MTClassroom and MTDashboard: Supporting Analysis of Teacher Attention in an Orchestrated Multi-tabletop Classroom

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Abstract: In spite of the substantial progress in CSCL, there is still some distance between the promise of educational technology for classroom learning and what is readily achieved. Emerging tabletop devices can offer new means to enhance teachers' classroom control and awareness. These technologies can help them orchestrate activities, and capture, analyse and visualise students' collaborative interactions. This paper presents MTClassroom and MTDashboard, that were designed, deployed and tested to support the teacher in orchestrating collaborative learning activities at an authentic classroom. MTClassroom is an enriched multi-tabletop environment that captures aspects of students' activity as they work in small groups. MTDashboard is an orchestration tool displayed at a handheld device, giving the teacher control over classroom activities and providing 'real-time' indicators of participation and task progress of each group. We analysed teacher's attention by triangulating quantitative evidence captured by our environment with qualitative observations and teacher's perceptions. We investigated the affordances of our environment and the impact of the information provided to the teacher through the MTDashboard. The contribution of this paper is the novel approach for providing teachers with key indicators of small-group collaboration in the classroom and analysing their impact on teachers' attention to help them manage their time more effectively.

Introduction and Related Work

Research on Computer-Supported Collaborative Learning (CSCL) has demonstrated that small group collaboration can activate particular learning mechanisms and that educational technology resources can be used to mediate and facilitate such collaborative activities (Roschelle et al., 1995; Stahl, 2006). In spite of this substantial progress in research and practice, there is still some distance between the promise of technology and what has actually been delivered in most classrooms. This issue is particularly important for CSCL due to over-generalisation from a small pilot study's findings and over-expectation of new technology (Dillenbourg et al., 2011a). Cuban et al. (2001) argued that the role of teachers is critical to determine the success of deploying technological innovations in the classroom. This points to the need to consider the potentially key role for creating new mechanisms that can help *teachers* design and orchestrate learning activities (Dillenbourg et al., 2010; Prieto et al., 2011), so that they can successfully use emerging technologies in the classroom.

An obstacle in using personal computers in the classroom is that these tend to make it more difficult to promote face-to-face collaboration due to their small display and single input (Morgan et al., 2009). By contrast, emerging shared devices, such as multi-touch tabletops, offer a large enriched interface that learners can use simultaneously to create artefacts. They also offer access to digital content while students collaborate and negotiate understanding face-to-face with equal opportunities of participation (Dillenbourg et al., 2011a). Our work aims to tackle the issues described above by providing a suite of hardware and software tools for (i) enabling students to work in small groups and build virtual artefacts in the form of concept maps that represent their shared understanding (Figure 1, right), and (ii) enabling teachers to orchestrate the learning activities and teach curriculum content. We present MTClassroom (Figure 1, centre) and MTDashboard (Figure 1, left), which were both deployed and tested in authentic classroom sessions. MTClassroom is an enriched multi-tabletop classroom that captures aspects of students' learning and interaction processes as they work in small groups. MTDashboard on an orchestration tool displayed at a handheld device that allows a teacher to control classroom

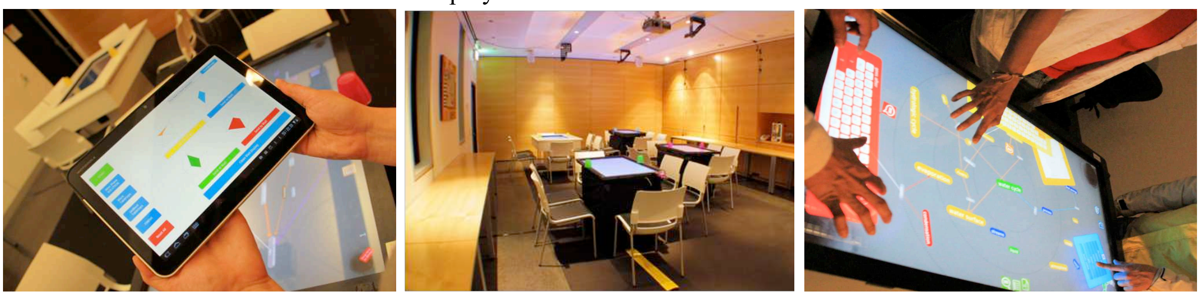

Figure 1. MTDashboard (Left), MTClassroom (Centre) and the Concept Mapping application (Right).

activities and obtain live visual indicators of collaboration or progress of each group. The main contribution of this paper is the presentation of an approach that provides indicators of small-groups' performance on the teacher's dashboard, and our study of its impact on the teacher's decisions about the groups needing attention.

