*You have to reduce the steps to provide feedback to a minimum*". To save time when creating

feedback, they emphasised that all input fields in the template should be optional, and teachers should only fill in the fields they want. That underlines the importance of good usability, which is efficient and time-saving.

RE10: Don't forget positive feedback. Five of ten teachers liked the idea that the feedback template asks teachers to give positive feedback, as this type of feedback is often neglected. One teacher said: "*It's good to be reminded to give positive feedback as well; Most of the time, you focus on weaknesses and I think it is good to let them know about their strengths as well.*"

RE11: Suggest editable feedback texts. Four teachers found the text suggestions in the feedback template helpful, appreciating that they can reduce the workload of writing repetitive feedback messages. However, two teachers stressed the importance of the texts being editable to be adjusted depending on the situation as one of them stated, "*Having some feedback already prepared can be useful but with the possibility to personalise it and select the feedback you want.*"

RE12: Facilitate the creation of peer learning groups. Four teachers mentioned that selecting a performance group for feedback could be useful in creating smaller learning groups to promote peer learning. One teacher stated: "*Sending feedback to the group could be useful if I want to organise an extra class just for weaker students on a topic, or I could suggest a student who performs well to talk to weaker students. This can be useful to socialise the learning process*".

RE13: Automatic reminder to re-send feedback. The feedback automation feature (Figure 7) was positively received by four teachers, who found it convenient for sending repetitive feedback messages. One teacher said, for instance, "*It is convenient that I don't have to copy-paste the old feedback from somewhere else;*". Three teachers added an improvement to turn the feedback automation into an automatic reminder to send feedback which can be adapted to the context if needed; one teacher said: "*The system could automatically remind me, 'Last time you gave the following feedback to students who behaved similarly… would you like to do that again?' and then I can customise the feedback if I want and send it*".

These feedback-system-related requirements mentioned above can address the abstract formulated challenge *C3, which is the lack of time of teachers to provide individual feedback to each student among all ability levels*. *C3*, therefore, supports all mentioned feedback requirements RE9, RE10, RE11, RE12, and RE13, even though they cannot be derived directly from the abstractly formulated challenge *C3*.

4.4 | Final requirements

All interview phases, such as exploring challenges, ideation and LAC_Template evaluation and improvement, served to define and validate requirements for an LA Cockpit for FA in secondary school contexts. Table 4 presents how the 16 requirements for the design of such a tool were derived from the three individual phases of the co-design process, with some requirements being derived from only one phase, while others came up repeatedly in multiple phases. They are categorised into general requirements, requirements for monitoring learning and for a feedback system. The general ones present the technical prerequisites that the system needs to fulfil first before the ones specific to the monitoring of learning for the provision of feedback are discussed.

5 | DISCUSSION

To answer our first research question regarding the challenges of secondary school teachers in monitoring students' learning and providing feedback, we identified three challenges in this study. These include *C1 Lack of time in manually assessing learning outcomes on a regular basis* and *C2 Lack of technology in assessing learning outcomes*. We could map these challenges to *RF1 to provide teachers with up-to-date data* and *RF2 the capability to assess students' (free-text) responses on FA automatically*. Compared to multiple-choice, free-text tasks are better suited to test students' active knowledge (Livingston, 2009). The automatic scoring of students' free-text answers can be performed using NLP models, such as the model proposed by Gombert et al. (2022), with an F1 score above 90% in assessing the correctness of short answers in formative physics assessments.

A further challenge teachers faced was *C3, the lack of time to provide individual feedback to each student*. This challenge has been similarly explored in several studies. While teachers aim to distribute their attention evenly among students of all performance/ability levels (CORNO, 2008; Tomlinson et al., 2003), in practice, they often tend to spend more time supporting low-ability students (Deunk et al., 2015). Knoop-van Campen et al. (2021) showed that teacher dashboards can counteract this uneven allocation of feedback across different performance groups and can have an important equalising effect on teacher feedback practices.

To answer our second research question regarding the requirements of a secondary school teacher dashboard to monitor the learning progress in FA, we identified several monitoring-related requirements: An LA Cockpit should display problematic learning goals (RF4) and tasks (RF5) of the whole class. Visualising the progress of each student in their learning goals (RF6) and their scores in each task (RF7) were also seen as relevant. Furthermore, teachers requested RF8, that struggling students should be represented on the teacher dashboard.

