Displaying the Collaborative Process as Meta-Knowledge.
Description of a Mirroring Strategy and its Results.

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Abstract. There is consensus as regards the fact that group strategies and group building processes are a significant aspect of knowledge for those who work collaboratively. The decision as to which indicators educators select and display when accompanying collaborative groups is a strategic one. Likewise, the point in time when the group can access information about their collaboration –after the process is completed or during the process – is also important. In this article, we propose and discuss a collaborative work monitoring strategy that is implemented as a mirroring technique which has been tested in a post-graduate educational experience in 2016. Preliminary results would confirm the idea that the group benefits from knowing how the collaborative process is progressing and would also indicate that there is a greater awareness in each team member in relation to his/her own task and those of their peers.

Keywords. Collaborative work indicators, Collaborative work monitoring, mirroring strategy, Meta-knowledge and collaborative work.

1 What, when and how to display collaboration

There is agreement as to the importance of group work and performance awareness by all participants in the group [1], [2], [3], [4]. In [5], the authors describe three types of information that can be considered to be essential for collaborative learning:

- Public information about what group members effectively do, also mentioned in [6];
- Cognitive information about background knowledge and/or self-regulation abilities for learning in each member (also acknowledged in [7] and [8]; and
- Social information about group dynamics, as perceived by collaborators [9].

In [10], there is an interesting analysis about the importance of the decisions and experiences of others for every individual in their everyday lives. This article mentions that the idea of computer systems supporting these activities was introduced as early as 1999, and that computer systems can be used to help these activities gain visibility and understand these relations. The concept of social translucence is thus introduced as a feature of computer systems that can facilitate communication, showing simple quantitative aspects of user participation in a shared task. This approach is based on three features, also discussed in [10]. The first of these, visibility, refers to the idea that users can have access to social information that is presented as figures or charts. The second feature, awareness, considers the impact of the information of the activities being carried out by others on the activity carried out by each member and coexistence and collective work rules. Finally, the feature of responsibility refers to individual self-regulation processes that can occur as a result of user awareness about their own actions or the actions of the other members of the group. These pioneer ideas were continued by various authors to build work group performance visibility systems used for small groups, social groups and even networks.

As regards small groups, the work presented in [11], where [3] and [12] are quoted, and where the concept of mirroring is further discussed, is relevant for our work. The authors define mirroring as "systems that reflect, or mirror, group interactions" (pp. 119). These systems show interaction indicators that should be defined based on the type of work to be carried out and the composition of the group. There are other works, such as [13], that not only offer a description of the interaction events, but also present them based on predefined indicators and by comparison with expected standards. These indicators represent the status of the interaction, together with a set of expected or desirable values and parameters. There are different possible visualization types: bar charts, pie charts, map of forum topics (indicating task and topic dispersion) and even collective development of conceptual maps [4]. Based on the hypothesis of Dimitracopoulou [13], and in agreement with the publications mentioned above, this information could favor both group work itself as well as the work carried out by the coordinators that monitor and guide the group. Visualization structures, with appropriate representations, can help students with their meta-cognitive development, as well as help regulate the collaborative activity. Each tool that is used for the group task involves making decisions as regards the information or indicator that is shown, and how and when it is shown. The possibility of showing performance and progress information is closely linked to the situation of collaborative work, be it on-site or distance work, as well as with time management – synchronous or asynchronous. Once the group started its collaborative work, identifying specific points in time within the activity to show progress is a complex task. In the literature, indicators are most commonly displayed ex post facto, i.e., after the group work is completed. However, tools can and should define time windows (as Manuel Castells describes in [14]) for (abstract) breaks during work to see where it is going and how that relates to what was expected.

This article is organized as follows: Section 2, presents some background on collaboration monitoring tools, Section 3 describes the mirroring strategy proposed and

its application, Section 4 discusses the results obtained, and Section 5 presents our conclusions.

2 Collaborative Work Visualization Tools

In this section, some tools used for monitoring collaborative work are classified and described to show how they support this activity, which indicators they show, and how visualization takes place. This background information has been used for the mirroring proposal described in the next section. Tools have been grouped in the following three categories:

- Mirroring Tools: this category includes tools that automatically mirror the activity of the members of the work group. These are graphical representations of the actions of each group member in each tool.
- Metacognitive Tools: this category includes the previous one (mirroring) and it also shows information about any deviations in the development of indicators from what was expected. Some examples could include marked heterogeneity in participation by group members, spread topics, etc.
- Guiding Systems: this category includes both previous ones and adds a space for educator guidance and intervention.

