Towards the Integration of Collaboration Analytics and Interactive Surfaces

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Abstract. Emerging surface devices have the potential to promote collaboration in multiple forms. They can provide users with natural, ubiquitous and pervasive ways to interact with collaborators face to face or through the network. However, *learning to collaborate* is not a straightforward task. It commonly requires coaching or deep self-reflection. A key affordance of these devices, that has received little attention, is their potential to *unobtrusively* capture digital footprints of the collaboration process. We investigate collaboration in the classroom and through the network using what we call: *Collaboration Analytics* in learning contexts. Our studies revealed design features that are important to perform *automatic* analysis of student's interactions. According to our studies in *authentic* learning settings, surface devices have the potential to make visible various aspects of student's collaboration that are currently invisible for teachers and students themselves. We highlight the importance of using *Collaboration Analytics* to enhance teacher's awareness that can help provide more effective *in-time support* or foster student's reflection.

Keywords: CSCL, Face-to-face Collaboration, Tabletops, Learning Analytics, Mobile devices

1 Introduction

The development of collaboration skills, both for collocated and for remote settings, is crucial in a wide number of areas [17]. These areas range from generation of value in industry to the creation of knowledge in learning contexts. However, learning to collaborate is not a straightforward task. It commonly requires coaching or deep self-reflection [12]. Over at least the last two decades, there has been substantial progress in the development of technologies that enable learners to collaborate, mainly through web-based systems [19]. Alternatively, emerging surface devices, such as interactive tabletops, tablets, whiteboards and mobile devices, have the potential to promote collaboration in multiple forms. They can provide users with natural, ubiquitous and pervasive ways to interact with collaborators, face to face or through the network.

A key affordance of these devices, that has received little attention, is their potential to capture the digital footprints of the collaboration process [9]. We investigate the different ways in which these collaborator's data, captured in the classroom and through networked learning tools, can be exploited using *Collaboration Analytics*.

In this paper we use the concept of *Collaboration Analytics* for the analysis techniques that can be applied to exploit rich interaction data captured from a collaborative learning environment. Under this umbrella we include artificial intelligence approaches, data mining algorithms, process mining, statistics and visualisations. Research in this area is spread out. It can be found as subsets of research in learning analytics (LAK) [18], educational data mining (EDM) [1] and Computer-Supported Collaborative Learning (CSCL) [7]. The term Collaboration Analytics has also been used by Wang *et al*. [21] in reference to a clustering technique applied to mining user patterns from their collaboration activities.

The aim of this paper is to drive attention on the synergy between two different but overlapping areas of research: Collaboration Analytics and the use of interactive surfaces for collaboration. Surface devices offer new ways for learners to interact with computers. However, as any other new educational technology, in order to justify their integration into the classroom, they should provide additional support to teachers or learners, beyond what the teacher can do without such technology [5].

This paper proposes a conceptual model to integrate the use of Collaboration Analytics to enhance *awareness* of student's collaborative interactions through networked, ubiquitous and pervasive learning settings. We propose this model based on our first-hand experience of deploying interactive surface devices in authentic learning environments. Our studies revealed design features that are important for performing automatic analysis of student's interactions. According to our studies in authentic learning settings, surface devices have the potential of making visible various aspects of student's collaboration that are currently invisible for teachers or students themselves. Our approach is highly influenced by the metaphor of 'classroom' orchestration, which considers the design of learning activities and the management of the classroom resources, learning processes and teaching actions [6, 15]. This makes our approach especially targeted to help teacher's provide more effective in-time support.

The paper is organised as follows: Section 2 defines some ideal considerations for deploying a Collaboration Analytics solution in pervasive and ubiquitous learning environments; Section 3 describes our conceptual model and a discussion of the implementation; Section 4 describes some example implementations that illustrate different scenarios in which our Collaboration Analytics model can be applied. These include a single-tabletop setting, a multi-tabletop classroom ecology and a tablet-tabletop informal learning setting. Our studies revealed design features that are important for performing automatic analysis of student's interactions.

2 Design Considerations to Implement Collaboration Analytics in Ubiquitous and Pervasive Learning Environments

This section presents a number of ideal considerations that can influence the design and implementation of a Collaboration Analytics solution in a technology-enhanced learning environment. We target learning activities that involve the use of web-based tools as well as ubiquitous and pervasive tools. These technologies include surface devices that can be used for face-to-face collaboration or mobile devices that can be used as personal spaces. The aim of the considerations is not prescriptive, they are the result of our empirical analysis of a number of studies that involve principles at the intersection of Human-Computer Interaction (HCI), CSCL and Collaboration Analytics disciplines [3, 8, 9, 10]. We have conducted these studies both *in the wild* and under controlled conditions. We additionally build on the metaphor of classroom orchestration [6]. The design considerations are:

The Teacher should keep the role as the main actor in classroom orchestration. The design of the system should primarily focus on providing services to assist teacher's actions and enhance their awareness in the classroom [6]. The teacher is the orchestrator of the learning activities, the class script, the technology and the whole learning experience. The technology should be designed to serve the teacher, so that they can perform the orchestration tasks more effectively.