Additional requirements for monitoring, which primarily do not describe what pieces of information the dashboard should display but rather how it should function and how its contents should be structured and highlighted, were discovered. These (RF9, RF10, and RF11) emerged only during phase 3 of the co-design process when the LAC_Template was introduced as a suggestion. This indicates that during co-design processes, incorporating suggestions can help reveal more specific requirements from teachers that might remain undiscovered compared to brainstorming sessions without suggestions. Moreover, by iteratively prototyping and testing the LAC_Template,

TABLE 4 Final requirements for the monitoring components and feedback system, showing from which phases of the co-design interviews the requirements were derived.

		Derived from...		
	Final requirements	Phase 1 exploring challenges	Phase 2 ideation	Phase 3 LAC_Template evaluation & improvement
General Requirements	RF1 Provide up-to-date data	RC1		
	RF2 Assess (free-text) responses automatically	RC2		
	RF3 Simple User Interface		RI1	RE1
Requirements for Monitoring	RF4 Problematic learning goals of the whole class		RI2	RE2
	RF5 Problematic tasks of the whole class		RI3	RE3
	RF6 Each student's progress on the learning goals		RI4	RE4
	RF7 Each student's task scores		RI5	RE5
	RF8 Students who struggle		RI6	
	RF9 Show how learning goals and tasks are connected			RE6
	RF10 Start from class overview & dive into detailed views			RE7
	RF11 Alerts that highlight problems			RE8
Requirements for Feedback System	RF12 Reduce the steps to create feedback	RC3		RE9
	RF13 Don't forget positive feedback	RC3		RE10
	RF14 Suggest editable feedback texts	RC3		RE11
	RF15 Facilitate the creation of peer learning groups	RC3		RE12
	RF16 Automatic reminder to re-send feedback	RC3		RE13

Note: For each final requirement (RFx), the requirements derived from the challenges (RCx), the ideation phase (RIx) and the evaluation (REx) were marked. Requirements from phases without the LAC_Template are marked in blue and requirements from the phase including the LAC_Template in purple.

ideas for improvements were directly validated or discarded during the co-design process. Thus, teachers in later interviews could evaluate an already matured iteration of the prototype and further refine it from there. One of the more specific requirements is RF10, a navigation structure that allows teachers to start with an overview and then drill down into detailed views. A similar "deep dive" feature was also implemented in a prototype resulting from a co-design study by Holstein et al. (2019) on developing a teacher-facing classroom orchestration tool. Including alerts that highlight problems (RF11) was also implemented in the co-design study by Holstein et al. (2019). Several dashboard studies highlight teachers' challenges in determining actionable steps when viewing a dashboard because teachers lack support in translating the information presented in dashboards into pedagogical actions (Sergis & Sampson, 2017). Visual interpretational aid such as alerts can help teachers to focus on relevant situations and to make effective interventions (van Leeuwen et al., 2022). Martinez-Maldonado et al. (2015), for instance, compared the impact of two dashboards, one with information only and one with information plus alerts. The study found that the system with alerts led to more effective teacher interventions and better student learning outcomes than the system with information only.

To answer our third research question, regarding the needed features of a feedback system in a teacher dashboard to facilitate personalised feedback in FA, we defined several criteria for the implementation of a feedback system, which can address challenge C3, the lack of time to provide individual feedback. Despite evidence that positive feedback does not directly improve student performance (Parkes et al., 2013; Prochazka et al., 2020), *RF13 to not forget positive feedback* is highly valued by teachers in this study. Since positive feedback increases motivation (Deci, 1971; Mouratidis et al., 2008), the popularity of positive feedback in this study suggests that student motivation plays an important role among secondary school teachers. However, positive feedback may also reduce the effectiveness of corrective feedback (V. J. Shute, 2008), which poses a challenge of finding the optimal balance between positive and corrective feedback to maintain high motivation and to ensure that students value corrective feedback.

The literature confirms the requirement RF15 to facilitate the creation of peer learning groups with an LA Cockpit. Implementing peer instruction offers several advantages, such as a better understanding of concepts,

lower failure rates, increased student motivation (Mazur, 1997), and the opportunity for students to create new knowledge and share skills through discussions with classmates (Tullis & Goldstone, 2020).