To date, full class sets of interactive tabletops have been studied in research contexts, rather than authentic learning environments. One important project that explored the use of tabletops in the classroom is SynergyNet (Mercier et al., 2012). This was a multi-tabletop environment used to investigate the quality of school children's collaboration and the ways teachers can interact with their system. Another similar environment was presented by Do-Lenh (2012), which could track command cards for the teacher to orchestrate the tables and also showed task progress indicators at a wall display that all the class could see. Both environments explored ways that a teacher can use these devices for classroom orchestration, in terms of collaboration and usability, respectively. A third example was provided by a teacher's dashboard proposed by Martinez-Maldonado et al. (2012b), who evaluated a system that offered visual indicators of group work at each tabletop to help teachers decide which group needed more attention over the duration of a class. However, in all this previous work, the studies were not linked to authentic curricula; nor were they prepared by the teacher.

The work we present in this paper builds on principles of classroom orchestration (Dillenbourg et al., 2011b), specifically on the dimensions of regulation and awareness (Prieto et al., 2011). MTClassroom provides an environment that captures live information about each learner collaborating at the classroom and MTDashboard is the interface that provides control functions and indicators enabling the teacher to be aware of each group's progress and activity. Our work goes beyond previous research by showing how the captured data can be used by the teacher in two ways: in class for light-weight indicators of students' progress; and after class, to analyse the ways they allocated their attention between the student groups.

Design of our Educational Technology

The main motivation for designing MTClassroom and MTDashboard is that, as the use of technology in and out the classroom is spreading, large amounts of learner data can be captured and summarised. These summaries of data can be exploited to show information that might otherwise not be easily available. This can be provided to teachers so that they can better decide which students may need timely interventions (Bull et al., 2012) or for later reflection on how their classroom attention was divided. Interactive tabletops are devices that have the potential to support knowledge co-construction in small teams (Dillenbourg et al., 2011a) and also to capture aspects of learners collaborative interactions (Martinez-Maldonado et al., 2012c). Next, we describe the principles of classroom orchestration and awareness that drove the design of the educational technology presented in this paper and then, our learning environments. These principles are as follows:

a) To support the role of the teacher as the main actor in classroom orchestration. The design of the system should primarily focus on providing services to assist teachers' actions and awareness in the classroom (Dillenbourg et al., 2010).

b) To support coordination of planned learning activities. The tools should support the enactment of the activities designed by the teacher, so that the learning objectives can be achieved (Prieto et al., 2011).

c) To support classroom regulation and management. The system should provide the teacher with functions to manage and adapt, to some extent, the macro script of the classroom activity (Dillenbourg et al., 2011b). We also highlight the importance of after-class analysis of the data that can be captured during the learning activities for reflection and evaluation.

d) To provide "light-weight" indicators about learners' progress. The system should be able to automatically capture small-groups' interactions data and present this information to the teacher to enhance their awareness and direct their attention (Bull et al., 2012; Martinez-Maldonado et al., 2012a).

MTClassroom: Multi-Interactive Tabletop Classroom

The MTClassroom is composed of a number of interconnected multi-touch interactive tabletops (4 were used in our study). Each tabletop consists of a 26 inch PQlabs multi-touch layer placed over a high-definition display of the same size. Each tabletop is enriched with an over-head depth sensor that detects the student who is touching the interactive surface at any time (Figure 2, left). In this way, the *host applications* running at the tabletops recognise and log differentiated actions performed by each student. From the *teacher's perspective,* MTClassroom offers functionalities for orchestrating the tabletops through a controller dashboard that allows teachers to send commands to the host applications to trigger actions such as blocking the touch input or moving to the next learning phase. A full description of the design of this tool is provided in the next section. Additionally, the system incorporates a connected wall projector that the teacher can use to display the artefact being created at a determined tabletop to lead reflection at classroom level (Figure 2, right).

