Symposium
Orchestration tools for teachers in the context of individual and collaborative learning: what information do teachers need and what do they do with it?

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Abstract: This symposium brings together research concerning orchestration tools aimed at supporting teachers in providing real time support to students in the classroom. Orchestration tools are based on the idea of capturing, analyzing, and visualizing student activities during class time and feeding them back to teachers to facilitate real time monitoring and support of students. With examples from the contexts of individual and collaborative learning, the symposium addresses two questions, namely what information about student activities teachers need, and how teachers use orchestration tools in their classrooms. Two papers focus on the first question, and furthermore investigate how teachers respond to initial versions of orchestration tools. The remaining two papers focus on how teachers actually use orchestration tools in their classrooms. The symposium as such offers examples of state of the art research and ample opportunity for discussing future directions in the field of teacher orchestration tools.

Focus of the symposium – teacher orchestration tools

Teachers play an essential role for student learning, as they are responsible for monitoring and orchestrating both cognitive and metacognitive processes, as well as social processes when it concerns collaboration among students (Kaendler et al., 2015; Prieto et al., 2011). Most computer-supported learning environments enable capturing of student activities, which can then be (automatically) analyzed and visualized on so called teacher orchestration tools to support teachers in the real-time orchestration of student learning (Verbert et al., 2014; Wise & Vytasek, 2017). In the growing field of research on teacher orchestration tools, important questions arise concerning the design and implementation of teacher orchestration tools (Van Leeuwen & Rummel, 2017). We need to ask what type of support teachers need from dashboards during their practice, and what factors enable or constrain the successful implementation of dashboards that provide support for teachers. This symposium brings together research concerning teacher orchestration tools, with examples from the contexts of individual and collaborative learning. The symposium focuses on two particular issues: 1) what information do teachers need that would help them to support their students, and how does that translate to design of an orchestration tool? Subsequently, 2) once the orchestration tool is designed, how do teachers actually use them in their classrooms? As an overarching question, we are interested in what lessons can be drawn about what makes orchestration tools helpful for teaching and learning.

Outline of contributions

The underlying structure of the symposium is a 2x2 design. The most prominent distinction between the papers is whether they address the *design* phase of orchestration tools, in particular the question of what information teachers need and how they respond to initial version of orchestration tools, or the *implementation* of orchestration tools, in particular how teachers actually use the orchestration tool in the classroom. A further dimension to characterize the contributions on is whether they provide an example of teacher orchestration tools in the context of individual learning or collaborative learning. Table 1 shows the 2x2 design of the symposium and the corresponding contribution for each cell.

Table 1: overview of symposium contributions

Context	*What information do teachers need?*	*What do teachers do with a dashboard in the classroom?*
Individual learning	Holstein et al. (contribution 1)	Molenaar et al. (contribution 3)
Collaborative learning	Van Leeuwen et al. (contribution 2)	Schwarz et al. (contribution 4)

Holstein et al. (contribution 1) and Van Leeuwen and Rummel (contribution 2) focus on what information teachers need to make decisions during the real time support of their students, using several techniques for eliciting teachers' thoughts. Holstein et al. followed a participatory design approach to elicit teachers' needs for information. They also employed simulated class sessions and small studies in live classrooms to test initial versions of their orchestration tool. Van Leeuwen et al used contextual inquiry and storyboarding to gauge teachers' responses to situations in their everyday practice as well as future scenarios of how orchestration tools could be implemented.

Molenaar and Knoop-van Campen (contribution 3) and Schwarz et al. (contribution 4) present studies on how teachers actually use orchestration tools in the classroom. In both studies, quantitative as well as rich qualitative data was obtained about how teachers interpreted the orchestration tool and how it guided their practice. By doing so, Molenaar et al for example demonstrate how differences in teachers' experience with orchestration tools influences the extent and specific way of using the orchestration tool as well as the type of feedback teachers give to their students. Schwarz et al. observed and interviewed a teacher in two cohorts of supporting multiple collaborating groups, illustrating how the teacher detected the needs of the groups by a combination of using the orchestration tool and his own observations.