Teachers' emphasis on the importance of editable feedback suggestions (RF14) indicates their intention to be actively engaged in the feedback process rather than relying solely on automation. The feedback template provides a fixed structure with four fields based on feedback theory so that teachers can freely edit the content in these fields. However, if teachers unfamiliar with feedback theory extensively modify or delete the suggested feedback, it may compromise the feedback quality. Therefore, it is important that the system suggests high-quality texts to teachers that are acceptable to teachers. To implement a system that suggests such editable high-quality feedback texts based on students' responses to FA, Large Language Models such as GPT[3] or LLaMA[4] could be used as an assistant to help teachers write feedback.

In addition to that, the intentionally blank fourth input field in the feedback system (see Figure 6) enables teachers to input feedback freely, without being limited to the text suggestions. These types of features can provide teachers with control over the feedback process, allowing active participation instead of complete reliance on automation.

Still concerning RQ3, adapting the initial automation function to an automated reminder to re-send feedback (RF16), in which teachers can review and adjust the feedback suggestions if necessary, indicates teachers' need for control in teaching. This illustrates, on the one hand, that feedback should not be sent uncontrolled; on the other hand, teachers could benefit from the support of the system to efficiently distribute feedback to all students who need it. Therefore, an automatic reminder for feedback can be a compromise that considers both factors—teacher control and efficiency. Involving teachers in the feedback creation process could reduce concerns that technology will undermine their role in the classroom (van Leeuwen, 2019). The claim that automated feedback systems such as ITS neglect the role of the teacher in the feedback process (Pinheiro et al., 2021) and the results from this study highlight the potential of semi-automated feedback systems such as an LA Cockpit. These systems could be designed to act as assistants, empowering teachers with control over the distribution of feedback and the level of automation involved. Since most of the feedback systems in digital learning environments are provided automatically by adaptive learning technologies or ITS, an LA Cockpit can provide an example of how augmented feedback, proposed by Di Mitri et al. (2022), can be used to enhance traditional educational feedback by augmenting it with digital data and artificial intelligence. However, one challenge for future research could be to find the "*right balance*" *(if there is one)* between automation to leverage the potential of technology to provide personalised feedback at scale and teacher control to empower them without undermining their role in schools.

A limitation of this work is that the proposed requirements and LAC_Template have not been tested and validated in authentic classroom situations and therefore may not be fully aligned with teachers' daily practices. Based on the proposed requirements, a technically fully functional version of an LA cockpit needs to be implemented, field-tested, and refined to align it with teachers' daily practice.

Future research should implement and evaluate a fully functional version of an LA Cockpit in real-world settings and investigate (1) how it affects teachers' feedback practices, (2) if and how it provides them with added value, and (3) how they can incorporate it into their daily work. To conduct these investigations, the dashboard evaluation framework proposed by van Leeuwen et al. (2019), would be interesting. This framework categorises the support type a teacher dashboard provides into mirroring, alerting or advising. Future research should furthermore investigate teachers' feedback practices with an LA Cockpit to understand how teachers translate their insights from the dashboard visualisations into pedagogical actions. However, the design of the feedback system in this study primarily focused on positive feedback, corrective feedback, and recommendations without delving deeper into other feedback types. Future research on teachers' feedback practices with the LA Cockpit should also consider and promote the use of other types of feedback, such as task-related, process-related and metacognitive feedback.

Subsequently, a step further should be taken. As the ultimate goal of LA is to impact students' learning (van Leeuwen et al., 2022), a future study should investigate whether LA Cockpit-guided feedback leads to improved student learning outcomes. This could enable the transfer from LA research into educational practice and empower teachers to provide informative feedback in their school practice. Another possible direction for future research is to incorporate Large Language Models into the feedback system, to scale individualised feedback suggestions that teachers can use to send students. Efforts in the direction of automated generation of feedback suggestions, which teachers only need to review before sending, can cut the amount of time teachers would spend creating feedback and thus increase acceptance of such teacher-controlled feedback systems as an LA Cockpit.

