

# An Exploratory Evaluation of a Collaboration Feedback Report

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## ABSTRACT

Providing formative feedback to foster collaboration and improve students' practice has been an emerging topic in CSCL and LA research communities. However, this pedagogical practice could be unrealistic in authentic classrooms, as observing and annotating improvements for every student and group exceeds the teacher's capabilities. In the research area of group work and collaborative learning, current learning analytics solutions have reported accurate computational models to understand collaboration processes, yet evaluating formative collaboration feedback, where the final user is the student, is an under-explored research area. This paper reports an exploratory evaluation to understand the effects a collaboration feedback report through an authentic study conducted in regular classes. Fifty students from a Computer Science undergraduate program participated in the study. We followed a user-centered design approach to define six collaboration aspects that are relevant to students. These aspects were part of initial prototypes for the feedback report. From the exploratory intervention, we did not find effects between students who received the feedback (experimental condition) report and those who did not (control condition). Finally, this paper discusses design implications for further feedback report designs and interventions.

## CCS CONCEPTS

• **Human-centered computing** → *Human computer interaction (HCI)*; • **Applied computing** → **Collaborative learning**.

## KEYWORDS

collaboration analytics, collaboration feedback report, human-centered design

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## 1 INTRODUCTION

Learning to collaborate requires practice [1]. Due to the importance of collaboration in today's workplace [4], higher institutions are increasingly including collaboration opportunities inside and outside the classroom. Students can experience first-hand what is to analyze, solve complex problems, and construct new knowledge with others. Despite this frequent exposure to collaborative activities, the collaboration skills of higher-education students tend to remain low even after obtaining their professional degree [19]. This disconnection between increased exposure and low performance levels could be pedagogically explained by the *lack of formative feedback*.

Specifically, developing collaboration skills requires deliberate practice [7]; that is, carefully designed practice sessions where motivated students learn a specific aspect of a skill. During such deliberate practice, students' performance and behavior is observed and measured to enable immediate formative feedback. These activities are repeated until the student reaches a desired level of performance. Then, they advance to a new, more challenging practice task. Deliberate practice has been proved successful for the development of physical and cognitive skills ranged from running, chess, interprofessional communication, and even insurance sales [17]. Providing the individual, immediate formative feedback that deliberate practice needs, however, is extremely onerous for teachers, especially for teachers whose direct objective is not to teach collaboration. Such an absence of adequate feedback hinders the development of collaboration skills [7], even for students who are highly motivate and experience an increase in regular practice.

Learning analytics (LA) can provide a techno-pedagogical solution to this problem by guiding the capture and measurement of students' collaborative actions to later provide the needed feedback. Designing, implementing, and evaluating a solution to provide timely analytic formative feedback about collaboration skills is in the purview of learning analytics research. Praharaj et al.'s recent survey of automated analysis for collaboration [14] describes how existing efforts have extracted indicators from different low-level data that can generate an understanding of both observable and hidden patterns of social dynamics (e.g., coordination), learning [15], and productive problem-solving [12]. The CSCL and LA communities have also reported the evaluation of mirroring dashboards

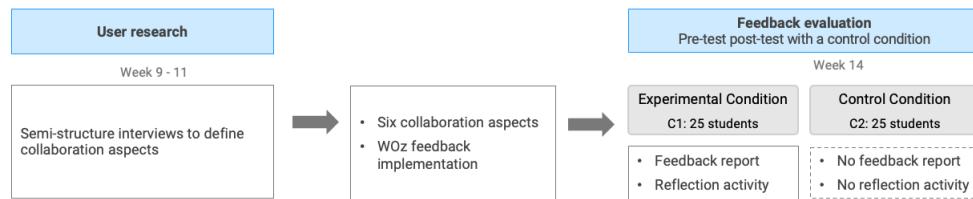


Figure 1: Study design for defining collaboration aspects and exploring feedback

displaying group data indicators such as participation rates, interaction with peers, contribution to the activity, and symmetry [9, 18].