MTClassroom can run different learning applications. In this study, the classroom activity consisted of the elaboration of concept maps. Concept mapping is an activity that encourages meaningful learning and, when maps are constructed in small groups, can foster externalisation and negotiation of diverse perspectives (Novak, 1995; Stahl, 2006). This tabletop concept mapping application (Martinez-Maldonado et al., 2010)permits

Figure 2. MTClassroom in action (Left). Reflection driven by the teacher using the wall display (Right)

students to have access to a list of suggested concepts and linking words, or type their own words, in order to build a concept map that answers a question asked by the teacher. Prior to the classroom activity, the teacher uses a desktop concept mapping editor to create the list of suggested concepts and linking words, and generate a *Master Concept Map* with the *crucial or relevant* concepts and links that learners must include in their maps, as well as other *relevant* ones that might be expected.

From a *data capture perspective*, the system automatically differentiates students' actions at the tabletop according to their seating position. The logging system of each tabletop records all actions to a central repository that can be accessed in real time to generate indicators of group activity to be presented to the teacher. Additionally, *observation consoles* can be directly connected to the repository to capture synchronised qualitative data. In our study, two different observers submitted standardised annotations of the teacher's attention and interventions. More details about these are described in the next sections.

MTDashboard

Figure 3. MTDashboard: condition 1 (Left), being used in the classroom (Centre) and condition 2 (Right)

The MTDashboard is a multi-platform teacher's tool that contains both controlling and awareness components (Figure 3, right). In this study, the dashboard was displayed at a handheld tablet device that the teacher carried while walking around the classroom to monitor student progress (Figure 3, centre). The design of this dashboard was driven by the requirements specified by the teacher. The design was also based on principles of classroom orchestration of regulation and awareness (Dillenbourg et al., 2010; Prieto et al., 2011) and inspired by similar technologies applied in related work (Do-Lenh, 2012; Mercier et al., 2012). Figure 4 shows details of the MTDashboard interface that includes the following components. A) *General functions*, commands that the teacher can use with any tabletop. These are, "Start" (Figure 4, A1) and "Finish" (A4) commands, to explicitly mark the boundaries of the activity; a "Send message" (A6) command, so the teacher can send text reminders to all the tables about, for example, the time left for the activity; "Block" (A2) to freeze the table when the teacher wants students' attention and "Unblock" (A3) commands for the teacher to get students' attention when needed: and a "Reset" (A5) command to clean up the tabletop interfaces and making them ready for students in next

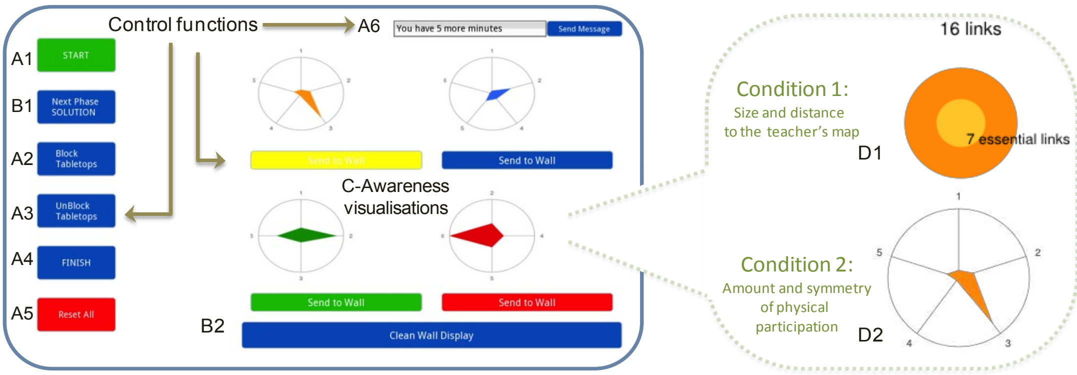

Figure 4. User interface of the MTDashboard (annotated to show Control functions A1-6, B1-2, C, D1-2).

tutorial. B) *Configurable functions*, may be applicable in various activities but their meaning depends on the macro-script definition. These include the "Jump to the next phase" (B1) and "Send to the wall" (B2) commands. Figure 3 (left) shows that in our case, this latter shows a concept map of one tabletop in the wall display. And finally, C) *Awareness visualisations,* which can show key information about each group progress, participation or other indicators that may be coupled to the domain (D1-2 are explained in detail below).