6 | CONCLUSION

The goal of this study was to set requirements for designing an LA Cockpit, a teacher dashboard with an integrated feedback system to monitor students' learning and facilitate the provision of feedback (Karademir et al., 2022), for the specific case of FA in secondary school. To reach this goal, we conducted ten co-design interviews with secondary school teachers in which we first explored their challenges in monitoring students' learning progress and providing feedback to students. Then we asked teachers to describe the features of an LA Cockpit to monitor learning and provide feedback in FA. Next, the teachers were provided with the LAC_Template, a design template which we had prepared in advance to support them in extracting requirements from it. Teachers were therefore asked to evaluate and improve the LAC_Template. Based on that, further design requirements were derived.

[3] https://openai.com/gpt-4
[4] https://ai.meta.com/llama/

As a result of this co-design methodology, we identified 3 challenges that an LA Cockpit should address and 16 final requirements that it should meet. The teachers' challenges that an LA Cockpit should address are the lack of time to assess students' learning outcomes on a regular basis manually (C1), the lack of technology in assessing learning outcomes (C2) and the lack of time to provide individual feedback to each student (C3).

Among the 16 final requirements, 8 were classified as requirements for monitoring student learning. These include showing alerts that highlight critical areas that require teacher attention (RF11), problematic learning goals for the entire class (RF4) and the tasks to which the learning goals are linked (RF9). In addition, teachers suggested that the LA Cockpit should start with visualising a broad class overview and provide the ability to dive deeper into more detailed views (RF10).

Moreover, 5 design requirements for the feedback system were established. These describe that the feedback system should reduce the steps for teachers to create feedback (RF12), promote the provision of positive feedback (RF13), and facilitate the creation of peer learning groups (RF15). Results from this study can serve as guidelines for the development of teacher dashboards designed for FA scenarios with the capability to monitor and provide students with personalised feedback.

This study exemplifies how an LA Cockpit, functioning as a teacher dashboard with an integrated feedback system, could address teachers' main challenges, particularly the time constraints hindering them from providing individual feedback to students. Features supporting the feedback creation process, like a feedback template and the automation of steps from this process, could assist teachers in providing their students with more individual support. However, the results also highlight that, despite the use of automation in feedback systems, teachers prefer to remain actively engaged in the feedback process which leads to the need for features that give teachers the ability to adapt suggestions given by the system and to control feedback automation. This allows them to orchestrate feedback automation, ensuring beneficial cooperation between teacher and technology, where the teacher remains in charge, and technology functions as an assistant. We hope that this study will help to establish teacher dashboards and semi-automated feedback systems as an integrated whole in the form of LA Cockpits in the future. When developing feedback systems, it is essential to foster a beneficial collaboration between teachers and automation, leveraging the strengths of humans and technology in a complementary way.

AUTHOR CONTRIBUTIONS

Onur Karademir: Conceptualization; investigation; writing – original draft; methodology; validation; visualization; writing – review and editing; data curation; resources; formal analysis. **Daniele Di Mitri:** Conceptualization; methodology; writing – review and editing; supervision. **Jan Schneider:** Supervision; methodology; writing – original draft; conceptualization; writing – review and editing. **Ioana Jivet:** Writing – review and editing; conceptualization; writing – original draft; methodology; supervision. **Jörn Allmang:** Conceptualization. **Sebastian Gombert:** Writing – review and editing. **Marcus Kubsch:** Conceptualization. **Knut Neumann:** Funding acquisition. **Hendrik Drachsler:** Funding acquisition; supervision.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was approved by the Ethics Committee of the IPN–Leibniz Institute for Science and Mathematics Education. All participants gave written informed consent before taking part in the study.

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REFERENCES

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, *5*(1), 7–74. https://doi.org/10.1080/0969595980050102

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability(Formerly: Journal of Personnel Evaluation in Education)*, *21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Bodily, R., & Verbert, K. (2017). Review of research on student-facing learning analytics dashboards and educational recommender systems. *IEEE Transactions on Learning Technologies*, *1–1*, 405–418. https://doi.org/10.1109/TLT.2017.2740172

Boehler, M. L., Rogers, D. A., Schwind, C. J., Mayforth, R., Quin, J., Williams, R. G., & Dunnington, G. (2006). An investigation of medical student reactions to feedback: A randomised controlled trial. *Medical Education*, *40*(8), 746–749. https://doi.org/10.1111/j.1365-2929.2006.02503.x

Bulunuz, N., Bulunuz, M., & Peker, H. (2014). Effects of formative assessment probes integrated in extra-curricular hands-on science: Middle school Students' understanding. *Journal of Baltic Science Education*, *13*(2), 243–258.

