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Developing dynamic dashboards for facilitating classroom orchestration

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Abstract: Classroom orchestration is a multifaceted pedagogical challenge, requiring the teacher to simultaneously manage classroom activities across multiple social levels (individual, group, and class) and under various constraints. Dashboards are one of the most popular technological tools developed to help the teacher; however, most often display static and often overwhelming amounts of data. To address this challenge, we are building a dynamic dashboard where teachers will have the flexibility to choose what information they want to see and when. To make our software more teacher-friendly, we co-designed the dashboard with teachers across two studies, determining a few key performance metrics that they will find most useful and actionable in bustling classroom scenarios. As mobility was a key factor highlighted by the teachers, the dashboard will be made available on a tablet or other mobile device.

Introduction

Classroom orchestration, the process of managing the flow of activities, student configurations across multiple social configurations, materials, and class progression within a learning environment during its enactment (Dillenbourg et al., 2009), has been recognized as one of the grand challenges facing the learning sciences (STELLAR, 2011). However, the need to monitor these various facets of the classroom in real-time and providing both conceptual and logistical support places a heavy load on teachers (Dillenbourg, 2011; Dimitriadis, 2012). In response, researchers have begun to investigate the role that technology can play in supporting this orchestration. In particular, teacher dashboards have seen growing interest as a tool that can provide teachers with timely insight into the state of the class while reducing teachers' orchestrational load (Matuk et al., 2019). Teacher dashboards can provide a lens into learning and activities in classrooms, which is especially helpful because teachers cannot attend to all groups in their classrooms at once (Leeuwen, Rummel & VanGog, 2010).

Dashboards typically present data on student performance at three levels: progress of individual students in a classroom, progress of and participation patterns from small groups, or progress of the class as a whole (Dillenbourg, 2012; Tissenbaum & Slotta, 2019; Mottus, et al., 2015). For each level, several types of performance metrics can be used. For example, symmetry of participation and collaboration from groups can tell teachers which group members are contributing to discussions (Liu & Nesbit, 2020; Martinez-Maldonado et al., 2013). Information about the whole class can include class status, class average and range, behavior engagement in class (for example, how long the teacher or students talked, or the number of hand raises), or alerting the teacher to which students need help (AlZoubi et al. 2021; Dickler et al., 2021; Dourado et al., 2021). At the individual level, teachers are provided with information about correct or incorrect responses to questions (Knoop Van-Campen & Molenaar, 2020), the amount of interactions with technology in terms of touches or mouse clicks (Martinez-Maldonado et al., 2012), or alerts that tell the teacher if a particular student is off task, idling, or has a question (Azevedo et al., 2021). However, providing a lot of information while the class is in progress can easily overwhelm teachers (Ahn et al., 2019); additionally, not all of the presented information is relevant at all times. A limitation to teacher dashboards is that the information on most dashboards remains static throughout the entire class period (Xhakaj et al., 2021), and the teacher has limited flexibility in choosing the information they want to see for a specific class period, activity, or for a particular goal for instruction.

We propose a dynamic dashboard that provides teachers with the flexibility to select what information they want displayed for a specific lesson for a specific class. In this paper, we leverage user interface (UI) design guidelines, stemming from a long history of research in the human-computer interaction (HCI) domain, on personalization and customizability of graphical user interfaces (Vermette et al., 2019; McGrenere, 2002). Despite prior HCI work proposing UI design guidelines for information displays and for dynamic customization and personalization of UIs, those guidelines have yet to find their way systematically into the design of teacher dashboards. In this paper, we will present our initial design ideas based on two participatory design sessions (Matuk et al., 2015) with teachers. Participatory design is an essential method to give teachers a voice in the development of the technologies that they will be implementing in their classrooms and to ensure that those technologies meet their needs (Holstein et al., 2019). In the first session, we asked teachers about what types of information might be most useful to them. We created mockups of a dashboard interface based on their input, and in the second session, showed the teachers the mockups and asked for their feedback on specific features of the dashboard. Using design guidelines from HCI (e.g., Shneiderman's (2016) eight golden rules of UI design and feedback from our design sessions, we present the resulting designs in this paper.