The four contributions together touch upon several recurring issues that are of interest to the ISLS community. For example, the role of teachers' prior knowledge of their students is a recurring issue both in the design and implementation of orchestration tools. Another recurring issue is the way the teacher and the orchestration tool 'complement' each other: which tasks are best performed by the teacher, and what specific role should the orchestration tool take on? Another overarching issue is the role of context. Although all papers are situated in the domain of mathematics, two papers concern individual learning, and the other two concern collaborative learning. As such, the question is whether teachers' needs for information and how they use orchestration tools differs for these contexts – is the orchestration load on teachers different in these two situations, and what does that mean for designing orchestration tools?

Outline of the symposium during ICLS2018

Our plan for the symposium session is to first have brief reports about the four studies. During the four presentations, the audience is invited to share their questions and points for discussion through PresentersWall, a live feed that displays the audience's input. For example, audience input could concern ideas about: (1) what lessons we can learn from the four studies concerning factors that make orchestration tools more or less effective, and (2) how the emerging field of teacher orchestration tools needs to develop and what might be promising directions for future research.

Then, the discussant (Alyssa Wise) is asked to respond to a selection of the audience's input in light of the four presentations and in light of her own expertise. Finally, the floor will be opened for plenary discussion.

To summarize, by bringing together four studies concerning the design and implementation of teacher orchestration tools, our aim is to offer examples of new empirical work and to address important questions in this field that are of interest to the ISLS community. The following pages contain brief descriptions of all four contributions to the symposium.

Contribution 1
Balancing between teacher and student needs in the design of classroom orchestration tools

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Introduction

Teacher orchestration tools are frequently designed to support teachers in more effectively *monitoring* their students, under the hypothesis that this will ultimately lead to improved student learning (Molenaar & Knoop-van Campen 2017; Rodriguez-Triana, et al., 2017; Van Leeuwen, 2015). Such tools must also be both *usable* and *useful* to teachers; designed based on an understanding of teachers' needs and desires for real-time support, and the actual challenges they face in orchestrating complex classroom activities (Rodriguez-Triana, et al., 2017). In our current work, we are designing real-time orchestration tools for classrooms using intelligent tutoring systems (ITSs). We examine teachers' expressed *desires* for real-time analytics and students' observed *needs* for teacher support, investigating how best to balance between these.

Methods

In the first phase of our design process, we adopted a participatory design approach (Hanington & Martin, 2012), working closely with K-12 math teachers to understand their desires for real-time analytics, and directly involving them throughout the design process (Holstein, Hong, Tegene, McLaren, & Aleven, 2018a; Holstein, McLaren, & Aleven, 2017). The resulting prototype is a pair of mixed-reality smart glasses, which augment teachers' perceptions of student learning, metacognition, and behavior – displaying real-time indicators floating directly above students' heads. The indicators shown by Lumilo are ideas generated and iteratively refined by teachers, and implemented using established student modeling methods (e.g., Desmarais & Baker, 2012).

To understand how teachers might use Lumilo, prior to deploying in real classrooms, we conducted a series of simulated class sessions, using a new prototyping method called Replay Enactments (REs). In each of six sessions, historical student interactions were replayed in ITS interfaces, on separate computers in a classroom setting (but with no actual students present). During 40-minute replay sessions, teachers wore Lumilo, while monitoring the "class". If a teacher thought they would intervene with a "student" at a given time, the teacher would approach and enact the help session aloud (Holstein et al., 2018a). Meanwhile, Lumilo tracked teacher activity moment-by-moment. Analyses of data from 6 REs suggested that Lumilo can guide teachers' time towards students who would otherwise exhibit lower learning in the software, as measured by posttest scores, controlling for pretest ($r = -0.17$, $p < 0.01$) (Holstein, et al., 2018a). However, the magnitude of this correlation suggested room for improvement. We adopted a causal model search approach (Spirtes, Glymour, & Scheines, 2000) to identify mediators of this observed relationship, which could inform a redesign.