Bulut, O., Gorgun, G., Yildirim-Erbasli, S. N., Wongvorachan, T., Daniels, L. M., Gao, Y., Lai, K. W., & Shin, J. (2023). Standing on the shoulders of giants: Online formative assessments as the foundation for predictive learning analytics models. *British Journal of Educational Technology*, *54*(1), 19–39. https://doi.org/10.1111/bjet.13276

Clark, I. (2012). Formative assessment: Assessment is for self-regulated learning. *Educational Psychology Review*, *24*(2), 205–249. https://doi.org/10.1007/s10648-011-9191-6

Corno, L. (2008). On teaching adaptively. *Educational Psychologist*, *43*(3), 161–173. https://doi.org/10.1080/00461520802178466

Damşa, C., & de Lange, T. (2019). Student-centred learning environments in higher education. *Uniped*, *42*(1), 9–26. https://doi.org/10.18261/issn.1893-8981-2019-01-02

Deci, E. L. (1971). Effects of externally mediated rewards on intrinsic motivation. *Journal of Personality and Social Psychology*, *18*, 105–115. https://doi.org/10.1037/h0030644

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*, 627–668. https://doi.org/10.1037/0033-2909.125.6.627

Deunk, M., Doolaard, S., Smale-Jacobse, A., & Bosker, R. J. (2015). *Differentiation within and across classrooms: A systematic review of studies into the cognitive effects of differentiation practices*. RUG/GION.

Di Mitri, D., Gombert, S., & Karademir, O. (2022). Reflecting on the actionable components of a model for augmented feedback.

Dollinger, M., Liu, D., Arthars, N., & Lodge, J. (2019). Working together in learning analytics towards the Co-creation of value. *Journal of Learning Analytics*, *6*(2), Article 2. https://doi.org/10.18608/jla.2019.62.2

Dourado, R. A., Rodrigues, R. L., Ferreira, N., Mello, R. F., Gomes, A. S., & Verbert, K. (2021). A Teacher-facing Learning Analytics Dashboard for Process-oriented Feedback in Online Learning. *LAK21: 11th International Learning Analytics and Knowledge Conference*. 482–489 https://doi.org/10.1145/3448139.3448187

Faber, J. M., Luyten, H., & Visscher, A. J. (2017). The effects of a digital formative assessment tool on mathematics achievement and student motivation: Results of a randomized experiment. *Computers & Education*, *106*, 83–96. https://doi.org/10.1016/j.compedu.2016.12.001

Gombert, S., Di Mitri, D., Karademir, O., Kubsch, M., Kolbe, H., Tautz, S., Grimm, A., Bohm, I., Neumann, K., & Drachsler, H. (2022). Coding energy knowledge in constructed responses with explainable NLP models. *Journal of Computer Assisted Learning*, *39*, 767–786. https://doi.org/10.1111/jcal.12767

Granberg, C., Palm, T., & Palmberg, B. (2021). A case study of a formative assessment practice and the effects on students' self-regulated learning. *Studies in Educational Evaluation*, *68*, 100955. https://doi.org/10.1016/j.stueduc.2020.100955

Greller, W., & Drachsler, H. (2012). *Turning learning into numbers—A learning analytics framework*. Educational Technology & Society.

Hattie, J., & Timperley, H. (2007). The Power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-designing a real-time classroom orchestration tool to support teacher–AI complementarity. *Journal of Learning Analytics*, *6*(2), 2. https://doi.org/10.18608/jla.2019.62.3

Ifenthaler, D., Schumacher, C., & Şahin, M. (2021). System-based or Teacher-based Learning Analytics Feedback—What Works Best? https://doi.org/10.1109/ICALT52272.2021.00062

Jivet, I., Scheffel, M., Drachsler, H., & Specht, M. (2017). Awareness is not enough: pitfalls of learning analytics dashboards in the educational practice. https://doi.org/10.1007/978-3-319-66610-5_7