These efforts have been informed by data describing the group work process and performance actions and grounded in collaborative learning literature and theory. However, the reports they generate are generally disconnected from how students construct and navigate higher-level collaboration aspects (e.g., communication, coordination, mutual understanding). In fact, existing designs of feedback reports for students have not factored in students' situated practices, struggles, and perspectives. We argue that, if the aim is to provide feedback to students, the aspects a report displays need to speak to students, their experiences, priorities, and values [10] so that their interpretation of the data and analytics can actually pave the way towards a positive change.

The LA community has progressively turned towards human-centered methodologies for improving the adoption and the effective use of teaching and learning tools in practice [2]. The intent is to design feedback tools with and for users by exploring users' needs and desires and align these through the development cycle [9, 10]. As suggested by Martinez-Maldonado and colleagues [10], *collaboration analytics*—user interfaces that communicate actionable insights for improving collaboration—require the integration of theory, pedagogical interventions that generate data and analytics, and a human-centered design approach that empowers stakeholders to shape and build user interfaces. Few studies have begun to adopt this view. Echeverria [5] reported a three-step approach to explore teachers' and students' needs and desires for designing and developing a reflection tool in the context of teamwork nursing education. As a result, she mapped teamwork aspects to observable behaviors and analytics that can communicate meaningful insights [6]. Worsley and colleagues [20] derived seven collaboration aspects from students' answers to open-ended questionnaires and used these aspects to design a collaboration analytics prototype that provides feedback to students.

Grounded on observations of students' group work, interviews with students this paper extends current work by presenting a human-centered understanding of the collaboration aspects that make sense to students. Further, it follows current LA reporting trends to explore a possible use of these student-informed aspects in the design of a feedback report. As such, it contributes design implications for further work in collaboration analytics for end-user interfaces.

## 2 STUDY DESIGN

The design, implementation, and evaluation of a collaboration feedback report is illustrated through an authentic study conducted during regular classes of an undergraduate Database Systems (DBS) course from the Computer Science program in a South American university. Two sections (C1 and C2) from the DBS course taught during the first term of 2021 (18 weeks long) were part of this study. Fifty students (25 in each class) attended class sessions regularly. Each class was organized in groups of 2-4 students (9 groups in C1 and 8 groups in C2). Due to the COVID pandemic, classes were taught remotely. Before group activities, the teacher asked each group to record their participation and submit the recording as evidence of their work. All group work sessions were recorded with students' consent.

This study consisted of a user research and a feedback report design and evaluation stage (see Figure 1). The aim of the **user research stage** was to understand collaboration aspects according to students' perspectives. During weeks 9 to 11, students from both classes (C1 and C2) and from different courses in the same undergraduate CS program were invited to participate in a 45-min interview session. Members of the research team sent out emails to their students and research assistants, asking them to participate in the study.

The **feedback report design and evaluation stage** proposed a feedback report including the collaboration aspects identified in the first stage. The aim of this stage was to explore the report's effects on students' collaboration aspects. We designed a pre-test post-test intervention with a control condition. The intervention included two data collection sessions (1: week 4 and 2: week 15) and a control condition. Only the experimental condition received the feedback report. During session 1, students worked together to propose a solution for a database entity-relationship model (avg time: 35.24 mins). We chose video recordings from week 4 because of data availability, as 6 out of 9 groups submitted the video recordings as evidence of their collaboration. Video recordings from 12 groups (C1: 6 videos; C2: 6 videos) were obtained from this session. During week 14, six groups in the experimental condition (C1) received a feedback report generated with their own data from session 1. Afterwards, students submitted a reflection (Likert-scale and open-ended questions) on the assessment of the feedback report. During session 2, students worked together to deliver a solution for implementing several database queries (avg time: 68.25 mins). We chose week 15 due to student availability as it was the last group work activity of the semester. Video recordings from 12 groups (C1: 6 videos; C2: 6 videos) were obtained from this session. In the

next sections, we present the feedback report design, evaluation analyses, and results in detail.