The student's data collection should be Unobtrusive. This consideration is crucial to keep all data capture elements decoupled from the learning setting so the situation allows for natural face-to-face collaboration. Additionally, the driving goal should be to provide tools that can be deployed in the classroom and not only under constrained experimental settings.

The data collection solution should keep continued Tracking of student's activity in different learning activities and tools. Similarly to the previous consideration, the solution should offer the means for keeping track of student's activity. In the same way students log in into web-based learning tools, they should be able to be identified while they use ubiquitous or pervasive technologies.

The analytics solution should be deployed in Authentic scenarios. It is advisable to keep the learning environment as real as possible. This is students that have well defined learning goals and a clear idea of how the learning activities are connected to the *regular curricula* of the subject matter they study.

The analytics tools should be able to perform Automatically. It is advisable that the Collaboration Analytics solution provide group's indicators that require little or no human intervention to be produced so teachers can benefit from them. The goal is to enhance teacher's awareness of student's interactions and learning processes that might not be evident for a teacher by looking at group's final products but can be captured by the computer system automatically.

The analytics tools should both provide Real-time support and information to be analysed Post-hoc. It is advisable that the Collaboration Analytics solution provide useful awareness indicators during classroom sessions in the limited time available. It is also important to deliver key information for post-classroom analysis, assessment or activity re-designs.

3 Model for Integrating Collaboration Analytics in Ubiquitous and Pervasive Learning Environments

In this section we present our proposed conceptual model to integrate Collaboration Analytic tools in Learning Environments. Figure 1 illustrates the high-level components of this model. It is focused on the differentiation between three types of learning environments according to their context of use [13]. These are: web-based learning environments (accessed through desktop/laptop computers); ubiquitous learning environments, that are highly mobile and are aware, to some extent, of the physical environment where they are being used; and pervasive learning environments, which can capture information about the environment in which they are embedded.

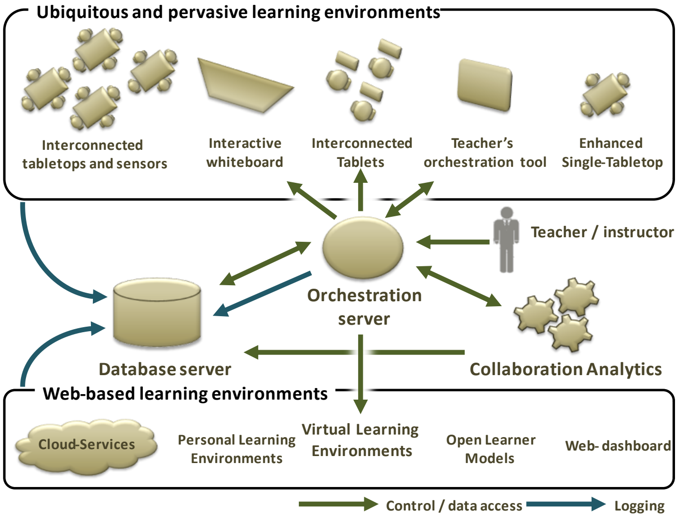

Fig. 1. Conceptual model to integrate Collaboration Analytics and ubiquitous and pervasive learning environments.

The ubiquitous and pervasive learning environments are grouped because they can offer the students opportunities to work in the physical world and collaborate face to face. They can also be used in conjunction. This group of learning environments can include a wide range of technologies. In this paper we focus on interactive surface devices that can be used alone or in combination. They can be implemented in the classroom or in informal learning situations (e.g. a school visit to a museum).

The web-based learning environments allow students to interact through the computer with learning content and their peers. It is a very important part of the model since most of the efforts on supporting collaborative learning; the management of whole courses and the application of analytics are based on these kinds of learning environments. In other words, teachers are already using these systems. Some teachers use a Virtual Learning Environment (VLE) to organise course content and associated learning activities, but can also use other web tools such as wikis, forums, chat, email, distributed documents and so on [14]. Alternatively, some of these web-based tools capture and analyse student's interactions to present information back to the user in the form of (open) learner models or a dashboard for the teacher to monitor progress of students [2]. These visual and statistical aids are already Analytics tools.

Our model proposes to bring together the various learning environments using an orchestration server, a central repository (ideally, in the form of a common unified database) and a Collaboration Analytics engine. The objective is that student's interaction data can be captured through various learning activities, mediums and tools, to provide support to teachers or even students themselves. The orchestration server should be the main tool for the teacher to: design, manage, regulate and monitor learning activities in their plan [16]. These functions can be performed in different areas. One of them is in the classroom, where teachers can directly coordinate technologies (e.g. tabletops, tablets and whiteboards) and orchestrated learning tools (e.g., editors, communication apps and collaborative writing tools). Another level is at the whole course, where students may interact with ubiquitous and pervasive technologies in the classroom and continue working through web-based tools in the school lab or at home. The model focuses on the ability of the orchestration server to keep central control, allowing a unified way to log student's data across different learning spaces.