Kaliisa, R., Jivet, I., & Prinsloo, P. (2023). A checklist to guide the planning, designing, implementation, and evaluation of learning analytics dashboards. *International Journal of Educational Technology in Higher Education*, *20*(1), 28. https://doi.org/10.1186/s41239-023-00394-6

Karademir, O., Ahmad, A., Schneider, J., Di Mitri, D., Jivet, I., & Drachsler, H. (2022). *Designing the learning analytics cockpit—A dashboard that enables interventions*. In F. De la Prieta, R. Gennari, M. Temperini, T. Di Mascio, P. Vittorini, Z. Kubincova, E. Popescu, D. Rua Carneiro, L. Lancia, & A. Addone (Eds.), *Methodologies and Intelligent Systems for Technology Enhanced Learning, 11th International Conference* (pp. 95–104). Springer International Publishing. https://doi.org/10.1007/978-3-030-86618-1_10

Kippers, W. B., Wolterinck, C. H. D., Schildkamp, K., Poortman, C. L., & Visscher, A. J. (2018). Teachers' views on the use of assessment for learning and data-based decision making in classroom practice. *Teaching and Teacher Education*, *75*, 199–213. https://doi.org/10.1016/j.tate.2018.06.015

Knoop-van Campen, C. A. N., Wise, A., & Molenaar, I. (2021). The equalizing effect of teacher dashboards on feedback in K-12 classrooms. *Interactive Learning Environments*, 1–17. https://doi.org/10.1080/10494820.2021.1931346

Kovanovic, V., Mazziotti, C., & Lodge, J. (2021). Learning analytics for primary and secondary schools. *Journal of Learning Analytics*, *8*(2), 2. https://doi.org/10.18608/jla.2021.7543

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 275–297). Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.018

Kubsch, M., Czinczel, B., Lossjew, J., Wyrwich, T., Bednorz, D., Bernholt, S., Fiedler, D., Strauß, S., Cress, U., Drachsler, H., Neumann, K., & Rummel, N. (2022). Toward learning progression analytics—Developing learning environments for the automated analysis of learning using evidence centered design. *Frontiers in Education*, *7*, 1–15. https://doi.org/10.3389/feduc.2022.981910

Lee, H., Chung, H. Q., Zhang, Y., Abedi, J., & Warschauer, M. (2020). The effectiveness and features of formative assessment in US K-12 education: A systematic review. *Applied Measurement in Education*, *33*(2), 124–140. https://doi.org/10.1080/08957347.2020.1732383

Lim, L.-A., Dawson, S., Gašević, D., Joksimović, S., Pardo, A., Fudge, A., & Gentili, S. (2021). Students' perceptions of, and emotional responses to, personalised learning analytics-based feedback: An exploratory study of four courses. *Assessment & Evaluation in Higher Education*, *46*(3), 339–359. https://doi.org/10.1080/02602938.2020.1782831

Livingston, S. A. (2009). Constructed-response test questions: Why we use them; How we Score Them. 11.

Maier, U., Wolf, N., & Randler, C. (2016). Effects of a computer-assisted formative assessment intervention based on multiple-tier diagnostic items and different feedback types. *Computers & Education*, *95*, 85–98. https://doi.org/10.1016/j.compedu.2015.12.002

Majumdar, R., Akçapınar, A., Akçapınar, G., Ogata, H., & Flanagan, B. (2019). LAView: Learning analytics dashboard towards evidence-based education. *Companion Proceedings of the 9th International Conference on Learning Analytics and Knowledge*. https://repository.kulib.kyoto-u.ac.jp/dspace/handle/2433/244127

Martinez-Maldonado, R., Clayphan, A., Yacef, K., & Kay, J. (2015). MTFeedback: Providing notifications to enhance teacher awareness of small group work in the classroom. *IEEE Transactions on Learning Technologies*, *8*(2), 187–200. https://doi.org/10.1109/TLT.2014.2365027

Martinez-Maldonado, R., Elliott, D., Axisa, C., Power, T., Echeverria, V., & Buckingham Shum, S. (2020). Designing translucent learning analytics with teachers: An elicitation process. *Interactive Learning Environments*, *30*(6), 1077–1091. https://doi.org/10.1080/10494820.2019.1710541

Mazur, E. (1997). Peer instruction: A User's manual. In *Peer instruction: A user's manual*. Prentice Hall.

