Chen, W. et al. (Eds.) (2017). Proceedings of the 25th International Conference on Computers in Education.
New Zealand: Asia-Pacific Society for Computers in Education

# DBCollab: Automated Feedback for Face-to-Face Group Database Design

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**Abstract:** Developing effective teamwork and collaboration skills is regarded as a key graduate attribute for employability. As a result, higher education institutions are striving to help students foster these skills through authentic learning scenarios. Although face-to-face (f2f) group tasks are common in most classrooms, it is challenging to collect evidence about the group processes. As a result, to date, it is difficult to assess group tasks in ways other than through teachers' direct observations and students' self-reports, or by measuring the quality of their final product. However, there are other critical aspects of group-work that students need to receive feedback on, for example, interaction dynamics or the collaboration processes. This paper explores the potential of using interactive surfaces and sensors to track key indicators of group-work, to provide automated feedback about *epistemic* and *social* aspects. We conducted a pilot study in an authentic classroom, in the context of database design. The contributions of this paper are: 1) the operationalisation of the DBCollab tool as a means for supporting group database design and collecting multimodal traces of the activity using interactive surfaces and sensors; and 2) empirical evidence that points at the potential of presenting these traces to group members in order to provoke *immediate* and *post-hoc* productive reflection about their activity.

**Keywords:** automated feedback; collaboration analytics; interactive surfaces; multimodal; f2f

## 1. Introduction

Collaborating effectively and knowing how to be a team player have been acknowledged as critical 21st century skills that professionals are required to develop for the future workforce (Bellanca, 2011). Thus, education providers are strongly encouraged to support the improvement of these professional skills. Although there are a wide variety of uses of the terms teamwork and collaboration (presenting quite differentiated characteristics in terms of leadership, roles, shared goals etc. Campbell (2011)), in this paper we focus on those situations where small groups of people need to interact face-to-face to establish common ground in order to complete a specific common task (Dillenbourg, 1999). Indeed, face-to-face (f2f), collocated collaboration activities are not uncommon in regular classrooms and teachers often try to design tasks to nurture skills that can help students learn how to perform effectively in both teamwork and collaborative situations (Guiller et al., 2008). However, teachers often find it difficult to assess and provide effective feedback on group work (Strijbos, 2011). This is partly because it is hard to collect evidence about what happened during the collaborative activity which can serve as a basis to formulate feedback or to support reflection. As a result, teachers commonly provide feedback in regards of the final outputs of the collaborative activity (e.g. final marks, comments, incorrect responses) or based on the limited observations they can make whilst the activity unfolded. This sometimes discourages teachers from considering group tasks as a core component of the assessment and students from being fond of group-based tasks (Pfaff & Huddleston, 2003).

Most of the efforts to automatically capture group's interactions, with the purpose of providing support and/or feedback, have been developed for distributed or online contexts (e.g. forums, chats, blogs, social networks) (Jeong & Hmelo-Silver, 2010). Some exceptional works have explored the use of interactive surfaces and sensors to capture the complexity of collocated collaboration (see review in Martinez-Maldonado et al., 2016). Authors of these systems have suggested that providing teachers and students with automatically captured evidence about their group dynamics may predict group performance (e.g. Olguin et al., 2009) and support reflection and regulation (e.g. Bachour et al., 2010).

However, these studies have been limited to investigate the provision of feedback only on social aspects of collaboration, lacking information on epistemic aspects.

This paper explores the potential of interactive surfaces and sensing technologies to both support collocated collaboration and provide automated feedback. Feedback in the form of automated assessment and visualisations is provided just after group members complete their task. The aim of this is to provoke group reflection on epistemic and social dimensions of collaboration. We investigate the potential of presenting these analytics of group activity to group members through a pilot study conducted under authentic classroom conditions in the context of collaborative design of databases. For this, we deployed the DBCollab tool, a multi-display environment based on multiple tablet devices connected to an interactive tabletop (see Figure 1, left) that facilitates the collaborative design of Entity-Relationship diagrams. The system also features multimodal sensors (i.e. kinect depth sensor camera and microphone array) that capture group and individual traces of activity. The system provides an interactive dashboard that contains a set of visualisations automatically generated which are presented to learners just after completing their task (see Figure 1, right). In short, the contributions of this paper are: 1) the operationalisation of the DBCollab tool as a means for supporting group database design and for collecting traces of the collaborative activity using interactive surfaces and multimodal sensors; and 2) empirical evidence that points at the potential of presenting these traces to group members in order to provoke *immediate* and *delayed* reflection about their activity.