2.1 Big Five

These are visualization tools that match the Big Five groups theory. In [15], a set of visualization tools specific for collaborative work in computer environments is presented, all of them linked to the theoretical framework discussed by Albert Bandura [16] as part of the social cognitive theory (SCT). This framework identifies the five abilities (big five) that define group work: 1. symbolization ability; 2. prefiguration and planning ability; 3. learning through observation; 4. self-regulation; 5. self-reflection. As an example of metacognitive tools, the Activity Radar can be mentioned, which is a circle that represents the participation range of each group member based on a standard reference. This standard reference can be the average for the group in the past, a predefined standard or the activity of a group member. This standard is represented as the center point in the circle (see Fig.1 A.).

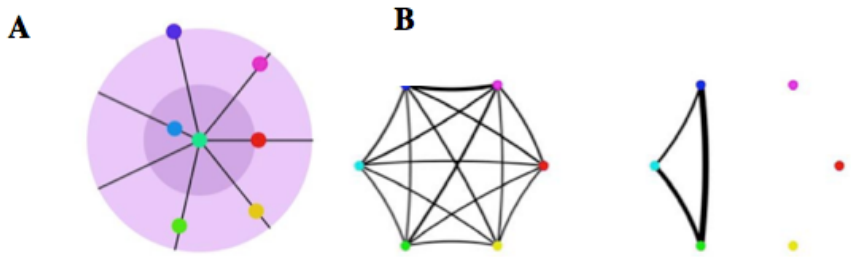

Fig. 1. A. Participation radar, according to Big Five.
Fig. 1. B. Interaction networks in two tools with different density and relations (taken from [15])

Another representation is based on Social Media Analysis (SMA). It quantifies the relations between players to create graphical networks that represent these relations as a whole. Networks have three basic components: players, boundaries, and relations. Players are represented by dots and relations are represented by lines joining them (1 B).

2.2 Drew. Dialogical Reasoning Educational Web tool

According to [12], this is a web tool that shows a graphic representation of the topic map that is generated in an argumentative analysis system. It is developed as part of the SCALE Project of the European Community, which focuses on collaborative learning for argumentation using Internet in secondary schools. Its tools are designed to help students develop, refine and expand their argumentative knowledge in a given field. The educator has a specific role in the software that allows viewing what is going on and adding tasks and participants. For this reason, this tool is considered to belong to the Guiding Systems category.

2.3 iBee. Bulletin Board Enrollee Envisioner

Created and presented by [28], iBee is a software application that follows the bulletin board model and that works as a plug-in in a virtual teaching and learning environment. Its main features include: 1. Visualization in real time of the relation between key words and students; 2. Visualization of a conversation trajectory in a given period; 3. Visualization of student's most recent participation levels and key word use frequency; and 4. Message placement based on key words, represented through the flowers and bees metaphor, so that students can simply click to access them. iBee can be considered as a mirroring tool within the categories described above.

3 Implemented Mirroring Strategy

In this section, the mirroring visualization strategy that was designed and implemented to carry out a collaborative activity in a post-graduate course at the School of Computer Science of the UNLP is described. The course in question was "Distance Education," part of the Master in Information Technology Applied to Education. Cohort 2016 included 11 students. For this task, participants were divided into 2 groups: one with 5 members and another one with 6. The reduced number of students and the existence of only two work groups favored the development of this strategy, since each individual and group activity has to be thoroughly reviewed using each of the tools selected.

3.1 Description of the Mirroring Strategy

The eighth class in this course consists of a collaborative writing e-activity, where participants receive, as a first stage, an individual assignment (unknown to their classmates). In a second stage, they are asked to use their individual productions developed based on their individual assignments and collaboratively create a book. They have 6 weeks to work on this task, and it was during this period that the mirroring visualization strategy described below was carried out. The first activity consisted in telling the participants about the implementation of this strategy, describing the type of work that this would involve and emphasizing the use of the tools that had been made available to the groups to be able to carry out on-line monitoring tasks. Together with this initial information, a document detailing the map of indicators on which monitoring tasks would focus and a schedule for information presentation, based on the collaborative work stages considered in the assignment, was also distributed. The indicators selected to carry out the mirroring strategy can be divided into individual indicators and group indicators (see Table 1). Individual indicators consider, from a quantitative standpoint, the number of messages exchanged with other group members in each stage of the assignment and the number of messages in each of the tools being used. From a qualitative point of view, messages were classified based on their contents in: organization-oriented messages, group emotional/motivational management messages, and messages dealing with task-specific issues. The group indicators analyzed were linked to the concept of interdependence, and the creation of topic maps following [4] was also considered.