Results and Discussion

Through our co-design process, 8 indicator types emerged. These included "misuse of the software" (divided into *gaming-the-system/help-abuse* and making *rapid attempts*), *unproductive persistence* or "wheel-spinning" (Beck & Gong, 2013), *high/low recent performance, help avoidance* (Aleven, Roll, McLaren, & Koedinger, 2016), and *prolonged inactivity*. Importantly, we found that some of these alerts were valuable to teachers for reasons other than guiding interventions. For example, teachers found alerts about high recent performance valuable, in part, because they found such alerts personally motivating (Holstein et al., 2017; 2018a).

Using data from REs, we found that teacher time allocation while using Lumilo was strongly driven by alerts of student *rapid attempts* or *gaming/help-abuse*, but less strongly by *high recent error rate* or *unproductive persistence* (Holstein, McLaren, & Aleven, 2018b). Other alert types did not significantly drive teacher time. The causal model learned with FCI (Spirtes et al., 2000) on data from 115 middle school math students suggested that, out of 7 teacher-generated ideas for negative alerts, only one corresponded to a student state with a direct harmful impact on student learning: *unproductive persistence* (Beck & Gong, 2013). Based on these analyses, we iterated upon Lumilo's design, prioritizing alerts about unproductive persistence and its identified causes (*help avoidance* or *gaming/help-abuse*). In subsequent studies, teachers using this updated prototype in live classrooms continued to make use of all alert types. At the same time, the strongest predictors of teachers' overall time allocation were alerts of unproductive persistence, followed by help avoidance and gaming/help-abuse, suggesting the redesign may have been effective in redirecting teachers' time to student behaviors with the greatest impact on learning (Holstein, McLaren, & Aleven, 2018b; 2018c).

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Contribution 2
Considering teachers' informational needs and the role division between teacher and orchestration tool in the context of collaborative learning.

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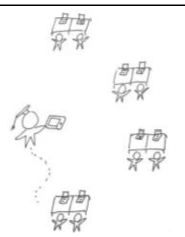
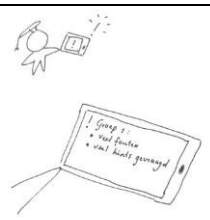
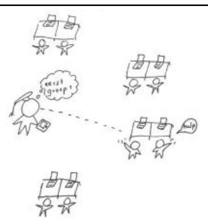
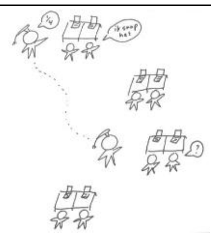
Introduction

Teacher orchestration tools are hypothesized to support teachers in monitoring and supporting student learning (Van Leeuwen, 2015). The study presented here served as input to developing a teacher orchestration tool in the context of collaborative fraction assignments. It was examined what information teachers need to make informed decisions, and what role division between teacher and orchestration tool best serves teachers' practice.

Method

Elaborate sessions lasting 1.5 hours were held with 10 primary school teachers (8 were female), in which multiple techniques were used for eliciting teachers' thoughts. The teachers' mean age was 30.2 (*SD* = 3.9). On average, they had 8.2 years teaching experience (*SD* = 7.4). The interviews consisted of two parts. In the first part of the interview we used contextual inquiry, which means understanding of teachers' experiences was sought by asking how they would act and react in certain situations (Hanington & Martin, 2012). Teachers were prompted with different types of situations that may occur during orchestration of collaborative learning, and were asked to explain as fully as possible how they would act and what information they would need to make decisions. Second, storyboarding was used to elicit teachers' responses to four scenarios of how a teacher could use an orchestration tool (see Table 2 for an example). With storyboarding, drawn stories are used of how intended users may interact with the object under study (Hanington & Martin, 2012), in this case the object being teacher orchestration tools. The storyboards differed in the function the orchestration tool fulfilled, ranging from only displaying information, to alerting the teacher, to advising the teacher what to do.

Table 2: example of storyboard

1	2	3	4
			

1. Students are collaborating in dyads. Teacher walks through the classroom with dashboard. *2.* Dashboard gives an alert about group 1, who made relatively many mistakes and asked for a lot of hints. *3.* Teacher notices another group raises their hand, but decides to go to group 1 first. *4.* Teacher gives explanation until group 1 grasps the idea, then walks to the group that raised their hand.