Study Description

Authentic classroom sessions. Two sets of tutorial sessions were taught in Semester 1 and 2, 2012, by the School of Business of the University of Sydney. In the *first set* of 14 classroom sessions, we investigated how a teacher can design and orchestrate small-group activities using an enriched classroom, and subsequently analyse the data to assess that design (Martinez-Maldonado et al., 2012a). The technology used in this preliminary study *did not* have any awareness or control functions available to the teacher. The study informed design of the tools needed to *orchestrate* a classroom, for the second iteration. *This paper focuses on that second set of classroom sessions*. It had 8 tutorials, run in the 6th week of Semester 2, 2012, for a course titled "Management and Organisational Ethics". In total, 140 students attended these tutorials. Each had 15 to 20 students. The teacher arbitrarily formed four groups, with 4 or 5 students at each table. All students knew each other. The teacher designed a case-resolution activity to cover the set topic as defined in the curriculum for that week.

Activity design. A macro-script was defined by the teacher for the tutorials as follows: 1) *Introduction* (10 minutes): the teacher forms groups, explains the tutorial objective, teaches students how to use the minimalistic concept mapping application and explains the objectives of the first activity. 2) *Activity 1* (10 min.): the teacher uses the MTDashboard to ensure that all groups *start* at the same time. The four tabletops respond by clearing the interface and loading a small scaffolding concept map (5 concepts and 2 links set by the teacher). Students have to complete this map showing how the main actors of the case are linked. 3) *Reflection 1* (5 min.): the teacher *blocks* the tabletops and introduces Activity 2, explaining it and leading class discussion about possible solutions to the case. 4) *Activity 2* (15 min.): for the teacher, this is *"the most important activity of the tutorial from the learning perspective".* The teacher *unblocks* the tabletops; and students discuss the task and complete their concept map. 5) *Group sharing and final reflection* (10 min.): the teacher *blocks* the tabletops again and then asks each group to share their solution with the class. The teacher uses the function *send to the wall* for each table in turns. After each group has explained their concept map, the teacher summarises the outcomes of the activity and finishes the session. The class time was fixed at 50 minutes.

Visualisations presented to the teacher. Two different conditions of the MTDashboard were used across 8 sessions. For Condition 1, the dashboard (Figure 3, left, and Figure 4, lower right) included the *Group Map Visualisation* that represented the size and distance of each map to the teacher's map. This information was explicitly requested by the teacher because she wanted this concept map quality measure that is not normally available during the limited classroom time (Figure 4, D1). The second version of the dashboard (Figure 3, right) presented the visualisation *Radar of Physical Participation* that shows the number of touches on the tabletop per student and the equality among group member touches (Figure 4, D2). The design of this visualisation was suggested by the teacher in previous tutorials (Semester 1) who expressed that "*quantitative information about students' actions would be useful for identifying participation*". This visualisation was inspired by previous work on group chat communication and physical activity (Martinez-Maldonado et al., 2011). A larger range of visualisations (some more elaborated) were offered to the teacher (Martinez-Maldonado et al., 2012b), but not selected for this study.