The rest of the paper is structured as follows. Section 2 presents theoretical foundations of feedback and discusses current work focused on the provision of feedback to collocated groups. Section 3 describes the learning context of this work and the implementation of DBCollab. Section 4 presents the pilot study conducted under authentic classroom conditions. Section 5 presents results and discusses the potential of our toolset to generate the analytics means for provoking reflection through automated feedback. The paper finalises with conclusions and a brief discussion of future work in Section 6.

Figure 1. The DBCollab tool. *Left:* three learners interacting at the multi-display, multi-touch environment that facilitates the collaborative design of database diagrams. *Right:* a set of visualisations automatically presented to groups just after completing their task.

## 2. Background

### 2.1 Foundations of Feedback for Supporting Collocated Groups

*Feedback* can be broadly defined as any type of information provided by teachers, peers or external agents intended to improve students' performance (Boud & Molloy, 2013). *High quality feedback* should include information about: intended *goals*, current student's *performance*, and guidance for developing strategies to close the gap between these two (Sadler, 1989). Feedback has been demonstrated to have positive effects on learning when it is given *effectively* (i.e. avoiding criticism or negative and personal comments, understandable, specific and selective, balanced) (Nicol, 2010) and *timely* (immediate or delayed) (Hattie & Timperley, 2007). Reflecting on the feedback provides students with the opportunity to make adjustments for subsequent performance (Boud et al., 2013) .

Effective provision of feedback should answer the following questions: *what* is going to be informed? *to whom* the feedback is intended? *When* and *why* it should be presented, and *how* this information should be provided? (Hattie et al., 2007). In terms of group work, feedback can be related to *epistemic* aspects (e.g. grade, correct/incorrect answers, comments) or *social* aspects (e.g. participation, contribution, social interactions) (*what*) (Carvalho & Goodyear, 2014) and can be delivered through verbal, written, visual, audio or video information (*how*) (Boud et al., 2013). In terms of temporality (*when*), groups and/or individuals (*to whom*) expect to receive feedback from their peers, the teacher or any other agent/system during their task (real-time feedback), just after completing the activity (immediate feedback) or in the subsequent hours/days after the collaboration experience (post-hoc feedback). Finally, groups are expected to reflect upon strategies and performance for the next group-work activity (*why*) (London & Sessa, 2006).

Our work is grounded on these foundational principles to explore the provision of feedback for reflection about epistemic aspects (the task process, goal, outcomes), and social aspects (interaction process, and individual and group outcomes). Visual analytics about social and epistemic aspects of the group activity are automatically generated to provide feedback to group members *immediately after* the group have completed their work, and for *post-hoc reflection* days after the activity finalised.

### *2.2 Providing Feedback to Collocated Groups*

Most automated feedback systems for both individual and collaborative learning have been based on computer-mediated systems where all the group interactions are mediated and easily recorded by the support system (Pardo et al., 2017). Whilst this is suitable for non-collocated collaborative situations, these solutions do not provide support for those situations where face-to-face interaction is important. A critical challenge for providing automated feedback in collocated group-work environments is the capture of evidence for generating the feedback. Several technologies (i.e. array microphones, depth cameras, tabletops, wearables sensors) have been used to capture interaction data from collocated environments to analyse activity and mirror information back to collaborators. For example, research work conducted by DiMicco et al. (2007) and Bachour et al. (2010) was based on automatically capturing sound using microphone arrays to reveal speaker participation patterns in face-to-face discussions. In these cases, visualisations, such as bar charts, timelines, bouncing balls, were displayed during the discussion aimed at provoking changes on behaviour. Other work has utilised depth cameras to analyse social dynamics in a group brainstorming activity by estimating the attention of participants using a head tracking algorithm (Schiavo et al., 2014). Overt and subtle directives were displayed during the group activity to each participant to promote balanced participation. This and the previous examples have explored the impact of showing minimalistic feedback in real-time to group members with varied results. These include reports on the possible negative effects of making explicit traces of activity to underperformers resulting in undermining their participations even further.