Alternatively, the database server should provide a general baseline format to record student's data from multiple and heterogeneous sources. From an implementation perspective, to achieve this is very challenging. However, it is possible to establish a common layer for logging certain key student's activity. One example that shows that this is possible is Narcissus [20], which is a visual analytics tool that shows student's information from different learning activities.

Regarding the Collaboration Analytics role in the model, student's data can be analysed and exploited for self-regulation (if presented to students); for scaffolding, coaching and evaluation (by teachers); or for post-hoc analysis, design-based interventions, etc. (if presented to researchers or specialised teachers). The way that information is presented to the various actors in the learning environment can be shown through visualisations of key indicators so they (the actors) can take appropriate actions. Also, software agents can trigger automatic actions of regulation. These kind of automated actions have been explored in networked tutoring systems but not yet deeply explored in surface devices. By contrast, in face-to-face settings, that are the space where interactive surfaces are deployed, students commonly learn in the physical presence of an instructor who helps to guide the collaboration and in which the role of the technology is frequently less dominant. Therefore, it is important to define the ways in which the products of the Collaboration Analytics can enhance teacher's awareness of the aspects that she cannot easily monitor without technology.

4 Example Implementations

Next, we describe a few example lines of research that involve the implementation of certain parts of the model presented above, towards the development of a more general solution using Collaboration analytics and surface devices in learning settings.

Enhanced single-tabletop learning environments:
Single tabletop learning environments afford face-to-face collaboration and are ideal for small groups focused on specific learning or training tasks (Figure 2, left). We built an enhanced tabletop that can differentiate users touch activity and speech, capturing different aspects of student's interactions. In this setting, we have used collaboration analytics approaches to discover patterns of interaction or group strategies us-

ing data mining techniques [9], creating visualisations of group work and mirroring information to students in the form of (open) learner models [3].

Fig. 2**.** Left: Enhanced single-tabletop learning environment. Right: Using tablets and tabletops in an informal learning setting.

Synergy between tablets and tabletops:
The co-operation between tablets and tabletops can support informal learning, such as a semi-guided museum tour (Figure 2, right). In this case, tablets provide ubiquitous individual learning activities such as data collection (written notes, images and video). Tabletops afford bringing together individuals, supporting face-to-face collaboration, allowing individual work to be shared and promoting group discussion. In this scenario, Collaborative Analytics tools may help to keep continued tracking of student's knowledge creation processes and analyse the lifespan and use of the learning artefacts built by students in different periods and with various technologies.

Fig. 3. Left: Multiple enhanced tabletops in the classroom. Right: A teacher's dashboard.

Tabletops, teacher's dashboard and whiteboard in the classroom:
We developed a classroom ecology called MTClassroom [10] that integrates pervasive sensing systems and multiple surface technologies (Figure 3, left) – tabletops, a public display and a teacher's interactive dashboard. This environment can capture and analyse parts of the collaborative process of each group at a tabletop. In this way, we can provide the teacher with timely information on group performance, on-task

behaviour, and levels of participation [8]. It also allows a teacher to reflect on classroom dynamics, both in terms of the stages of their activity and time spent with each group [10]. The MTDashboard is the interactive teacher's interface that shows real-time visualisations that can help teachers take better decisions, such as which group to attend to next (Figure 3, right). The same dashboard can also support orchestration functions, allowing a teacher to co-ordinate a teaching script and technology together.

5 Conclusions

We presented a conceptual model that aims to motivate discussion about the integration of Collaboration Analytics tools and interactive surfaces. Interactive surfaces are good examples of devices that can afford the creation of ubiquitous or pervasive learning environments. We proposed a list of considerations to design solutions in the intersection of these fields. Without being prescriptive, and based on our empirical analysis, our design considerations are: that the teacher should have the main role in the solution, the capturing system should be unobtrusive and offer continued tracking among activities, the learning situation should be kept as authentic as possible (rather than a controlled experiment) and the analytics tools should offer the flexibility to perform automatically, in real-time or to provide results for post-hoc reflection. We base our empirical analysis on our studies applying analytics in single-table settings [3, 9], in a classroom ecology called MTClassroom [8, 10], our research on teacher's dashboards [11], and from an informal learning environment where tablets and a tabletop are used for individual and collaborative activities in a single script [4].

We acknowledge that the implementation of the model may raise technical challenges. Different tools have different ways to interact and to record student's data. Some of them provide API's that allow the orchestration server interact with them; others may not have logging features at all. Some of these issues are gaining attention of other researchers (e.g. in the CSCL community [14]). The aim of the model is not to suggest that a single tool will solve all these problems; but to serve as a driver of future research and design directions. The model additionally raises awareness of the possible applications of a solution that integrates orchestration, analytics and monitoring of learning activities. It also presents a vision of the different disciplines involved (at least HCI, CSCL, EDM, LAK) and the implementation challenges.

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