Research questions. When teachers orchestrate multiple groups in the classroom, one of their challenges is to identify the group that most needs immediate attention (Dillenbourg et al., 2011b) whilst, concurrently, spending a relatively balanced amount of time with each group, to be fair to all students. This is where MTDashboard can provide awareness support for the teacher, enabling an informed decision about which group to attend next. For this, we sought to address the next questions: *What is the impact of the information provided to the teacher by the MTDashboard during the classroom sessions? Is the teacher attending the "lower achieving" groups according to the information provided?*

Data collection. We collected information from a number of sources to triangulate evidence. These sources included: automated capture of the MTClassroom, notes from an external observer focused on teacher's actions, notes from a second external observer focused on assessing each small-group work and notes from interviewing the teacher. The *automatically captured data* consisted of synchronised log of the host application at each tabletop (differentiated students' actions and partial states of the concept maps), logs of teacher's actions using the MTDashboard, and partial distances of group artefacts from the teacher map. The *manually captured quantitative/qualitative data* consisted of the observed time and duration of the moments when the teacher: i) *attended* or *intervened* a group, ii) looked at the MTDashboard, iii) spoke to the whole group, iv) walked around the class or did not look at any specific group. These observations were captured through a console synchronised with the application logs. The second set of observations consisted of quantitative assessments of perceived qualitative collaboration per group based on an adapted rating scheme (Meier et al., 2007). Our scheme has 4 dimensions of collaboration, quantified from -2 to 2, for each of (a) mutual understanding and dialogue management, (b) information pooling and consensus (c) task division, time management and technical coordination, and (d) reciprocity. The teacher also assessed groups at the end of each tutorial, using one of three possible values: low, medium or high achieving. Finally, we conducted semi-structured post-tutorial interviews with the teacher to obtain feedback on the functions and visualisations provided for classroom orchestration.

Data exploration. To analyse the teacher's attention distribution, we first define the terms *attention* and *intervention*. We consider that teachers pay *attention* to a group when their gaze is focused on or they interact with that group. *Intervention* is the *subset* of such *attention* that happens only when the teacher interacts with the group, therefore interrupting their work. We made this distinction based on a previous study in which teachers stated that for some outstanding groups they would "*see what they are doing*" but mostly leave them work by themselves (Martinez-Maldonado et al., 2012b). During the post-tutorial interviews the teacher commented that she "*tried to provide equal attention to all groups",* while "*focusing on groups that needed more help"*. This means that the teacher dynamically chose the order in which she attended to each group. Having made this distinction, we now describe an example of the teacher's actions at the MTClassroom. Figure 5 shows a transition diagram where the nodes represent the elements that were at the focus of teacher's attention. The nodes correspond to *each group*, the *MTDashboard* or the whole *Class*. The latter includes the times when the teacher was not attending to any particular group or gave a message to the whole class. The directed arrows between the nodes represent the transitions recorded by the external observer (45 transitions registered in this example). In this group, the teacher devoted most time to the *red* group (32% of attention and 29% of intervention time) compared with the others (20%, 26%, and 21%). In fact, the teacher assessed the *red* group as the only *low achieving* group in the class, therefore confirming that the attention in this class was not equally distributed. We also observed that the teacher never attended to the *green* group after looking at the dashboard. Coincidentally, the green group also received the fewest interventions. This motivated the analysis of the rest of the cases to find evidence that confirms the impact of the information delivered through the dashboard on teacher's attention. In other sessions, the accumulated attention was more egalitarian. An analysis of dispersion of *attention* and *intervention* among the sessions showed that the teacher paid attention to all groups largely equally (mean index of dispersion -Gini factor- for attention= 0.12 and intervention = 0.124, where zero means perfect equality). The next section describes our evaluation of the impact of the nature of the information displayed through the dashboard on teacher attention and intervention. The actions that the teacher took after looking at the MTDashboard are the focus of our evaluation (thicker transition lines in Figure 5).

Analysis and Discussion

This section is divided in three parts. The first two tackle our research questions and the last one explores the impact of teacher's feedback on students to complete our analysis of the orchestration loop at our environment.