Substantial work exploiting traces from tabletops has been presented in past years. Evans et al. (2016) automatically modelled social regulation processes occurring in a tabletop during user-centred design activities. Although, this work demonstrated that pattern analysis from touches interaction can reveal the quality of collaboration processes, this information was not presented in any form as a student facing interface. By contrast, the work presented by Martinez-Maldonado et al. (2011) explored the analysis of tabletop traces by integrating a microphone array and a depth camera to discover patterns from the multimodal data. Authors explored the impact of generating visualisations in real-time and showing these to the teacher to orchestrate multiple groups collaborating simultaneously (Martinez-Maldonado et al., 2015).

Our work builds on previous research by making visible some traces of groups activity to students themselves, which has not been deeply explored in previous work. Using similar technology to the one developed by Martinez-Maldonado et al. (2011) to capture traces of verbal and touch activity, our study attempts to explore the feasibility and potential of providing automated feedback on social and epistemic aspects of the group-work activity. In addition, contrary to the studies exposed above, where feedback information was presented during (in real-time) the activity, our study explores the provision of feedback when groups just has finished (immediately after) the activity and, after a while (post-hoc) the activity was performed, with the purpose of aiding reflective discussion and writing.

## 3. Design and Apparatus

We developed DBCollab, a tool for supporting collaborative database design and reflection about social and epistemic aspects of collaboration through the provision of automated feedback. The next subsections describe the design and implementation of our toolset.

### *3.1 Design Features of the Learning Environment*

The design of the DBCollab tool is based on previous work that focused on defining a set of design features for a multi-touch tabletop system to support argumentation (Falcones et al., 2016) and database design (Wong-Villacres et al., 2015). As a result, we designed DBCollab to support the following features: a) Structuring the task in sub-tasks; b) providing clue-based instructions; c) providing a shared view and highlighting individual contributions and; d) providing a collaborative puzzle-like interface (for more details see Falcones et al., 2016).

### *3.2 The DBCollab tool and the Sensing Technology*

The DBCollab tool was implemented using a) interactive surfaces (a tabletop and tablet devices) and b) sensors (a depth camera and a microphone array).

**Interactive Surfaces.** ***Shared interactive tabletop:*** A 60-inch Ideum tabletop (see Figure 2, IS1) was used to support simultaneous users' input by touching on the elements displayed at the interface. All actions were automatically logged. ***Individual tablet devices***: Each student is provided with a tablet device (see Figure 2, IS2). Through this personal device, they can add new cards by sending them to the shared view at the tabletop; and ask for, read, and share clues.

**Sensors.** ***Identification of the speaker:*** The microphone array built in a *Microsoft Kinect sensor* – V.2 is used to identify and record what student is speaking around the tabletop (Figure 1 - S2). The speech and estimated speaking time by each student are automatically recorded. ***Differentiation of users' touch:*** As the tabletop does not differentiate the user touching the interface, a *Microsoft Kinect sensor* -V.1 tracks student's hands regarding their position around the tabletop, identifying who touches the table (Martinez-Maldonado et al., 2011).


Figure 2. Interactive surfaces and sensors used for the implementation of the DBCollab tool.