### 3 STAGE 1: USER RESEARCH

#### 3.1 Data Collection and Analysis

To pursue a situated, human-centered approach for learning analytics of collaboration—as recommended in [2, 9, 10], we engaged 16 students (2 females, avg. age: 21.87 years, s.d. age: 3.18 years) in 45-min interview sessions. Interview protocols were designed based on the research team’s observations of video-recordings from session 1 and sought to elicit students’ reflections on their expectations, strengths, and weaknesses when collaborating. The protocol entailed engaging students in discussions about four short videos of different collaboration examples: two generic cases, and two excerpts from session 1 video-recordings showing their peers collaborating in a database problem solving activity. In discussing these videos, students identified and described the aspects they see as essential for effective collaboration.

The data was collected in the form of notes, video and audio recordings, which we transcribed. To relate students’ perspectives with existing theoretical work on collaboration, we first performed a deductive data analysis. In a Miro board, we added the collaboration aspects reported by various scholars, including [8] [20] [11] and the data excerpts where participants mentioned their expectations and concerns when working in groups (e.g., ‘communication’, ‘respect’, ‘empathy’, ‘persuasion’, ‘trust’, and ‘commitment’). Then, we iteratively grouped participants’ criteria with the theorized ones and named the resulting groups with terms that represented both perspectives. The six resulting groups represented student-identified collaboration aspects. To further unpack students’ construction of those aspects, we conducted an inductive analysis of the data under each group. We first coded the data with short phrases summarizing student’s actions when engaging in collaborative work. A second analysis of these codes then produced emerging themes representing the collaboration strategies that students value and the tensions they face when collaborating with others.

#### 3.2 Findings: A Student-Centered Perspective on Effective Collaboration

Our data analysis unearthed six aspects describing students’ expectations for an effective collaborative experience: coordination, communication, disagreement or problem management, mutual support, work environment, and commitment. We now present them by highlighting how they relate to each other, the particular strategies they demand students to master, and the various factors that often deter from their successful attainment.

**3.2.1 Coordination.** Coordinating group work was one of the aspects that most participants (13 out of 16) frequently mentioned as critical for collaboration. P14’s comment suggest that, for students, successful coordination is highly related to time optimization: *“To make good progress, it is extremely important not only to produce good work, but that working times are optimal.”* To that end, participants’ view of coordination aligns with Meier’s: the set up of short-term agreements that distribute work equally to avoid collaborators’ waste of time [11].

For participants, effective group work coordination entails mastering strategies such as determining who will act as the leader, defining the time, frequency, and format of group meetings, and being a good information manager who can process—for their collaborators—the information that instructors provide. For many participants (8 out of 16), coordination also entails continuously checking their peer’s work to realize *“if something is not OK”*-P3 and allotting enough time before to make sure that *“everything is consistent across the document.”*-P7.

Applying these strategies, however, is not often possible, especially considering the constraints of their everyday academic and social context. For example, P7 commented on how collaborators’ willingness to coordinate group work is hard to predict, and thus, account for: *“Once in my first semester, my two partners disappeared and showed up five minutes before the presentation asking what to say.”* As P5 explains, demanding accountability from peers can also entail a struggle for students; it can be uncomfortable and force them to undertake an unwanted leadership role: *“you start to reflect on why you need to push others so hard. This should not be my work, it should be the groups’ work!”*

These accounts suggest that, when providing feedback on their coordination skills, it might be relevant to direct students to resources for managing their collaborator’s unexpected actions and responses.