Participatory design studies with teachers

Context

The design studies we conducted were to inform the dashboard to help teachers see students' progress as they worked on a design-focused unit in Physics. In this unit, students work in groups to design a roller coaster, using an online simulation. Students wrote their design ideas and explanations of the science after conducting trials with different versions of their roller coaster designs. We are developing a digital notebook, based on a paper version used in several studies (Martin et al., 2019). The notebook will serve as a medium for students to write explanations based on the science they are learning. Students write down their hypotheses, run simulations, collect data, explain how the data informs their designs.

Students are asked to write short explanations to analysis questions related to the trials run in their simulations. These open-ended questions will be used to help inform teachers of what concepts or ideas students are using in their writing. The notebook also allows teachers to add multiple-choice questions (close-ended questions) as a quick check-in to quickly see whether most students are correctly understanding the material. Teachers will also be able to choose whether they would like to be given an analysis of the close-ended questions or investigate the data themselves. Multi-directional microphones can be used to record and parse multiple students speaking in a group. This data will allow us to understand the types of discourse happening in the groups and how much each individual is contributing. The notebook also uses PyrEval (Gao et al., 2019), an NLP technique to automatically analyze students' writing in their design essays and provide feedback to both students and teachers. Since the unit requires students to work in different social configurations (individual, group, class), information for each can be presented to teachers on the dashboard. The teacher can navigate between levels and decide which view is most essential to them at any given moment in the classroom.

The two studies presented in the current paper were conducted four months apart. The first study was conducted before the development process and the second study was conducted after the initial design. Eight teachers participated in the first study, and six teachers participated in the second study.

Study 1

Participants

Our initial participatory design study was conducted via Zoom and distributed over three sessions that lasted two hours each. Each session consisted of no more than three participants, which ensured each teacher would have the ability to provide us with feedback on our design and development of the dashboard. In total, eight middle school science teachers, with teaching experience between 9 and 34 years, participated in the study.

Design

In this study, our goal was to understand what dashboard functionalities teachers would be most interested in, given different classroom situations. We were specifically interested in the extent to which teachers were interested in metrics about progress at different levels (individual students, groups, or the entire class). For example, were teachers interested in information about the whole class, or just groups of students? What activity metrics, such as idleness, on task/off task students, were important to teachers? The functionalities were explained to the teachers verbally, as well as through detailed short text descriptions. The features have been placed under different sections showing whether they contain information about the whole class, groups, or individual students, but some metrics can cover multiple levels, such as idleness of groups or individual students. The functionalities were described as follows:

Whole class functionalities: (1) Class Status Overview: A general visualization of how the students are progressing in the class. This would be a way to quickly see where students are in the assignment. (2) Ask the Class: The ability to send a poll, or ask a question, to the entire class to gauge students' thoughts, understanding, or feelings. (3) Pause: Prevent the students from navigating or answering questions in their digital notebook, or stop them from playing with a simulation. (4) Close-ended Question Summary: By selecting a close-ended question (e.g., multiple choice), display a breakdown of answers throughout the class. (5) Close-ended Question Analysis: Perform analysis to find the trends in close-ended questions, then inform the teacher of the trends without the need for any investigation of the data. (6) Teacher Talk of Content Covered: Breakdown the amount of time in each class spent covering specific material and find which areas might need additional explanations. (7) Teaching Suggestions: Allowing the software to give the teacher suggestions that might improve their teaching (e.g. spend more time covering a topic, or when to visit a group).

Group functionality: (8) Student Participation in Groups: Information about the participation of each student in a group. This includes dominating the conversation, no contribution, or flagged word counts.