### *3.3 User Interface Implementation*

DBCollab allows the collaborative co-creation of database designs (diagrammatic entity-relationship schema) for up to three students. The software of the DBCollab tool is composed of three applications: a) the tablet interface; b) the tabletop interface (Figure 3); and c) the dashboard application (Figure 4). The tablet application lets individual members to create, edit cards and send them to the tabletop application through a server. The tabletop application allows students to move, link cards and identify group member’s actions. All elements created by a student are shown with a different colour (yellow, blue and red). In addition, the tabletop application is connected with a teacher’s application to obtain configuration information and to setup the task. Figure 3 depicts some of the features explained in the previous section. For stage I we can see a snapshot of the tablet device used by group member 1 (red) (see Figure 3, left). She is highlighting words that she considers important from the short description of the case study. During stage III she can ask for a ‘clue’ from three existing clues for this case study (see green button). She can also share the selected clue with group members 2 and 3 (blue and yellow) by tapping on the gray button *Share clue*. Figure 3 (right) shows the tabletop user interface for a group working in stage III. Group members can create and link cards, corresponding to entities and attributes in their data schema. Each card is identified with the group member’s colour.

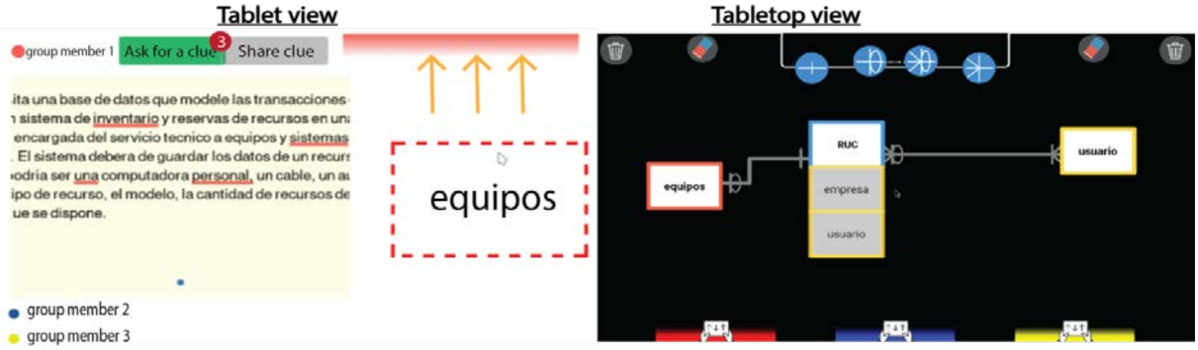


Figure 3. The DBCollab design tools. Left: the tablet interfaces used in stage I. Right: the tabletop interface mainly used in stage III.

After the design activity, the dashboard application generates both, the epistemic visual analytics elements (see A, B, C, D, E in Figure 4) and the social visual analytics elements ( see F, G, H, I elements from Figure 4) of collaboration. Next, we describe each of these feedback elements.

**A. Teacher’s Solution:** This element shows information obtained from the ideal solution proposed by the teacher, with the purpose of informing groups about the expected goal to be achieved.

**B. Group’s Solution:** This element shows the outcome of the group. In this way, students can compare both, the teacher’s and group’s solutions. This information is aimed at encouraging dialogue between teacher and group members to discuss discrepancies.

**C. Replay:** This feature of the interface allows students to replay the partial design solutions from the beginning to the end of the activity. This feature is aimed at supporting awareness about the epistemic process (e.g. showing how the group approached the task and build their final design, step by step). With this information, group members can reflect on how they were going and if the used strategy was useful to achieve the expected goal.

**D. Automatically Generated Grade:** This information was calculated from the degree of similarity between the teacher’s (A) and the group’s solution (B). Providing this information to the group can potentially help them to explicitly evaluate their outcome according to teacher’s expected goal.

**E. Correct and incorrect Entities and Relationships:** Also, by comparing both solutions (A) and (B), we presented correct and incorrect entities and relationships in a detailed list. With this information, group members can reflect on possible misconceptions and mistakes.

**F. Entities/Relationships and group touch’s actions: (Related to F1, F2 and F3)** This information was obtained from touch inputs by counting each time a group member added database elements i.e. attributes and relationships (F1- left, F2) and, counting each time a group member performed a touch action over an element i.e. create, delete and edit (F1-right, F3). Showing this information to the group could provoke reflection about participation at an individual level in the context of other group member’s actions.