Table 1. Mirroring individual and group work indicators

Dimensions/ Indicator Categories	Indicators
DIMENSION: INDIVIDUAL CONTRIBUTION BY EACH MEMBER	
Contribution by each member to collaborative work	Quantitative analysis • Number of messages exchanged with peers in each stage of the assignment. • Number of messages in each tool Qualitative analysis • Types of messages based on categories - Organization - Contents - Emotion
DIMENSION: COLLABORATIVE WORK ITSELF	
Interdependence (Group Concept)	Topic conceptual map Topics and duration

To keep track of collaborative work process information, a GoogleSites site was used, since students were already familiar with it and mirroring information was easy to access.

When developing this type of strategies, defining how information is going to be viewed is of the utmost importance. In this case, the information presentation formats used were the following, depending on the indicators: bar chart showing message number and quality by type of message (contents, organization, emotions) for each member of the group, and a map of topics detailing duration, in weeks, for each topic. Each topic was identified with a color and, for each topic, the individuals that worked on it are identified (with their initials). On the other hand, a graph as the one shown in Figure 2, showing the relation between topics and group members, was used. This graphic representation facilitates the analysis of participations and exchanges. For this proposal, graphs were built based on the following rules: a) they have nodes: participants and topics; b) the nodes corresponding to individuals are labeled with the initials of that individual, while topic nodes are labeled with the name of the topic; c) all nodes are represented with color circles; d) the lines linking each individual to a topic indicate that the former is related to the latter; e) the size of the nodes increases as the number of incoming or outgoing lines increases, and g) the thickness of the lines increases as the participation of an individual in a topic increases. Thus, the distance between the topic map and each group member can be seen, as well as the level of participation of each member.

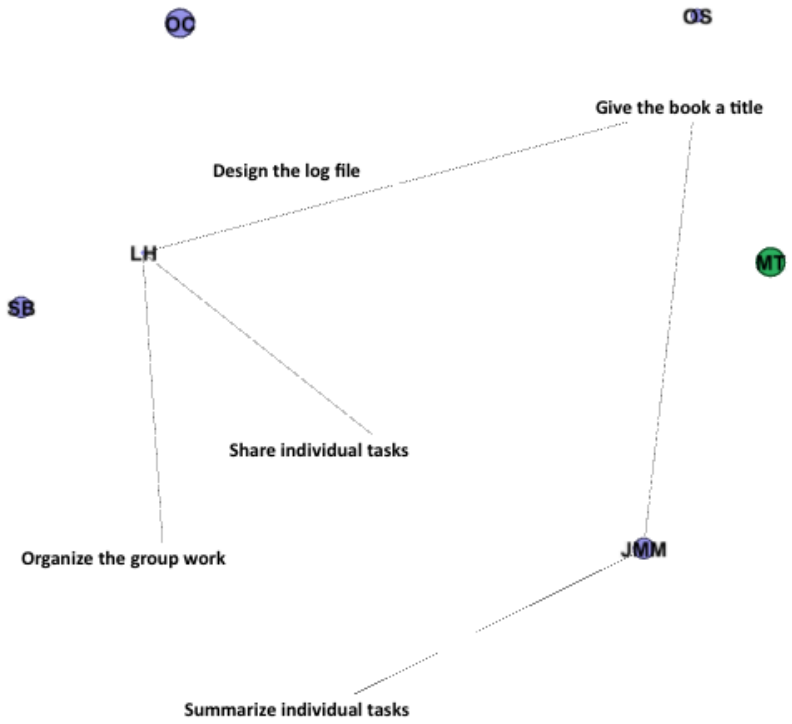

Fig. 2. Graph showing relations in mirroring information.

3.2 Impact of the Mirroring Strategy in Collaborative Work

In the week immediately following information publication weeks, a private individual inquiry instrument was responded by all group members to obtain feedback on their experience with collaborative work and the impact of the mirroring strategy. The instrument included 5 sections: 1. Personal data, 2. Individual work, 3. Use of tools, 4. Group work, and 5. Impact of the mirroring strategy. In this article, we focus on the feedback received in Section 5 of the instrument, which was aimed at obtaining the following information: information visualization frequency, information usefulness, attention to individual and/or group indicators, attention to the information of their own group versus that of the other group, information usefulness based on format, decisions that were changed based on the mirroring information obtained, and general opinion on how this strategy affected group work.