Individual functionalities: (9) Comparing Individual Students in the Class: The ability to compare a student against the class, which can show information about their learning trajectory or problems they may be facing alone. (10) Individual Student Explanation Writing Feedback Summaries: See a detailed summary of how a specific student performed on their writing questions. This summary could potentially provide information such as if the student is covering all the topics, if they are consistently misusing a concept, or if they aren't using enough scientific terminology to back up their claims.

Across level functionalities: (11) Messaging: Send messages directly to an individual students' notebook, to a group of students, or to the entire class. (12) Idleness: Show students who have been idle for too long, or students who are active when they should be listening. (13) Stuckness: Give information about students who may be stuck on a specific question. (14) On Task/Off Task: Detect which students are working on the assigned task, or the students who are off task. (15) Open-ended Question Summaries: Using an NLP algorithm, give writing summaries about the percentage of students covering specific content and find which topics are commonly being misunderstood, or mastered.

Due to the perceived requirements of screen size of each feature, as well as making teachers prioritize functionalities, an element of spatial restriction was added. The feature names were placed on rectangles, and were sized according to the spatial requirements they would likely need to display the relevant information. Some minor flexibility was allowed, including minimal overlapping and resizing, but any dashboard configurations which completely disregarded these requirements were removed from our analysis. Only one participant did not follow the sizing guidelines, so accordingly, their results were excluded from our analysis. An additional participant misunderstood what was being asked in the first scenario, so their first scenario data was not included in the analyses.

The three scenarios were designed in a way that encouraged the teacher to imagine a situation where the focus was on either (a) groups, (b) individual students, or (c) the entire class.

Scenario 1. The teachers were told to pretend they were in a classroom dealing with various groups who might include (a) group members talking about irrelevant information, (b) one student not contributing to the discussion or activity, and (c) groups where all members are working towards the task.

Scenario 2. The teachers were asked to imagine the students have time to work quietly, and individually, on their digital notebook questions. While the students are working, they often are (a) having varying levels of success with different questions, (b) become distracted, (c) are confused by content (across the whole class or only individually), and (d) any other challenges the teachers would expect.

Scenario 3. The final scenario involved covering a historically challenging concept for students to grasp. This topic, or class, was meant to remind teachers about classes where they know the material is challenging for most students, and what insights from the dashboard would allow them to best refine their teaching strategy as the class progresses.

After verbally explaining the scenario to the teachers, they were given time to place the functionality they would find most useful for each scenario on a blank tablet template. When all teachers were finished, they moved to the next scenario together. Further explanation of the functionality, or the scenario, was available at all times by a researcher willing to answer any questions that might arise.

Results

We collected a total of six dashboards for Scenario 1, seven for Scenario 2, and seven for Scenario 3. The maximum number of functionalities that teachers included on their dashboards was nine. Table 1 summarizes the key functionalities.

Examining the percentage shifts seen in Table 1, there is rarely agreed upon functionalities across all the participants. Outside of the first scenario, where five metrics had over 60% of teachers selecting them, Scenario 2 had only one feature selected by 60% or more participants and Scenario 3 had only two. This emphasizes the idea that certain features might be invaluable to address specific classroom environments (whole class, group, or individual), but the secondary metrics are more individualized to what the teacher finds most beneficial according to their own abilities or needs.

The constant shifts between functionalities also highlights the need for a dynamic dashboard. From the 15 functionalities that were given, the participants selected 73% in scenario 1, 87% in scenario 2, and 93% in scenario 3. Rather than attempting to find ways to elegantly display 11 or more functionalities at once, it seems like having the teachers curate which components are most needed on a particular day gives them ownership of their dashboard, and the freedom to adjust what functionalities can complement their teaching strategies for any given classroom scenario.

Table 1
Functionality as a percentage of selection across teachers and their changes through scenarios.