**3.2.2 Communication.** Collaboration literature emphasizes communication skills as a key aspect for effective team work [8, 20] through which collaborators actively share good quality information about their group work activity [8]. Participants agreed with this view. However, many (11 out of 16) emphasized a desire for exchanging information that can enable the planning and execution of coordination activities such as indicating *“whether they can be there or not [in a meeting], if they have to work or have another problem.”*-P9.

Although participants shared a strong desire to attain good communication with their peers, few to none highlighted they would like to receive feedback on their communication skills. Instead, many stressed a desire to be able to freely issue feedback to their peers even when their opinion might be controversial: *“I’d like there to exist a place where we can all give our opinions but anonymously so that there is no controversy amongst group members.”* - P16. Participants also expressed wanting to improve how they motivate others, *“to know what words to use to motivate my partners to share with me what is going on without making them feel offended or denigrated.”* - P1.

Participants’ expectations for improving their communication skills suggest a key lesson for crafting a feedback report. Instead of reporting the number of times that participants talked during group work, it might be important to highlight the number of times they could have expressed their opinions a bit more or did not motivate others to speak.

**3.2.3 Disagreement or Problem Management.** Managing disagreements emerged from our analysis as a key collaboration-related situation where effective communication skills are much needed. However, in the case of disagreement management, the communication required mostly entails discussing the content required and produced during group work (e.g., conceptual doubts and next steps

in a team project). To that regard, participants' accounts suggest that it is critical for them to know how to *"take someone's opinion into account for now and consider someone else's opinion for next time"*-P8. That is, to know how to work with their peers for reaching consensus.

Our data analysis suggests, however, that cultural and operational factors can often hinder students' ability to reach the needed consensus. Students' interpretation of a disagreement as *"points of friction"*-P1 or *"problems"*-P8, for example, leads them to avoid facing disagreements. P3 explains further: *"pushing for my opinion could create division among us."* In terms of operational factors, P1's experience sheds light on students' frequent disappointment towards a lack of an outside figure they can go to when unable to reach consensus: *"sometimes there are researchers, and professors that do not even listen to your request, they just say - you and your group members need to figure it out on your own."*

Similarly to providing students' feedback on communication skills, feedback on disagreement management requires to advise students on how to engage in discussions that do not jeopardize the group's well-being. Further, this particular feedback might also need to provide instructors with guidance on how to act as conflict managers.

**3.2.4 Mutual Support.** Joo [8] explained how, during effective collaborative experiences, teammates help each other beyond their assigned tasks, especially when others are unable to fulfill their roles. Participants' accounts suggest that students also recognize mutual support as critical for collaboration but that providing such support demands hard-to-develop skills. For example, students need to be keen observers of knowledge differences and conceptual doubts amongst their peers. Further, as P1's experience suggest, they need to have a positive perspective about the act of helping peers out: *"I always try to see what others need or are doing because in that way I can help and I learn in the process myself."* Few participants (3 out of 16) mentioned having such skills and using them at some point.

P2's account provides insights into why mutual support can be hard for students: *"I do not have the patience to do it. There are concepts that we should all know, like a linked list, and even if I explain it to my partner they need more details and I go like 'hmm'."* The hectic nature of academic life and the competitive culture that dominates higher-education institutions might be critical factors hindering opportunities to help others out; students must decide on how much time they can invest in leveling up their peers without damaging their opportunities of finishing their work and getting the grade they want to. Feedback on mutual support might have to consider if providing support to peers might already go beyond the limits of what a student can do based on their timeline and academic goals.

**3.2.5 Work Environment.** Another aspect that participants commonly discussed as relevant is students' ability to promote what Worsley [20] defines as a good climate that can lead to a welcoming and respectful working environment. As mentioned before, one strategy that students leverage to maintain a respectful group work climate is to avoid conflicts. Additional strategies that emerged from our data analysis are to *"avoid too frequent meetings that could become exhausting for team members"* - P1, engaging in *"friendly talk with my group members instead of using a bossy tone"* - P12,

and trying to keep an optimistic perspective *"despite the problems that arise when some collaborators just disappear and one must do more work than expected"* - P10.