Results and discussion

The contextual inquiry elicited 6 types of information that teachers use during collaborative learning to decide whether a group needs help: background information about the students in a group (like mathematical ability), whether groups get stuck (either because a task is too easy or too difficult), whether students show understanding of task-related concepts, whether groups are involved with the task (or display off-task behavior), the quality of the interaction between group members, and whether the group shows metacognitive understanding of their own strategies and progress. The storyboarding revealed that teachers would especially appreciate it if orchestration tools could help them with noticing students' misconceptions or point them to problems in the group interaction early on, in order to enable timely intervention. Also, teachers expressed need for support with monitoring multiple groups at the same time. The results are used as input for a follow up study in which we examine how teachers use orchestration tools that fulfill different roles.

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Contribution 3
Experience matters:
The impact of dashboards on teachers' feedback

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Introduction

Teacher dashboards provide teachers during lessons with concurrent information about students' abilities, progress, performance, and errors made (Molenaar & Van Schaik, 2017; Van Leeuwen et al. 2014). Teachers can use this information to adapt their teaching practices to the students' individual needs, but only when teachers are aware of the data, able to interpret the data properly, and can translate their interpretation into appropriate pedagogical actions (Molenaar & Knoop-van Campen, 2017; Verbert et. al. 2014). We expect that teacher experience with dashboards is likely to influence how they use dashboards during teaching. Therefore, this study examines how teachers' dashboard usage during lessons influences feedback given to individual students, and how this is associated with teachers' experience.

Method

Primary school teachers (N = 40) were observed during one mathematics lesson (50 minutes) taught in grade 2 to 6. Adaptive educational technology (Snappet) is used on a daily basis in these classrooms. While students made exercises on their tablets, realtime data of learner progress and performance were shown on dashboards. The observations were performed by Snappet-coaches (expert-teachers with a coaching function). They were trained to observe teachers' feedback (task, person, process, social & metacognitive) and initiating actions (dashboard, student, teachers) using the Classroom Observation App. A distinction was made between in-experienced (N = 12), middle (N = 12) and experienced (N = 16) teachers. Both teachers themselves and observers indicated teachers' experience in using the adaptive educational technology. The agreement-rate between teachers and observers was 70%, in case of disagreement the observers coding was followed. None-parametric analyses were performed with Independent-Samples Kruskal-Wallis Tests.

Results

On average teachers gave 49.95 times (SD = 26.79) feedback to an individual student during a lesson and no differences in feedback frequency were found between in-, middle and experienced teachers. Teachers consulted the dashboard on average 7,83 times (SD = 8.06) during a lesson and as expected experienced teachers consulted the dashboard more often (M = 11.63, SD = 8.96), compared to middle (M = 6.08, SD = 11.63) and in-experienced teachers (M = 4.92, SD = 8.24), $H(2)$ = 8.61, p = .014. On average 72% (SD = 26%) of a teachers' dashboard consultations were followed by feedback and this did not differ between the three groups. Most feedback was given on teachers own initiative (58%) or in response to students' questions (29%), only 13% of the feedback was provided after dashboard consultation. Although they did not differ in the frequency of giving feedback, experienced teachers provided feedback more often after dashboard consultation (17%) compared to middle (9%) and in-experienced teachers (10%), $H(2) = 7.38$, $p = .025$ (see Figure 1). Additionally, a significant difference was found with regard to the type of feedback given: experienced teachers gave more feedback related to the task (34%) compared to in-experienced teachers (21%), $H(2) = 8.91$, $p = .012$ (see Figure 2).

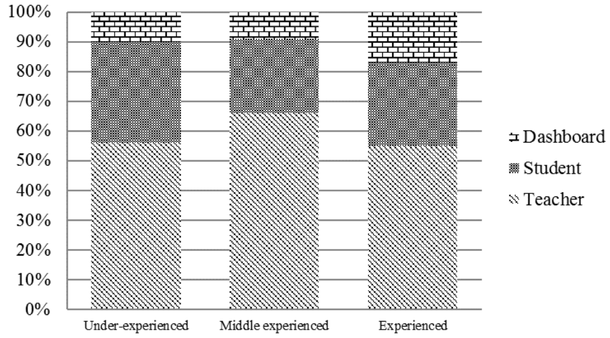

Figure 1. Feedback initiation.