Social level	***Functionality***	***Scenario 1***	***Scenario 2***	***Scenario 3***
Whole Class	Class Status Overview	33%	43% (↑10%)	43%
	Ask the Class	67%	29% (↓38%)	57% (↑28%)
	Pause	83%	57% (↓26%)	57%
	Close-ended Question Summary	33%	14% (↓19%)	43% (↑29%)
	Close-ended Question Analysis	33%	57% (↑24%)	100% (↑43%)
	Teacher Talk of Content Covered	17%	0% (↓17%)	29% (↑29%)
	Teaching Suggestions	0%	43% (↑43%)	43%
Group	Student Participation in Groups	100%	0% (↓100%)	0%
Individual	Comparing Individual Students in the Class	0%	14% (↑14%)	14%
	Individual Student Explanation Writing Feedback Summaries	0%	57% (↑57%)	71% (↑14%)
Across levels	Messaging	83%	86% (↑3%)	14% (↓72%)
	Idleness	17%	29% (↑12%)	14% (↓15%)
	Stuckness	50%	57% (↑7%)	29% (↓28%)
	On Task/Off Task	67%	71% (↑4%)	14% (↓57%)
	Open-ended Question Summaries	0%	20% (↑20%)	57% (↑28%)

Study 2

Participants

The aim of our second study was to get feedback from teachers on the initial design of the dashboard developed based on the results of Study 1. This study was conducted in-person with six teachers, four of whom had participated in the first study. All six teachers were middle school teachers in the U.S. who had taught science for 7 to 34 years who are planning to implement the Physics roller coaster design unit in Spring 2022.

Design

We created an initial dashboard design with a set of options to show information about individual students, groups and the whole class. In this study, teachers were asked to give their feedback on each screen showing specific functionalities. Figure 1 shows all the mockup screens included in the study. Information shown on each screen is described below.

(a) Class Status: An overview page meant to give quick insight to what is happening. Icons provide a visual representation of the challenges students might be facing in real time. A change in the icon color from grey (no challenge detected) to red (teacher support needed) directs the teacher's attention to which group he or she needs to focus on with what priority.

(b) Group Progress: This visualization can quickly allow teachers to determine which groups might need to be interacted with, or if the entire classroom is moving slower than expected through the material.

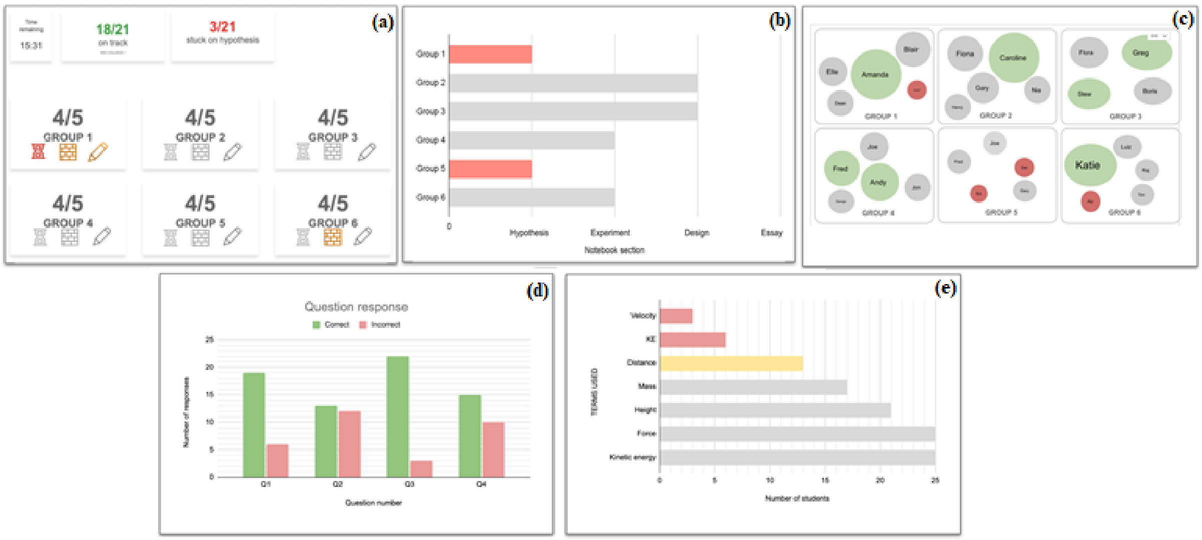
(c) Participation within the group: This chart shows which students are participating in group discussions, or not actively contributing. Additional information is embedded by changing the color of the circles to show whether their contributions are positive or negative, based on the content of their speech.