As P9's account highlights, however, these strategies are harder to mobilize when team members do not know each other: *"I do not like to speak up too much in a group where I don't know most people, it's uncomfortable."* Participants such as P14 explains that *"it is only after the second or third week of working together that trust starts to develop and we get to know what each other likes and how we tend to behave."* When providing feedback to students about their ability to ensure a welcoming working environment, thus, it might become critical to acknowledge the starting level of familiarity of team members and the progress they are making to that regard.

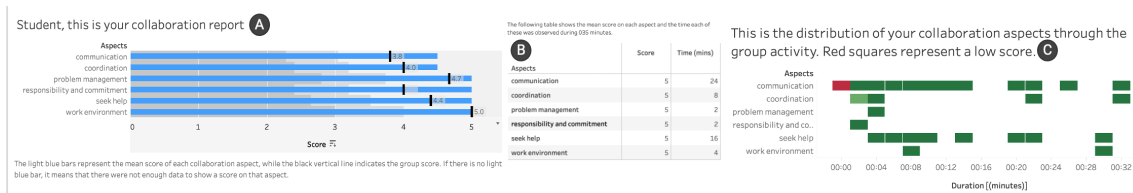
**3.2.6 Commitment.** An expectation that all team members show themselves committed to their group's success was another collaboration aspect that emerged from our data analysis. P10's account sheds light on participants view of what such commitment entails: *"it does not matter that much how good they are [at the subject at hand], what matters is that they are here, trying to do the best they can."* To that end, their view aligns with Joo's which describes how, in effective collaboration, participants make the best use of their ability to accomplish a group project [8]. The evidence that commitment is taking place entails seeing team members leveraging many of the strategies that were mentioned in previous sections: to communicate options and ideas as well as to share current barriers for participation. P6's comment highlights ownership of group's goals as an additional strategy that is particular to the enactment of commitment: *"I expect them to make the project their own, and not to act like it's only the responsibility of a few of us."*

Some participants shared, however, that the utilitarian thinking that higher-education often promotes makes full commitment a hard goal to attain. Students often make decisions about how much to commit to group work based on their perception of how relevant a class is for them: *"I have had experiences where my collaborators have clearly said to me that they are not willing to miss their sleep for that class."*-P7. Further, as P5 explains, successful group work is not really the end goal, grades and passing a class are: *"the students I have worked with often see projects as one more thing they have to do to pass, and so they are not willing to invest more into it. Instructors also tend to feed into that way of thinking."* Feedback on students' level of commitment might need to help students visualize the benefits of getting involved in group work beyond utilitarianism.

## 4 STAGE 2: FEEDBACK REPORT DESIGN AND EVALUATION

The user research stage helped to identify the collaboration aspects that students value and a series of nuances for using them in a student feedback report. However, for our report design, we decided to only include information that an automatized system could collect and process. Our goal was to explore the impact that such type of data—which current work in analytical reports and learning dashboards emphasizes [9, 16]—could have on collaboration learning.

To implement and evaluate the feedback report prototype, we followed a Wizard-of-Oz approach. While the reports were generated from a manual coding of session 1 videos, students thought the



**Figure 2: An example of the feedback report shared with students. It consisted of three parts: A) a bar chart, B) a table, and C) a timeline.**