Molenaar, I., & Knoop-van Campen, C. (2017). Teacher Dashboards in Practice: Usage and Impact (p. 138). https://doi.org/10.1007/978-3-319-66610-5_10

Molenaar, I., & Knoop-van Campen, C. (2018). How teachers make dashboard information actionable. *IEEE Transactions on Learning Technologies*, *1–1*, 347–355. https://doi.org/10.1109/TLT.2018.2851585

Molenaar, I., & Knoop-van Campen, C. A. N. (2019). How teachers make dashboard information actionable. *IEEE Transactions on Learning Technologies*, *12*(3), 347–355. https://doi.org/10.1109/TLT.2018.2851585

Molenaar, I., & van Schaik, A. (2016). A methodology to investigate the usage of educational technologies on tablets in schools. 116. https://repository.ubn.ru.nl/handle/2066/161373

Mouratidis, A., Vansteenkiste, M., Lens, W., & Sideridis, G. (2008). The motivating role of positive feedback in sport and physical education: Evidence for a motivational model. *Journal of Sport & Exercise Psychology*, *30*(2), 240–268. https://doi.org/10.1123/jsep.30.2.240

O'Connor, H., & Gibson, N. (2003). A step-by-step guide to qualitative data analysis. *Pimatisiwin: A Journal of Indigenous and Aboriginal Community Health*, *1*(1), 63–90.

Pardo, A., Jovanovic, J., Dawson, S., Gašević, D., & Mirriahi, N. (2019). Using learning analytics to scale the provision of personalised feedback. *British Journal of Educational Technology*, *50*(1), 128–138. https://doi.org/10.1111/bjet.12592

Parkes, J., Abercrombie, S., & McCarty, T. (2013). Feedback sandwiches affect perceptions but not performance. *Advances in Health Sciences Education*, *18*(3), 397–407. https://doi.org/10.1007/s10459-012-9377-9

Pinheiro, A., Barbosa, A., Carvalho, R., Freitas, F., Tsai, Y.-S., Gasevic, D., & Ferreira, R. (2021). Automatic feedback in online learning environments: A systematic literature review. *Computers and Education: Artificial Intelligence*, *2*, 100027. https://doi.org/10.1016/j.caeai.2021.100027

Prochazka, J., Ovcari, M., & Durinik, M. (2020). Sandwich feedback: The empirical evidence of its effectiveness. *Learning and Motivation*, *71*, 101649. https://doi.org/10.1016/j.lmot.2020.101649

Rogers, D. A., Boehler, M. L., Schwind, C. J., Meier, A. H., Wall, J. C. H., & Brenner, M. J. (2012). Engaging medical students in the feedback process. *American Journal of Surgery*, *203*(1), 21–25. https://doi.org/10.1016/j.amjsurg.2011.07.009

Rubin, H. J., & Rubin, I. S. (2011). *Qualitative interviewing: The art of hearing data*. SAGE.

Sergis, S., & Sampson, D. G. (2017). Teaching and learning analytics to support teacher inquiry: A systematic literature review. In A. Peña-Ayala (Ed.), *Learning analytics: Fundaments, applications, and trends: A view of the current state of the art to enhance e-learning* (pp. 25–63). Springer International Publishing. https://doi.org/10.1007/978-3-319-52977-6_2

Shute, V. j., & Rahimi, S. (2017). Review of computer-based assessment for learning in elementary and secondary education. *Journal of Computer Assisted Learning*, *33*(1), 1–19. https://doi.org/10.1111/jcal.12172

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153–189. https://doi.org/10.3102/0034654307313795

Shute, V. J., Hansen, E. G., & Almond, R. G. (2008). You can't fatten a hog by weighing it–or can you? Evaluating an assessment for learning system called ACED. *International Journal of Artificial Intelligence in Education*, *18*(4), 289–316.