(d) Close-ended Questions: This screen shows an overview of students' responses to close-ended questions (such as multiple choice questions). If a large number of students answer a question incorrectly, it can indicate that the teachers may need to revisit the corresponding topic or idea in class.

(e) Open-ended Questions: This screen would provide insights on how students are utilizing science ideas and concepts in their essay writing. Using different types of NLP techniques, the information could show what terms are being used or which concepts are being used correctly in students' writing.

After viewing each screen, the participants were asked to answer questions about each of the screens. These questions focused on whether the information would be useful, and how it could be used by the teacher.

Figure 1
Dashboard content screens from our design feedback session.



Results

The first screen teachers were presented with was the Class Status Overview (Figure 1a). The teachers were asked to guess what the icons represented, to see how intuitive they were. Five teachers correctly identified the wall icon as being stuck, but the hourglass (idleness) and pencil (off-task) were largely assumed to represent other indicators such as time remaining, time spent on a question, or active typing. During the discussion about the meaning of the icons, the teachers remarked that the intended icon representations made sense, but they would likely need a key having the icons appear on the navigation with the corresponding functionality name, or additional time to become familiar with them, showing where customization could alleviate a learning curve.

Teachers were largely in favor of the analysis provided at the top of Class Status Overview. However, when answering how they would use this information, they uniformly agreed that it would allow them to know which groups need to be focused on. One participant remarked, "these signals will help me to reach students in need, faster."

For the second screen, Group Progress (Figure 1b), some teachers asked for a more fine-grained view of which specific members of the group were struggling, so that they could effectively assist the individual students who needed it the most. This veered the discussion towards whether the Class Status screen was needed if Group Progress gave similar information, but in more detail. When asked to indicate if they had a preference of one screen over the other, a different teacher commented:

> *".. does it matter which one we pick …. the teacher, they might want to pick one over the other … [so they can] look at the more data and just isolate what they think is important to them."*

Further on in the discussion, the teachers brought up that access to this individual information screen may be especially helpful for special education staff for special ed or ELL (English Language Learners) students, as well as for grouping strategies. For example, if the special needs students are all in different groups, the staff "can see their four students in four different groups, so that they know which group they need to go to next to support their specific students on their caseload."

All these points highlight the need for having a customizable dashboard where teachers (or special education staff) can choose which information would be most useful for them in a particular session. Teachers agreed they would utilize the information to support both students who were struggling and those who were progressing faster than others.

When the teachers were asked how they usually hone in on struggling groups or individual students in class, they mentioned knowing which groups or students regularly need check ins, noticing students "goofing around", or students raising their hand or "pulling your shirt". This indicates teachers already have a well-defined system for knowing which student(s) to give their attention to, and in what order. This implies that our system should not add further cognitive load on the teachers and that the interface needs to be designed to give actionable information (e.g., two students in Group 1 are stuck), but not specific actions (e.g., go to Group 1 now). One area where our system can add benefit is for highlighting class-level issues, as suggested by one teacher:

> *"... if you're walking around, sometimes it takes a little while before you notice that it's most kids. So if it's in real time, and you can see right on there that.. all the groups are not progressing, that will save some time so that you can stop and address it right away."*

The Participation screen (Figure 1c) inspired interesting responses on how the information could be useful and brought up concerns on how the metrics would be defined and whether students could easily manipulate them. One teacher also remarked on how the information could be used with other selected functionalities, to give richer insights to how the students are learning.