Analysis, part 1. For the first question (*What is the impact of the information we provided to the teacher in real-time during the classroom sessions?),* we started by analysing whether there was any relation between the observed *performance* of each of the 32 groups during the tutorials with the accumulated amount of time that the teacher dedicated to attend or intervene each of them. We divided the groups according to the two conditions of the information that was provided to the teacher through the MTDashboard. The two conditions were: (i) *distance to teacher's map* and (ii) *physical participation*. We performed correlation analyses between *attention/intervention* and group *performance* measured in different levels and from different sources: the external observer that measured collaboration, the artefact that students built and the teacher assessment. Table 1 shows the results of these analyses, where *Attention time* and *Intervention time* are the proportions of the time the teacher dedicated to inspect and interact, or just interact, with specific groups respectively. Regarding the columns of groups' performance, columns *ob1*, *ob2*, *ob3* and *ob4* correspond the 4 categories used by the external observer to assess group's collaboration according to the schema adapted from Meier et al. (2007). Column *Obc* corresponds to the correlations with the cumulative score of these 4. Columns *Size map* and *Dist* correspond to the correlations with, respectively, the size and the distance of groups' map to the teacher's map. Finally, the column *Tchr* indicates the correlations with the quality of each group as assessed by the teacher.

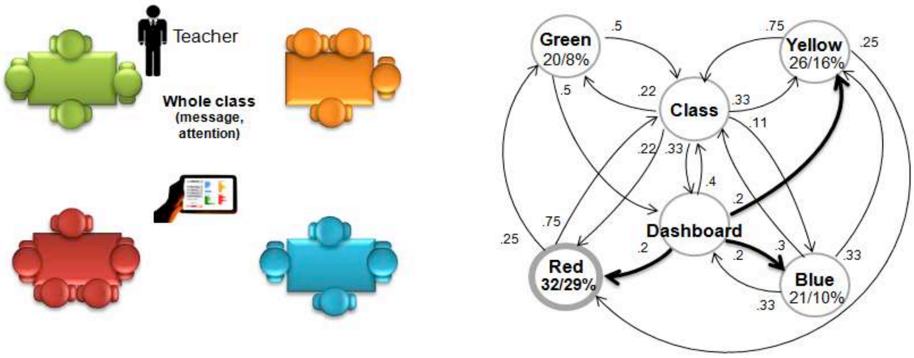

Figure 5. An illustrative transition diagram of the process of teacher's attention in one classroom

Results showed a difference between the two conditions for the correlation between *observed collaboration* and *attention/intervention time*. For condition (i) *distance to teacher's map*, we found a significant positive correlation between levels of collaboration and the attention and intervention provided by the teacher (columns *ob2*, *ob3* and *Obc*, left). On the other hand, for condition (ii) *physical participation*, we found a negative moderate correlation (columns ob1, ob3, ob4 and Obc, right). From a teaching perspective, a negative correlation might appear desirable, since it would mean that the teacher provided more attention to the low groups. However, a perfect correlation is unrealistic, since the teacher cannot totally neglect high achieving students. To explain these findings, we triangulated this evidence with the teacher's statements during the post-tutorial interviews. The teacher found that the information provided in condition (i) was useful during the class and it was expressed as: "*I looked at the number of relevant links because one group could have 21 links, but how many of them actually matched my map? For a group with 9 linkages with most of them matching my map, I would be satisfied*". This means that information about the distance to teacher's map in condition (i) helped the teacher recognise the groups that might have needed more help. The analysis supports this since the only negative correlation of condition (i) was for column *Dist* (-0.3 and -0.16 for attention and intervention). The level of collaboration of groups does not determine the qualitative aspects of their artefacts, therefore there were no negative correlations for *observed collaboration* in condition (i).

Table 1: Correlation analyses between Attention/Intervention and Groups' performance.

	i) Distance to teacher's map								ii) Physical participation							
Groups' performance ▶	Observed collaboration					Size map	Dist	Tchr	Observed collaboration					Size map	Dist	Tchr
	ob1	ob2	ob3	ob4	Obc				ob1	ob2	ob3	ob4	Obc			
Attention time (%)	-0.20	0.33	0.34	-0.10	0.44	0.29	-0.30	-0.10	-0.26	-0.10	-0.33	-0.32	-0.30	-0.10	0.48	0.00
Intervention time (%)	-0.10	0.37	0.34	0.02	0.45	0.34	-0.16	0.02	-0.20	0.05	-0.32	-0.38	-0.27	0.03	0.34	0.15
Correlation ▶	low -	med/ low +	med/ low +	no	+ p<=0.1	med/ low +	low -	no	low-	no	med/ low -	med/ low -	med -	no	+ p<=0.1	no