report was generated by a computer. The coding process entailed two researchers identifying *instances of collaboration* in the two sets of videos we collected in session 1 and 2 according to the six aspects previously identified: (1) communication, (2) mutual support, (3) coordination, (4) work environment; (5) commitment, and (6) disagreement or problem management. Each video recording was divided into two-minute segments. First, the researchers watched the whole video to get the context of the different collaboration aspects. Then, they recognized one or several aspects exhibited per student and assigned a score ranging from 1 to 5 (1: very bad and 5: very good) per observed aspect in the time segment [3]. For example, a student showing a fair *coordination* in one session time segment would receive a coordination score of 3. A student showing a high coordination level would reach a coordination score of 5. No evidence of coordination would lead to an absence of a score. To ensure agreement, both researchers first watched and coded one random video to agree upon the observations and behaviors being categorized. Next, researchers coded another video separately (Cohen's kappa: 0.49) and then discussed disagreements, until reaching consensus (Cohen's kappa: 0.77). A total of 1194 collaboration instances were coded from data collection session 1 and 2, and the experimental (C1) and control (C2) conditions. While we adopted a manual coding, we foresee the automation of this step by using existing machine learning models (e.g., [14]).

Using the results of the coding process, we generated the reports for the experimental condition (C1) which included six groups (15 students). The feedback report consisted of (see Fig. 2): A) a bar graph representing the individual median score obtained on each collaboration aspect and a comparison of these values in relation to the group score (black line); B) a table summarizing the median score and the time (in minutes) observed on each aspect; and, C) a timeline showing the distribution of aspects and its score (identified by a color-scale) during the group work activity. The report was implemented using Tableau Software. As part of our human-centered design approach, once students received their reports, we asked them to answer a reflection activity comprised of one Likert-scale item (i.e., *Indicate the level of agreement regarding the information provided in the report*), and three open-ended questions (i.e., *Why did you agree or disagree with the information provided in the report? Do you think this information would help you to improve your collaboration skills? What additional information would you like to see?*). The goal was to further explore students' perspective on the report's usefulness and improvement opportunities.

## 4.1 Data Analysis

Our unit of analysis was the collaboration instances carried out by a participant within a two-minute period. A unit, thus, might have

associated a collaboration aspect and a score as described above. Given the nature of the experimental design (pre-test post-test with a control condition), per unit of analysis, we calculated: a score for each collaboration aspect and a summative collaboration score, both for session 1 and session 2.

We calculated the proportions of collaboration per aspect per experimental condition and ran a Chi-Square test to check for statistical differences of the observed proportions between the conditions per collaboration aspect. Next, we explored whether the feedback report had a differential impact on the scores (at the aspect and summative level) between the experimental conditions. These analyses were carried out using a one-way repeated measures Anova, being the dependent variable the collaboration scores—both at the aspect level and at the summative level—and the independent variable, the experimental condition. Not all the collaboration aspects met the requirements for using this statistical test. We report results only for the communication and mutual support aspects. The overall collaboration (summative level) was also analyzed using a repeated measures Anova.

To analyze students' **reflections**, we calculated the frequencies for the Likert scale item and examined the consistency between responses to open-ended questions and students' level of agreement to the feedback report. We also computed the time each student spent interacting with the report using a mouse tracking software (e.g., mouse overflow).

## 4.2 Results and Findings

**4.2.1 Collaboration aspects and effects on the feedback report.** Figure 3 shows the distribution of the collaboration aspects per condition. *Communication* clearly overpasses the other aspects, both for session 1 and 2. In the second and third place appear *Mutual support* and *Coordination*, respectively. The other aspects appear in lesser percentages. When analyzing the distribution per condition, there is no clear trend. It is however, very explicit that the percentages differ among aspects and conditions. Moreover, from the results from the Chi-square test, we found significant differences in the distribution among conditions ( $\chi^2(5) = 102.6p < 0.001$ .) Table 1 summarizes the descriptives related to the feedback report's impact on session 1 and 2's *overall collaboration*, *communication*, and, *mutual support* scores (within subjects effect). On the *overall collaboration* aspect, C1 had a higher number of instances (N=626) than C2 (N=563). Note that C1's mean was higher for session 2 than for session 1. A similar trend is observed for C2's mean.