**G. Overall Touch and Speech Participation:** Overall participation was obtained from speech and touch inputs, mapped onto a timeline (accumulated participations vs. seconds). Ideally, showing this information to groups can provoke reflection about periods of high and low interaction. Also, this information can be used to help group members reflect on group interactions and how they should improve participation for a further activity.

From Dillenbourg's (1999) perspective about collaborative learning and the activity-centred analytic framework (Carvalho et al., 2014), Table 1 summarises the type of feedback offered by our dashboard regarding the epistemic and social aspects of collaboration. The expected goal in terms of social aspects of collaboration was not made explicit in the dashboard but it was implicitly stated by the teacher that all group members should equally contribute to the collaborative activity.

Table 1: Type of feedback related to the aspects of collaboration.

| | **Aspects of Collaboration** | |
|---|---|---|
| | Epistemic | Social |
| Goal | **A** | **Implicit** |
| Process | **C** | **G** |
| Outcome | **B, D, E** | **F1, F2, F3, H** |

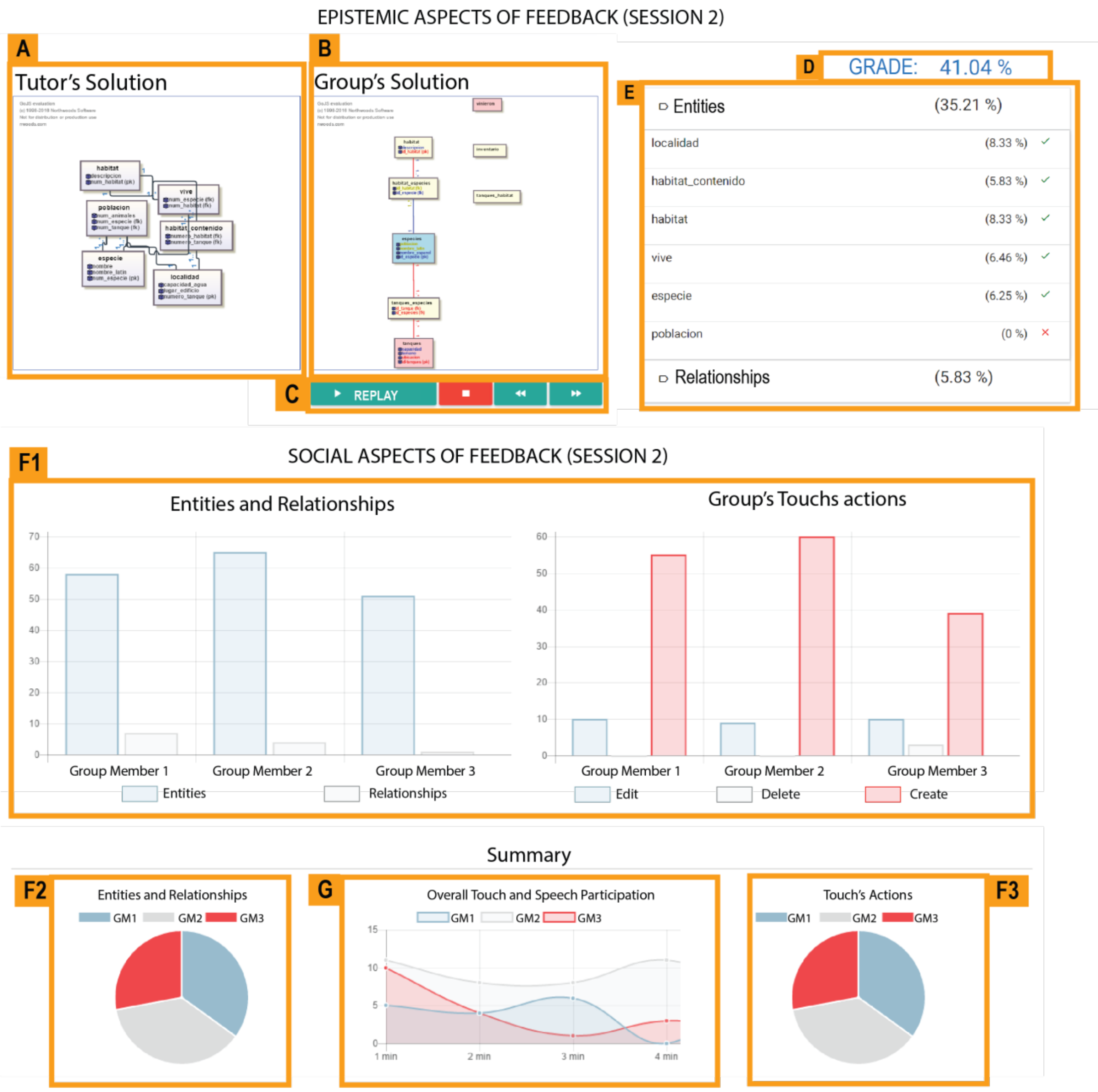

Figure 4. The DBCollab feedback tool. Information generated automatically from student's interactions, grouped into epistemic and social aspects.

## 4. Pilot Study

Fifteen undergraduate participants, ranging from 21 to 26 years old, enrolled in an introductory Database Systems subject, were asked to use the DBCollab tool during their regular classes. Participants were organised in triads. The teacher, who was part of the research team (first author of this paper), set two sessions (Sessions 1 and 2) to use the DBCollab tool with students and for the research team to gather evidence about their reactions after receiving automated feedback. Students were asked to sign an informed consent form explaining that all the collected data would be used for research purposes and that no personal information will be shared or used for formal assessment. The duration of each classroom session was two and a half hours. One DBCollab system was used; thus, groups were allocated 30-minutes time slots to perform the design activity. The purpose of the session 1 was to let students to familiarise themselves with the tool, so no automated feedback was provided in Session 1. In Session 2, automatically generated feedback was provided to the groups. The focus of this paper is Session 2, in which groups performed the following:

1. ***Collaborative design activity (20 min):*** each group was asked to solve the same database design problem using DBCollab. At the end, they presented a final design of the database to the teacher.