For condition (ii), the teacher expressed that the information provided by the *Radars of participation* was good but was not used much because "*a lot of the times groups decided that one only person was going to do the links or I [the teacher] could tell by looking at the table that everyone was discussing but only two or three people were actually moving things around. Then, by looking at the diagrams only, I couldn't interpret [them] as the group was not working*". Therefore, during these tutorials for the second condition, the teacher mostly used what she could observe and listen from each group work. We argue that this is the reason why the attention and intervention are more aligned to the *observed* level of collaboration (negative correlations for columns *ob1*, *ob3*, *ob4*, *Obs* in condition *Physical participation*). As the information about the size of the map and the distance to the teacher's map was not provided in this condition, we found no correlation or positive correlation respectively (columns *Size map* and *Dist*). Finally, the teacher's assessment seemed independent from her decisions to provide attention (values are close to zero in *Tchr* columns for both conditions). The teacher described that groups' assessment was primarily based on the explanations that each presented to the class towards the end of the tutorial, and also influenced by the students' conversations that she could overhear and the groups' indicators of distance to teacher's map provided in condition (i). Therefore, the teacher's assessment was not connected to their evaluation of which groups needed the most help at some point. This suggests that, while the cumulative analysis (*part 1)* is informative in both conditions, we also need to conduct further analysis taking into account the moments when attention was provided to groups.

Analysis, part 2. As groups' needs for teacher attention vary in time, the teacher needs to continuously monitor groups' performance to try and keep the levels across groups as close as possible. Here is where our second research question arises: *is the teacher attending the 'less achieving' groups according to the information provided*? To answer this, we analysed the decisions made by the teacher right after looking at the dashboard. There were 38 teacher's actions that were captured by the external observer and synchronised with the MTClassroom's logs (17 for *distance to teacher's map* and 21 for *physical participation* conditions).

Condition (i). For each moment when the teacher looked at the dashboard and for each group in the classroom, we calculated the quantitative indicators of size and distance of the map provided by the *Group map visualisation* at that exact moment. Then, the groups were ranked from the smallest and furthest map to teacher's map to the biggest and closest map at that point in time. There were 3 possible ranks: *furthest behind* group(s), the *strongest* group(s), and the groups in between. The strongest group at a determined moment was the one with more relevant links and less irrelevant links according to the teacher's map. Then, we identified the group that the teacher chose to attend next. After this, we assessed the category of the group chosen by the teacher, for example, if the teacher chose a furthest behind group or a strong one. Table 2 shows the results of this analysis. Column A corresponds to the 17 cases of teacher's attention after inspecting the dashboard of the condition under analysis (i). Column B corresponds to the other cases where the second type of information was provided (ii). We found that when the map size and distance to the teacher's map information was provided (column A) the teacher only decided to attend the strongest group 18% of the times (3 out of 17 cases). On the contrary, when this information was not provided, the teacher attended the strongest group 43% of the times (9 out of 21). This confirms that showing information of each group's artefact in 'real-time' had some impact on the teacher's decision as to which group to attend next. It also validates what the teacher expressed, that looking at the number of relevant links added by each group helped her have a better idea of groups' performance.

Table 2: Analysis the groups that the teacher attended for condition (i) distance to teacher's map.

Condition: distance to teacher's map	A) Map information was provided		B) No information about the map was provided	
Total	**17**	**Proportion %**	21	Proportion %
Less achieving	**5**	**29.41**	4	19.05
Not the best groups	**9**	**52.94**	8	38.10
The best group	**3**	**17.65**	9	42.86

Condition (ii). We calculated the information provided by the visualisation *radar of physical participation* for the 38 cases when the teacher looked at the dashboard. We had the same 3 possible ranks. In this case, the strongest group was the more equilibrated in terms of participation. We measured the rank using an index of dispersion, the Gini coefficient. This is a number between zero and 1, where zero means perfect equality of students' participation. We followed the same process as the previous condition. Results are shown in Table 3. These confirm that the participation radar, at least in the way in which we presented it, did not provide information to the teacher to take decisions about which group to attend next. The teacher decided to attend low or high achieving groups almost with no difference (33%, 38% and 28% of the times). The post-tutorials interview confirmed that the teacher did not use the information about physical participation, justifying this with the argument that "*not everyone was touching the tabletop but they were speaking a lot and this is good from a learning perspective*". The teacher also argued that this information "*would be very helpful in a bigger class*". The teacher described this as follows: "*I cannot observe 80 people but I can observe 20 people, I could tell who was talking. It would be fantastic to check the participation information for a bigger group*".