As for *communication*, C1 reached higher means than C2 on both sessions. Finally, on the *mutual support* aspect, C1 showed a slightly higher value on session 2 compared to session 1. Furthermore, in session 2, C1 obtained a higher mean in comparison with C2. Note



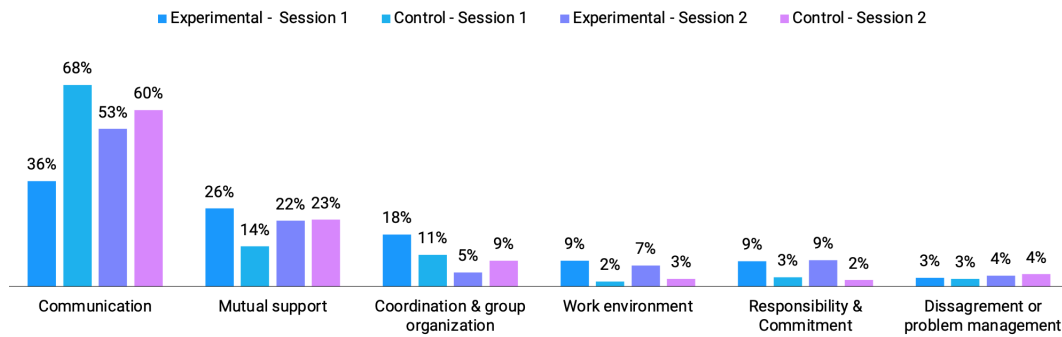


Figure 3: Distributions of aspects per condition and sessions (1 and 2)

Table 1: Descriptives of collaboration instances for overall collaboration, communication and mutual support aspects.

Aspect	Experimental Condition (C1)				Control Condition (C2)			
	Session 1		Session 2		Session 1		Session 2	
	Mean ± S.D.	N	Mean ± S.D.	N	Mean ± S.D.	N	Mean ± S.D.	N
Overall Collaboration	3.08 ± 4.81	626	4.46 ± 5.65	626	1.87 ± 2.68	563	3.49 ± 3.04	563
Communication	3.86 ± 1.31	111	4.11 ± 1.15	111	3.60 ± 1.27	101	3.74 ± 1.03	101
Mutual Support	4.14 ± 1.43	49	4.24 ± 1.20	49	4.29 ± 1.07	14	4.07 ± 1.50	14

the changes in N in the different aspects: instances in one category differ from the others because the number of instances also differ between session 1 and 2. Not all the students exhibited the same number of instances for each aspect in each session. In addition, we ran a repeated measures ANOVA among the conditions (*overall collaboration*:  $F(1, 1187)=0.50$ ;  $p=0.48$ ; *communication*:  $F(1,210)=0.31$ ;  $p=0.58$ ; *mutual support*:  $F(1,61)=0.32$ ;  $p=0.57$ ). Thus, the feedback report did not have any effect on students' overall collaboration or its aspects.

**4.2.2 Students' Reflections on the Feedback Report.** On average, students spent 11.35 mins. (S.D.: 7.99 mins) exploring the information presented in the report. Out of 15 students, 5 completely agreed; 8 agreed and 2 did not agree with the information presented in the feedback report. Students that agreed and completely agreed (13 out of 15) mentioned that most of the information in the report fulfilled their expectations. However, a small number (3 out of 15) complained that the report did not acknowledge activities outside of the video recording. Students' reflections were aligned with the aspects in which they got a lower score. Most of their comments were related to the internalization of the lack of communication (e.g., "I recognize I should communicate more with my partners" - S2, "I know I usually do not talk much during group activities" - S14). Comments from students with higher scores stressed the report's ability to render collaboration visible (e.g., "This report allowed me to observe the student's process within the group and the commitment to do the activity" - S4). Almost all students (except for one) agreed that the feedback report could help them to improve their collaboration. In terms of opportunities for improving the report, students comments highly aligned with the nuanced aspects of collaboration identified in the user research stage. Students asked for more information about interactions with other students, explanations of the scores, and recommendations for improvement. Some students also

asked for the report to show their improvement along time and set clear goals to attain. To that regard, it is key to consider delivering various reports along the academic term and not just once.

