International Society of the Learning Sciences

An Investigation of Dashboard in Collaborative Inquiry: The Dynamic Interplay between Technology and Pedagogy in Classroom Orchestration

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Abstract: This study investigates the uses of a teacher dashboard in a technology-rich, problem-based learning (PBL) environment incorporating collaborative game-based learning for middle school science inquiry. The dashboard, designed through participatory approaches with teachers, provides real-time data visualization of students' learning activities, aiming to reduce teachers' orchestration load and enhance PBL facilitation. Findings indicate the teacher actively orchestrated classroom activities using the dashboard, balancing between digital insights and personal observation. The study extends current models of dashboard interaction by integrating classroom observations and teachers' prior knowledge into the interpretation phase. It emphasizes the need for dashboards to offer strategic-level support, enabling teachers to tailor instruction effectively. This approach not only reduces the orchestration load but also promotes meaningful student engagement and collaborative inquiry in a PBL setting.

Introduction

Classroom orchestration describes the real-time management activities in multiple social planes (Dillenbourg et al., 2018) such as technology-rich problem-based learning (PBL) classrooms, in which teachers must manage multiple complex activities. Moreover, when the technological tools were designed and developed for collaborative learning, they might fall short in offering support for teacher orchestration with a rich set of activities (Dillenbourg, 2013). Orchestration load refers to the efforts required for teachers to conduct learning activities in the classrooms, including both physical components such as moving around the classroom, and cognitive components, such as providing facilitation to support students' learning. Introducing new technological tools into the classroom can increase teachers' orchestration load, bringing complexity and uncertainty for collaborative learning (Dillenbourg, 2013). As a result, teachers under a high orchestration load may benefit from support to better enable the facilitation of complex learning activities. To meet the need for supportive resources, we designed a teacher dashboard to 1) reduce teachers' orchestration load, and 2) promote PBL facilitation to support students' learning. The teacher dashboard in this study refers to a real-time tool for teachers, providing data visualization of students' learning activities and presenting instant recommendations through learning analytics. It was designed and developed to help teachers access learning and collaborative processes as well as make informed decisions, with the underlying goal to reduce the orchestration load in classrooms and empower teachers to provide meaningful facilitations for students (Bae et al., 2023).

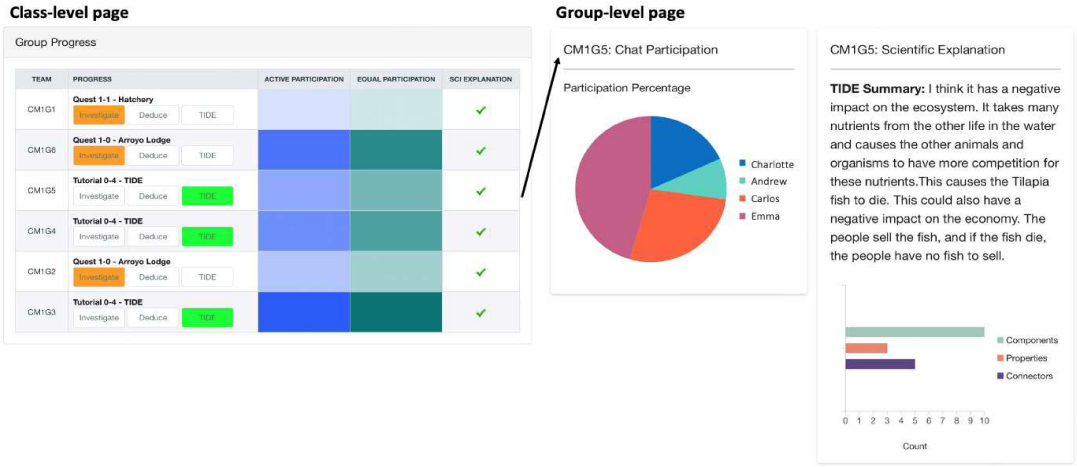
Research has been exploring the design stage of teacher dashboards (Holstein et al., 2019), aiming to foreground stakeholder opinions and teachers' needs, while some also examined their practical application in classrooms. The theoretical models (e.g. van Leeuwen et al., 2021) on how teachers translate information on the dashboard into actions describe the process of awareness (knowing the information on the dashboard is available for them), interpretation (sense-making based on the provided information), and enactment (making pedagogical actions). Experimental studies have revealed that the type of support provided in the dashboard and the time pressure will influence teachers' interpretation of the situations (van Leeuwen & Rummel, 2022). However, few studies have explored how teachers used a dashboard to support their classroom orchestration and inform their pedagogical decision-making in real collaborative inquiry classrooms. This study, as a case study, aims to investigate the following question: In a technology-rich PBL classroom, how does the teacher apply the dashboard to support classroom orchestration? The finding will provide a further understanding of teacher orchestration in problem-based learning, and design implications for teacher-facing orchestration technology.