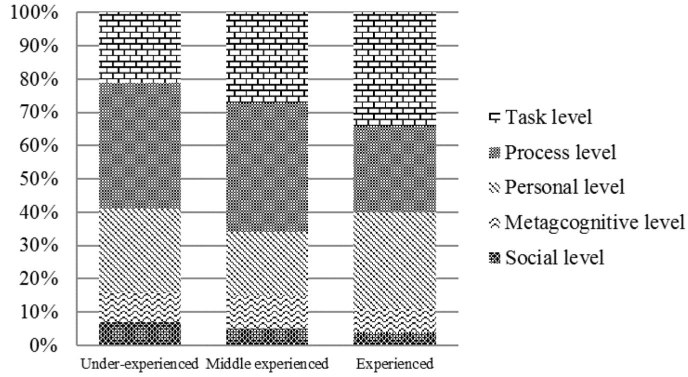

Figure 2. Types of feedback.

Discussion

Results indicated that even though the majority of the dashboard consultations resulted in feedback given to individual students, only a small part of all feedback was initiated by a dashboard consultation. We found evidence that more experience teachers gave more feedback based on dashboard consultations and they also differed in the type of feedback given. Teachers with more experience provided more task related feedback to students. This indicated that these teachers not only use the dashboard more often to inform their feedback actions, but that they also used the dashboard information differently to customize feedback to the needs of individual students. This demonstrated that dashboards indeed support teacher to adapt their teaching practices to the need of individual students and especially after teachers gained sufficient experience in using the orchestration tools.

Contribution 4
Orchestrating deep learning: A case-study in a geometry class

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Introduction

This paper is about orchestration of deep learning in a collaborative setting. We elaborate on the idea of critical moments in group-learning, events whose occurrence may lead to a particular development at the epistemic level regarding the shared object. We relied on research in educational psychology to identify seven critical moments: (a) idleness, (b) off-topic-talk, (c) technical problems, (d) explanation or challenge, (e) confusion, (f) correct solution and (g) incorrect solution. We conjectured that the teacher's identification of critical moments may facilitate further guidance towards deep learning among students. The complexity of small group settings in a classroom context does not allow teachers to be aware about these critical moments, though. Figure 3 describes the SAGLET system, based on the VMT environment (Stahl, 2009), which allows teachers to observe multiple groups engaging on problem solving in geometry. In Figure 3, we see that a teacher observes four windows of the VMT system. She is informed about a correct solution in room 696 and about a technical problem in room 697.

Figure 3. The SAGLET system, based on the VMT environment (Stahl, 2009).

Method

SAGLET capitalizes on machine learning techniques to inform on on-line critical moments, by sending alerts to the teacher, who decides then whether (and how) to use the alerts in his/her guidance of students. One teacher in an elementary school used SAGLET in order to help multiple groups of students solving difficult tasks in geometry. We observed how the teacher mediated two cohorts of multiple groups at two different times in a mathematics classroom. The teacher was trained to use the SAGLET system, and designed challenging problems in geometry that necessitated collaboration between Grade 6 students. Five groups of 2-3 were formed.

Results

We show that in both cases, the teacher could detect the needs of the groups (partly thanks to the alerts) and could provide adaptive guidance to all groups. We identified five kinds of intervention. Most of the interventions were of a scaffolding argumentation type. We see that the scaffolding of argumentation is the most frequent type of intervention. As mentioned before, this kind of intervention fits the CSCL spirit according to which guidance is ancillary to the co-construction of meaning. We saw that the forms of this scaffolding are varied, and included challenges or refutations expressed either in a chat mode or through GeoGebra. The most frequent intervention after the scaffolding of argumentation is the monitoring and supervision of the execution of the task – an intervention that refers to orchestration. The request for justifications and the social validation have a flavor of both orchestration and support to meaning making. It is noteworthy that the less frequent type of intervention is the encouragement of collaboration. After one preparatory session with SAGLET, students were already accustomed to collaborate – a fact that indicates that VMT affords collaboration.

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