## 5 DESIGN IMPLICATIONS

As a step towards human-centered designed feedback reports for collaboration, this work makes two contribution to the field of LA. *First*, it reports on **six student-identified collaboration aspects**: 1) communication; 2) mutual support; 3) coordination; 4) work environment; 5) commitment, and 6) disagreement or problem management. Some of these are consistent with previous LA [20] and CSCL literature [11]. The use of these aspects could lead to better adopted and more impactful feedback reports. *Second*, we explore the use of these aspects in the design of a feedback report and the effects it can have on students' collaboration aspects. Our results show that, when using the identified collaboration aspects in a feedback report that follows existing LA reporting trends [9, 16], the resulting report has no effect in students' collaboration aspects. We offer three design recommendations for automated collaboration feedback systems.

*Extended application:* As suggested by Blömeke and colleagues [1], learning to collaborate is a competence (a disposition, consisting of knowledge, skills and attitudes) and, as such, needs a sustained learning process. In this research, the feedback report was presented once to students, giving little time to such a complex competence to develop. Thus, the reports' impact on students was not evident. In contrast, the feedback given in oral presentations—which does not require such high levels of social interaction, can lead to students' improvements after just one intervention (cf. [13]). As the interview findings and students' reflections suggest, researchers, teachers, and academic staff should consider the measurement of collaboration skills across multiple courses and several periods (e.g., 1 semester, 2 years).

*Qualitative formative feedback:* The feedback report was designed using the paradigms and design recommendations that the LA community currently promotes [16]. However, the user research stage findings and students' reflections strongly suggest that, while students can explain the quantitative information presented in the report, they also need qualitative information (e.g., why that score and actionable advice) to define and pursue improving pathways. We advise better scaffolding of the information presented through more explainable information, context and details. Rule-based recommendation systems, natural language processing models and open learner models can help to that regard.

*Contextualized reports:* Although our feedback report factored six aspects of collaborations that emerged from students' perspectives, the user research findings unearthed a series of external factors that hinder collaboration and, thus, should also be considered. These include different perceptions in task commitment among participants, different level of knowledge about the subject at hand, a common perception of disagreements as disputes or problems, and higher-education institutions' tendency to promote a score-oriented culture, amongst others. Designing feedback reports with students might help in addressing these complex factors.

## 6 STUDY LIMITATIONS

The current study has limitations. Manually coded data may be subject to bias, as experts might have different conceptions on the behaviors explored in this work. Also, the collaboration aspects that did not appear consistently through the group-work activities, were not considered; therefore, these results cannot be generalized. Further work should consider the use of automated group and discourse analyses to compute collaboration aspects. Also, teachers' perspectives would need to be further explored to unearth tensions across stakeholders. As for the delivery of the feedback report, students received their reports with a delay of 10 weeks. By that time, they might have not been able to recall their actions/inactions or why they behaved in a certain manner during the group-work activity.

## 7 CONCLUSIONS

This article aimed to assess the effect of using a collaboration feedback report on the collaborative skills of CS students engaged in group-work activities. Given the high impact of feedback on learning, we expected a higher collaboration of students who received feedback. This study could not demonstrate higher scores for the overall collaboration nor on the collaboration aspects on students who received collaboration reports. Nevertheless, our findings are of help for practitioners and researchers in the area of collaboration and challenge them in testing the following in future work. Collaboration sessions and its corresponding feedback should be carried out in a sustained manner. Feedback reports should be delivered immediately and should include metrics, and the explanation of scores and how to enhance collaboration in a more personalized way. The

analyses of results of the feedback should take place during moments of reflection. Additionally, we acknowledge the importance of using, in reports, key aspects of collaboration under the names given by students. In this way, these aspects make more sense and have meaning for them, than those that have been established using the language of researchers and experts.

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