Teacher dashboard to support collaborative game-based learning

Following the PBL approach, [GAME] was designed for middle school students to engage in collaborative scientific inquiry and promote social knowledge construction. In this setting, students work in teams of three to four to tackle a problem of ecosystems by collecting information, sharing ideas, and negotiating with peers through chat. The game consists of a tutorial and three major quests, each following the same structure of exploration and negotiation. Students need to submit their group summary after each quest.

While students are engaging in the game, their group interaction within the learning environment is captured, analyzed, and displayed for teachers through the dashboard. The dashboard consists of both class-level and group-level information (see Figure 1). On the class-level page, each row represents each group while the columns include group number, their current progress in the game, active and equal participation, and "scientific explanation" indicating the quality of the group summary. The participation was captured and calculated based on the number of in-game chats, following the rationale that the more intense the color saturation is, the less active or unequal the participation is, therefore the more attention the group might need from the teacher. To investigate a certain group, the teacher can tap the group row and the group-level information will be provided. On the group-level page, teachers can view the relative distribution of chat participation, in the form of a pie chart, and their submitted group summary. The dashboard displays the number of components (science concepts), properties (description of the phenomenon), and connectors (the logic of the argument) words used in their group summary.

Figure 1
Teacher Dashboard



Methods

Participants and data collection

The case study was conducted in a science classroom middle school in the midwestern, U.S. Across five 70-minute class sessions, 22 six-grade students in six groups were participating in PBL using the [GAME], while one teacher Shelly (pseudonym), with more than 20 years of teaching experience, orchestrating the classroom with provided concurrent dashboard. The dashboard was displayed on a tablet so the teacher could carry it around the classroom and interact with it whenever needed. Shelly was provided a brief instruction on the dashboard along with the job aid explaining features. In our session, we emphasized the goal for actionable dashboard analytics to enhance, but not override, teacher decision-making and insights into individual and small group activity. We provided different displays and reasoned about ways in which low activity for one profile of student would be reasonable, but for a different profile, this would necessitate a check-in. Four types of data were collected during the implementation: 1) 350 minutes of videos on classroom orchestration captured by a camera following the teacher during the class; 2) screen recording of the tablet when the dashboard was in use; 3) five 10-15 minutes interviews recorded right after each class session; and 4) fieldnotes for each class session.

Data analysis

To investigate how the teacher used the dashboard in the classroom, we first aligned the classroom videos with the dashboard screen recordings in each session to capture what the teacher was looking at when interacting with the dashboard. Informed by the aligned video data, we then coded teacher actions into four categories with two levels (See Table 1). For example, when the teacher tapped into group 5 (see Figure 1), the action was coded as

"Observe" and "Group", and when the teacher made an announcement to the whole class, the action was coded as "Intervene" and "Class". Two researchers in the research team coded and reviewed the codes collaboratively. Coding issues were resolved by discussion with changes to categories as needed.

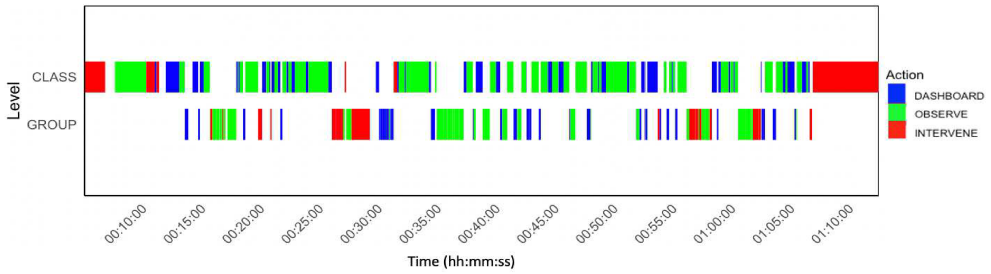
Table 1
Coding Scheme of Teacher Actions in Classrooms

Category	Code	Description
Action	Dashboard	Interacting or browsing information on the dashboard
	Observe	Making observations on certain groups without intervening
	Intervene	Talking to individual students or groups, or making class announcements
	Other	Other activities, such as talking to researchers or leaving the room
Level	Group	Groups or individuals in groups
	Class	Class-level interaction or observation without a specific target
	Other	Usually co-occurring with Other in Action