2. ***Feedback (5 min):*** each group was asked to navigate through the dashboard and explore all generated feedback.
3. ***Short interview (3-5 min):*** a researcher asked students, questions related to the automated feedback. Some of the questions were: Why do you think you got that grade for the final design? Do you think this feedback could help you to reflect on the group-work? Do you think this feedback is useful to help you to reflect on the activity performed?
4. ***Questionnaire about perceptions of the feedback:*** Each participant filled out a Likert-scale questionnaire with six questions: Q1) potential of feedback for both aspects; Q2) usefulness of feedback for both aspects; Q3) usefulness of feedback about social aspects; Q4) usefulness of feedback about epistemic aspects; Q5) usefulness of epistemic process feedback; and Q6) validity of the automated grade.
5. ***Writing reflection (post-hoc activity):*** Three days after the classroom collaborative design activity, each student received all feedback results by email and each group member was asked to write a reflective text about the collaborative activity, first as an individual reflection and then a shared group reflection.

## 5. Results and Discussion

This section presents the analysis of student's perceptions and reflections about DBCollab. As an initial exploration, we wanted to understand the overall perceptions of students to the tool (questionnaire responses). Then, we present a qualitative analysis of the reflective comments externalised by students during the short interview and the post-hoc reflective writing task.

### *5.1 Questionnaire Responses: Perception, Validity and Potential of the Feedback Provided*

Figure 5 shows the overview of students' responses to the questionnaire. Our dashboard was seen by most students (71.43%) as an effective support tool to provoke reflection (Q1). Regarding the usefulness of the dashboard for reflection on social aspects of collaboration (Figure 4, F, G elements), 64.28% of students completely agreed with this question (Q2). This may be explained by the fact that no explicit intended goal on social aspects was shown in the dashboard (see Table 1). As students were used to compare their current performance with something more explicit, such as a mark or score, they may have expected to see an indicator of what a good performance in collaboration was. Moreover, 50% of students found our dashboard useful when showing epistemic and social aspects of collaboration (Q3). Again, this overall perception from students could be diminished by the lack of assessment about the social aspects of collaboration.