Table 3: Analysis the groups that the teacher attended for condition (i) physical participation.

Condition: physical participation	A) No information about participation was provided		B) Participation condition	
Total	17	Proportion %	**21**	**Proportion %**
Less achieving	4	23.53	**7**	**33.33**
Not the best groups	9	52.94	**8**	**38.09**
The best group	4	23.53	**6**	**28.57**

Analysis, part 3. Finally, we investigated whether the teacher's intervention actually had an impact on students' performance immediately after. We considered as indicator of performance the number of relevant links created by each group. The teacher intervened groups a total of 74 times in the 8 classroom sessions. For each intervention, each group was ranked at the moment the teacher started the intervention from 1 to 4 (from low to high group, according to the teacher's map distance of the four groups in the class). Then, we assessed if there was an improvement (or decrease) of the map 2, 3, 4 and 5 minutes later (interventions lasted up to 2 minutes and each activity lasted from 8 to 10 minutes). For example, at minute 5:05 the teacher attends the Green group. At that exact moment, this group had the furthest map to the teacher map in the class, so their rank was 1. We divided the 74 interventions in two groups according to the 2 conditions of the information provided to the teacher. Results on the analyses of correlations between the rank of each attended group and the improvement of the teacher's map distance are shown in Table 4. For condition (i), *Distance to teacher's map*, we found significant negative correlations. This means that the groups that were lagging significantly improved their teacher's map distance after teacher's intervention. However no correlation was found in condition, (ii). We can therefore argue that the teacher's intervention had a significant impact on the groups' artefact when the information about the distance to the teacher's map was provided. This once again provides evidence that supports the benefits of showing information about the quality of students' work to the teacher in real time.

Table 4: the Impact of teacher's interventions: correlation analysis between the rank of a group among the others in the classroom and the improvement of their artefact's distance to the teacher's map.

Condition	# interventions	after 2 min	after 3 min	after 4 min	after 5 min	
Distance to teacher's map	40	-0.4, $p<=0.01$	-0.27, $p<=0.05$	-0.32, $p<0.025$	-0.27, $p<=0.05$	**Significant correlations**
Physical participation	34	0.08	-0.05	-0.05	-0.02	**No correlation**

Our analysis completed the circle of teacher's orchestration that includes: *awareness, intervention and students' action* following this intervention. We found some trends by analysing the accumulated attention and intervention by the end of the tutorials. Then, we obtained stronger evidence confirming the importance of showing indicators of quality of student's work to drive teacher's decision. Finally, we found that *informed* interventions of the teacher can lead students to improve their solutions according to teacher's perspective.

Conclusions and Future Work

We presented our enriched multi-tabletop classroom that afforded the unobtrusive data capture that makes possible to present two sets of information to the teacher in real-time. The potential of MTClassroom can be wide, from offering simple classroom orchestration controls to awareness and reflection tools. We confirmed that the data presented to the teacher in the classroom can drive their focus of attention especially when information about the *quality* of students work is delivered. The teacher described this as follows: "*I think the dashboard was really good, especially because it showed things about the quality of their work. If I haven't had this information about the relevant links then I had to look at the whole diagram so it would take longer to look at each map*". Our study also confirms that the teacher would value indicators of group work and individual participation for post-hoc analysis. The teacher expressed: "*I don't want to see a lot of information in the dashboard, this can be distracting. But more information can be provided after the tutorials for assessment wise, like who did what, when, and the quality of the work*". Our work in progress includes a detailed analysis of the information that should be delivered to the teacher during and after the classroom sessions; and the integration of other sources of information (e.g. verbal participation) and other analysis tools (e.g. data mining) to extract patterns of interaction that can provide more insightful indicators to the teachers in the classroom.

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