Siemens, G. (2013). Learning analytics: The emergence of a discipline. *American Behavioral Scientist*, *57*(10), 1380–1400. https://doi.org/10.1177/0002764213498851

Sousa, E. B. G. d., Alexandre, B., Ferreira Mello, R., Pontual Falcão, T., Vesin, B., & Gašević, D. (2021). Applications of learning analytics in high schools: A systematic literature review. *Frontiers in Artificial Intelligence*, *4*, 737891. https://doi.org/10.3389/frai.2021.737891

Stanja, J., Gritz, W., Krugel, J., Hoppe, A., & Dannemann, S. (2023). Formative assessment strategies for students' conceptions—The potential of learning analytics. *British Journal of Educational Technology*, *54*(1), 58–75. https://doi.org/10.1111/bjet.13288

Tempelaar, D. T., Rienties, B., & Giesbers, B. (2015). In search for the most informative data for feedback generation: Learning analytics in a data-rich context. *Computers in Human Behavior*, *47*, 157–167. https://doi.org/10.1016/j.chb.2014.05.038

Tomlinson, C. A., Brighton, C., Hertberg, H., Callahan, C. M., Moon, T. R., Brimijoin, K., Conover, L. A., & Reynolds, T. (2003). Differentiating instruction in response to student readiness, interest, and learning profile in academically diverse classrooms: A review of literature. *Journal for the Education of the Gifted*, *27*(2–3), 119–145. https://doi.org/10.1177/016235320302700203

Tsai, Y.-S., Mello, R. F., Jovanović, J., & Gašević, D. (2021). Student appreciation of data-driven feedback: A pilot study on OnTask. *LAK21: 11th International Learning Analytics and Knowledge Conference*, 511–517. https://doi.org/10.1145/3448139.3448212

Tullis, J. G., & Goldstone, R. L. (2020). Why does peer instruction benefit student learning? *Cognitive Research: Principles and Implications*, *5*(1), 15. https://doi.org/10.1186/s41235-020-00218-5

van der Kleij, F. M., Feskens, R. C. W., & Eggen, T. J. H. M. (2015). Effects of feedback in a computer-based learning environment on Students' learning outcomes: A meta-analysis. *Review of Educational Research*, *85*(4), 475–511. https://doi.org/10.3102/0034654314564881

van Leeuwen, A. (2019). Teachers' perceptions of the usability of learning analytics reports in a flipped university course: When and how does information become actionable knowledge? *Educational Technology Research and Development*, *67*(5), 1043–1064. https://doi.org/10.1007/s11423-018-09639-y

Van Leeuwen, A., Campen, C. A. N. K., Molenaar, I., & Rummel, N. (2021). How teacher characteristics relate to how teachers use dashboards: Results from two case studies in K-12. *Journal of Learning Analytics*, *8*(2), Article 2. https://doi.org/10.18608/jla.2021.7325

van Leeuwen, A., Rummel, N., & van Gog, T. (2019). What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning*, *14*(3), 261–289. https://doi.org/10.1007/s11412-019-09299-x

Van Leeuwen, A., Teasley, S. D., & Wise, A. F. (2022). Teacher and student facing learning analytics. In C. Lang, G. Siemens, & A. F. Wise (Eds.), *The handbook of learning analytics* (2nd ed., pp. 130–140). SOLAR. https://doi.org/10.18608/hla22.013

Verbert, K., Duval, E., Klerkx, J., Govaerts, S., & Santos, J. L. (2013). Learning analytics dashboard applications. *American Behavioral Scientist*, *57*(10), 1500–1509. https://doi.org/10.1177/0002764213479363

Wiliam, D. (2010). *The role of formative assessment in effective learning environments* (pp. 135–159). OECD. https://doi.org/10.1787/9789264086487-8-en

Wise, A. F., & Jung, Y. (2019). Teaching with analytics: Towards a situated model of instructional decision-making. *Journal of Learning Analytics*, *6*(2), Article 2. https://doi.org/10.18608/jla.2019.62.4

Xhakaj, F., Aleven, V., & McLaren, B. M. (2017). Effects of a teacher dashboard for an intelligent tutoring system on teacher knowledge, lesson planning, lessons and student learning. In É. Lavoué, H. Drachsler, K. Verbert, J. Broisin, & M. Pérez-Sanagustín (Eds.), *Data driven approaches in digital education* (Vol. 10474, pp. 315–329). Springer International Publishing. https://doi.org/10.1007/978-3-319-66610-5_23

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The Power of Feedback Revisited: A Meta-Analysis of Educational Feedback Research. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.03087

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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