In addition, 64.28% of the students completed agreed that feedback about epistemic aspects of the collaborative activity (see Figure 4, A, B, C, D, E elements) was useful for reflection (Q4). Nonetheless, a small group of students (7.14%), disagreed with this. When analysing comments about the tool, students stated that the grade needs to be improved, which lead us to the result of the last question (Q6). When exploring the perception of usefulness about the task replay (Figure 4, element C) in the dashboard, only half of the students perceived this feature as useful for provoking reflection (Q5). Students seemed to be more engaged with information presented as summaries (Boud et al., 2013). Finally, regarding the validity of the automated grade and correct and incorrect responses (Figure 4, element D, E), students had lower credibility for the automated generation of this information, for which only 14.29% agreed. This perception could negatively impact the usefulness of epistemic aspects (Q4). Students expressed that the grade should be improved according to the teacher's solution. More flexibility and less ambiguity should be considered when analysing the similarities of both solutions. This result is related to a recent concern about "*algorithmic accountability*" (Diakopoulos, 2015), indicating that we need to ensure that algorithms we use should be accountable rather than appearing as *black boxes* to students.

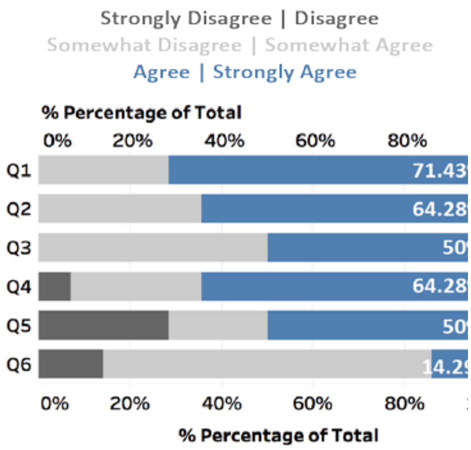


Figure 5. Results from student's questionnaire.

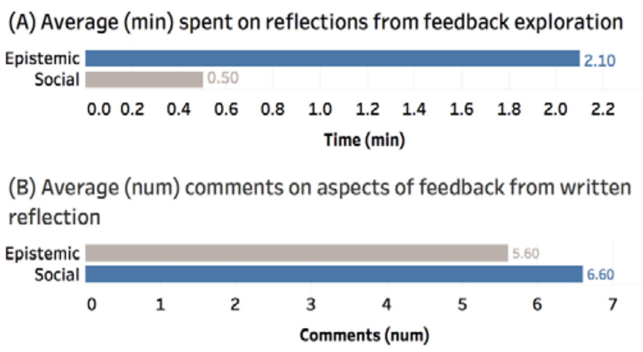


Figure 6. (A) Time spent and (B) comments from reflections about feedback.

### *5.2 Qualitative Analysis of Student Reflections*

Although the questionnaire responses provide an overview of the perception of students, we explored more deeply the student's thoughts and reflections from the feedback provided.

***First***, by analysing the reactions of students when they interacted with the dashboard and the short interviews we gathered some evidence that points at the potential of supporting student reflection by providing timely, automatically generated indicators of epistemic and social aspects of the activity. For this analysis, we tagged the time that every group spent on reflecting about a specific epistemic or social dashboard element. Figure 6 (A) depicts the average time groups spent (min) for both, social and epistemic aspects. For the epistemic feedback, all groups dedicated a significant amount of time to compare their solution (element A) with the teacher's solution (element B), with the purpose of analysing possible misconceptions about learning performance. All groups, at some point tried to explain why the teacher's solution had a database design element and why they forgot to add it to their final solution. For example, in the interviews, some of the students expressed this as follows: *"What is the meaning of this [pointing to a part of the teacher's solution]? Oh, I see, that is part of the solution we missed"*. Moreover, most students did not reflect deeper on the grade (element D). Some students indicated that the level of detail of the explanation provided in the dashboard is still not sufficient to understand. One student expressed this as follows: *"I think there is more detail here [pointing into both, group and teacher's solution - A and B elements] rather than here [correct and incorrect entities and relationships- E element]"*. In addition, not all the groups (3 out of 5) spent time to explore the replay option (element C). This could explain its low-rating of usefulness in the questionnaire (Q5).