Findings

Our preliminary analysis showed the orchestration the teacher was engaged in with the dashboard and continuing observation in the physical environment. Due to limited space, in this paper, we will present one 70-minute class session from day 3 out of the five sessions to unpack how the teacher orchestrated the class across levels. On day 3, the teacher was familiar with the dashboard information and the students were on track in the game. In this session, the teacher interacted with students across all three social planes for 14.2 minutes for 21.1% of the whole session time, including the briefing at the start and the debriefing at the end. Shelly's active orchestration was demonstrated by her close monitoring across the session with the dashboard (16.3 mins, 24.2%), and with observation of the classroom (34.2 mins, 50.7%). Her attention shifted across levels (see Figure 2) during the class while cross-checking the dashboard information with her observation of the classroom.

Figure 2
Action Distribution Over Time in a PBL Session



Enactment informed by dashboard, observation, and prior knowledge of students

In our analysis, we sought to understand teacher activity patterns across the span of the lesson by coding each action at units of one second. As displayed in Figure 2, almost every instance of dashboard access (blue) is followed by teacher observation (green). There are almost no instances in which teacher intervention (red) follows dashboard access (blue), indicating the teacher did not intervene immediately following dashboard access. For example, Shelly accessed the class-level dashboard identifying Group 3 needed attention for participation (see Figure 1), and then she walked around Group 3 to observe the situation. After confirming the dashboard information with her observation, she decided to intervene by suggesting "Hey, talk to your group more." It suggests that the teacher did not intervene solely based on dashboard information, but instead, triangulated the dashboard information with her own observation of the classroom. This pattern aligns with Shelly's reflection in the post-session interview: "Because you are a teacher, you are a great eavesdropper, and you can laser focus on conversations at each of the tables. I prefer that to (in-game) chat because I also like to watch their facial expressions. You can't put that in chat, right?" While the dashboard provides behavioral and cognitive status during the collaborative inquiry, the observation in the classroom enriches Shelley's understanding of the situation by how she observes students' affective status. When the teacher identified a discrepancy between dashboard information and her observation for participation, she tended to interpret the situation with her prior knowledge of students. For example, Shelly described a situation in Group 1 when one student was helping another in face-to-face conversation and it was not captured as participation in the dashboard: "I've got in my mind to watch

when, like for example, Kale, he's not going to say a word, he just isn't. Colin is his guide dog. But as I'm watching where the active participation things are (not equal), I've paid attention to that group and I'm finding it. Yeah, it's equal." Thus, while the displayed participation information was designed to provide actionable information to teachers, the teacher did solely not rely on this. Shelly brought rich prior knowledge of her students into the classroom and therefore had expectations on participation patterns for different groups. Though the visualization for participation gradients could guide her attention on certain groups, she quickly made the decision not to intervene since she was "not surprised at all."

The Group Summary: "Delightfully Robust"

Shelly reflected that among all the information on the dashboard, she found the part of group-level scientific explanation most meaningful to her: "I need to know where they are, but this [scientific explanation] tells me their sense of making. And their thoughts and their problem-solving. And their ability to agree." She was able to identify the "delightfully robust" group summary, through not just the quantity or length of explanation but also the quality and accuracy as "Science is not about speed. It's about accuracy."

Discussion

This study demonstrates an active orchestration practice with a teacher dashboard in a collaborative PBL game-based learning context. Based on this investigation, the teacher's attention shifted regularly between group and class levels to monitor what was happening in the classroom. The design of the dashboard centered the teacher's role by having teachers take pedagogical actions supported by the analytics—the teacher's decision-making was informed not only by the dashboard but also by her observation of the classroom as well as prior knowledge of students. Meanwhile, the teacher focused on the quality and accuracy of students' scientific explanations on the dashboard, emphasizing pedagogical attention on reasoning over mere game progression.

The findings align with the current understanding of dashboard interaction following awareness, interpretation, and enactment (van Leeuwen et al., 2021). However, we have expanded the phase of interpretation by integrating other sources of information such as classroom observation and teachers' prior knowledge of students. This has implications for dashboard designs, particularly for any advising functions within the dashboard, providing strategy-level support such as questions to ask and concepts to address for teachers so that they can better tailor their instruction to meet the diverse needs of their students. This functionality would allow teachers to quickly identify key areas of focus, enabling them to offer more personalized and effective pedagogical support. By leveraging data-driven insights on the dashboard, teachers could provide just-in-time facilitation, fostering both collaborative inquiry and scientific discussion in groups.

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Acknowledgments

This study was supported by US National Science Foundation DRL-1561486, DRL-1561655, and DRL-2112635.