> *"I was wondering how the screens would interface with each other? We were talking about a kid using vocabulary the most… How does that correlate to their actual writing?"*

One teacher also mentioned a new way to utilize this information to promote equity in the classroom, which prompted us to think of ways we could further develop this idea for post-class analysis:

> *"... but I'm also going to want to bring and encourage some of those other voices to come out... We have people dominating conversations, while maybe we can be doing something, not necessarily the content piece, but like equity or voice to the classroom. This, I could find really useful as an after class kind of summary."*

Though the final two screens, Close-ended Questions (Figures 1d) and Open-ended Questions (Figure 1e), were both designed to be ways that teachers could find out what concepts need to be revisited and drive instruction, the teachers contributed some valuable insights on how they would personally use this information:

> *"It could drive instruction too. Maybe the teacher, umm.. phrased the question wrong. Or it was misunderstood by many students and .. you know, the teacher can go back and make adjustments to the lessons."*

One feature repeatedly requested by the teachers over the course of the session, was that the software be accessible on a mobile device, due to the necessity of freely navigating around their classroom, but still accessing the information in real-time. One teacher spoke about how they currently use another software in the classroom with some similar features like monitoring student activity and sending them messages, however:

> *"..you would be doing that from your teaching station or your.. your desk.. You wouldn't be out and about. So this is wonderful, if you did have the mobile.. device that you can be standing right next to them, and then identifying what is happening."*

Discussion

After conducting the two studies, it was evident that the teachers appreciated the opportunity to co-design software that would impact their classrooms. The results of the first study showed that teachers were aware of what functionality would best assist them in the classroom, and how those needs change based on the goals of each specific class. A clear example of this shift can be seen in all teachers removing a group-centric functionality once the session is directed towards individual student learning. We developed dashboard mockups, with multiple screens of information for different social levels, based on their feedback of what functionalities they would find most useful.

Some participants in Study 2 only desired a general overview that directs them to where they need to focus their attention; however, others were more interested in diving deeper into the data to see classroom trends, to improve current and future instruction. While teachers found certain screens more (or less) useful for managing at the class or group levels during class, most preferred information at the individual level for post-class analysis. However, an important point that was brought up, was that access to individual data during class for special needs or ELL students, could help make learning more equitable. This highlights not only the uniqueness of each teacher, but also each classroom situation, and indicates that giving individuals the flexibility to decide what information level they want to see in what circumstance is paramount to providing a tool that is embraced in all classrooms, and helps teachers optimally facilitate learning for their students.

A challenge exists in determining how to limit the amount of functionality to prevent information overload to the teachers, as they were often able to find uses for all functionality when asked if it would be useful to them. One approach we are considering is utilizing mixed-initiative personalization (Vitale et. al. 2020), where the software automatically recommends certain customizations (like suggesting functionalities based on whether the class will be focused on groups or individuals), but then the teacher has the option to customize from there (giving locus of control to the teacher but also limiting load on the teacher by giving an initial recommendation). Another approach is limiting some functionalities to be post-class, and others to be real-time, so there is a clear distinction to their uses.

Lastly, in both sessions, the need to have the information from our dashboard be accessible in a format that afforded mobility in the classroom was requested by multiple participants. The potential impact is largely dependent on their ability to traverse the classroom with the information from our dashboard.

Conclusion

Both sessions with teachers have shown us the need for a dynamic dashboard that can be tailored to their individual needs in the classroom. Even among the small set of teachers, the unique styles in how they teach are apparent in their functionality selection. Co-designing an interface that gives them flexibility for determining what they need, when it is needed most, excites them and reassures them that their voice is being heard in what would help them in the classroom.

But with this amount of knowledge at their fingertips, it is important that as researchers, we accurately define the metrics we will use to alert them of issues in their classroom and how such information is displayed. Clarifying language and icons in functionalities to ensure that teachers can accurately interpret the data will allow them to direct their attention to the needful students, armed with knowledge of the issue, even before they arrive to assist them.

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