Regarding the social aspects of the feedback, although groups were positive about the importance of showing this type of feedback, they were less concerned with reflecting about it in responses to question Q2. An explanation of this behaviour could be that the epistemic feedback is presented on the first screen, and to explore the social feedback, students had to remember to click a button and then the second screen is presented. Nonetheless, students suggested that the "touch's actions" helped them to compare their individual actions with those of other group members. This was described by one student as follows: *"Look at this! You [pointing to a specific portion of the touch's actions - element F3] took almost the half part of the pie chart! That is because you don't let the others participate"*. Also, groups made interesting reflections based on the overall touch and speech participation (element G) by identifying moments where they all were engaged with the activity. For example, one student said *"My highest participation point was in the first two minutes. Here [pointing to a part of the timeline visualisation] is where the group had more participation"*. Some students could also identify when they started to act as leaders. One of these students described this as follows: "… *over the time I started to give directions to my peers and then I verified if everything was ok*". A student referred to the timeline to emphasise when another peer was not engaged with the task. For example, one student said: "*[name of one peer], where is he [pointing to the timeline]? Look, he is gone"*. Finally, some students mentioned that the detailed participation per group member (element F) helped them to compare one with another peer's contribution to the solution.

***Second***, we analysed the written reflection (the post-hoc activity) by counting comments about epistemic and social aspects of the performed activity. Figure 6 (B) presents the average number of comments for both aspects. For this reflection activity, the numbers of social and epistemic written comments were much more balanced compared to Figure 6 (A). Regarding the epistemic aspects of the feedback, students commented on their performance with respect to the teacher's solution. A couple of students expressed this as follows: *"we got closer to the teacher's solution"* and *"our performance was bad, we had a lot of errors that were revised from the teacher's solution"*. Students also proposed strategies to improve their performance by means of knowledge preparation. For example, two students stated the following: *"I should have reviewed the concepts before coming to the class" and "next time, we should come more prepared to classes so we do not spend too much time thinking"*.

Social feedback elements helped students to reflect on their participation as individuals and as a group. Some students explained this as follows: *"my contributions helped the group to identify most of the elements for the final solution"* and *"overall, the group's contribution was balanced which helped us in reaching a good solution"*. Students also identified strategies for further improvement of group performance, such as their *"need for better organisation"* and a more "*equal distribution of specific tasks to solve the problems and give voice to all participants"*. In short, the reflective writing activity may have offered more time to recall and reflect more deeply about things that happened, not only in the epistemic domain, but also in the social domain (unlike what was observed immediately after feedback was provided, where students focused on the epistemic aspects of the task).

## 6. Conclusions and Future Work

This work presented our DBCollab tool aimed at capturing collaborative activities from interactive surfaces and sensors. Our tool can generate automated feedback from multimodal data traces, which is presented to groups just after the activity and for post-hoc analysis. We validated the provision of social and epistemic feedback for provoking reflection through the exploration of the tool in a partially authentic classroom scenario. When students explored the feedback *immediately after* the activity, they seemed more inclined to reflect on their task performance in comparison with the intended performance (e.g. what the teacher expected from them). By contrast, when students were provided with more time to reflect on the group and task performance (*post-hoc reflection*), a more egalitarian reflection was noticed. They suggested strategies for improving both social and epistemic aspects of the task. This paper should be seen as a first effort in a series of studies to realise the vision of supporting face-to-face collaborative activities by generating student-facing multimodal analytics interfaces that provoke immediate and post-hoc productive reflection.

Future work is directed towards two key strategies. Firstly, in this study, the formal grading was focused on the quality of the data schema design. Future work will better align the assessment criteria with the analytics, so that it is clear to students how the feedback in the dashboards connects to their primary concern (higher grades). Secondly, we will prototype enhancements to the visualisations designed to make the feedback more intelligible, and actionable, by highlighting key areas for attention.

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