4 Results Obtained in the Mirroring Experience

In this section, the most significant results obtained through the inquiry described in the previous section, administered through an on-line survey, are discussed.

As regards the visualization frequency with which the information in GoogleDocs was referenced, the following questions were asked: How many times did you visit the information site for the collaborative process? Answer options established a frequency ranging from 1 to 5, 1 being Never and 5 being Daily. Figure 3 shows the results, which indicate that **30% of the students accessed the information daily, while 44% of them indicated a frequency between 3 and 4 on the scale**. They were also asked about their reasons to access the information. Below are some of the answers received: *"I was curious about the type of information that was being considered," "I was interested in knowing how information was presented and the data that were displayed about the participation of other group members*," and *"I thought it was important to know if what happened as part of our collaborative work was present in the system."*

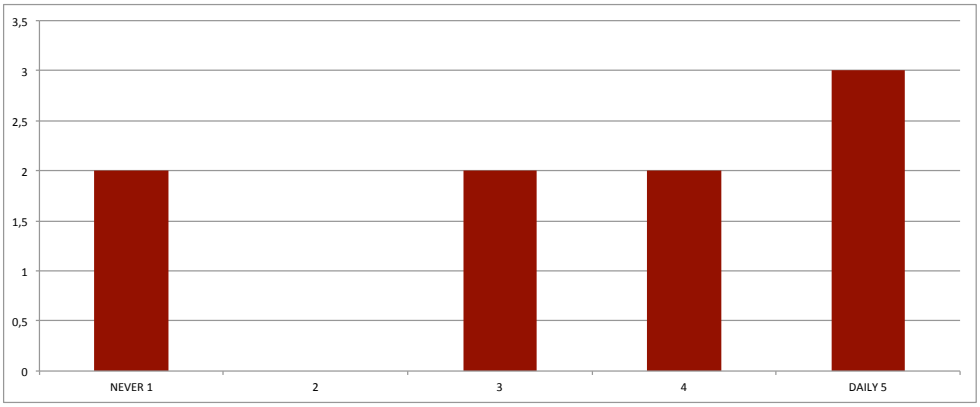

Fig. 3. Mirroring information site access frequency

The issue of **information type and format was of interest**, since the indicators that had been selected were at play and their potential to understand, communicate and even improve collaborative work. The corresponding question was: "What type of information did you find most useful?" Answer options listed all formats that had been used to present monitoring information: text, numerical values, data tables, bar charts, group work graphs, images, etc. The answers obtained are presented in Figure 4.

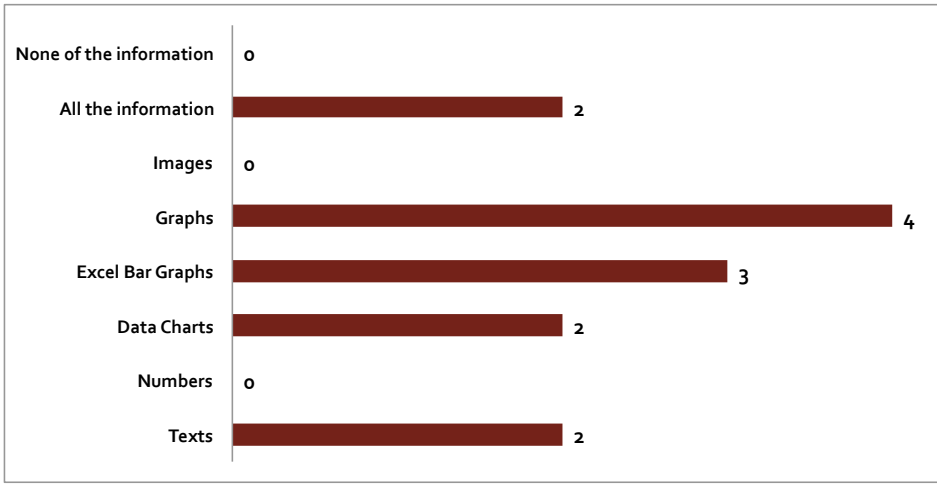

Fig. 4. Access to information by format

More than one answer could be indicated in this item, since information types were no exclusive. Starting by the information that was selected by most participants (4 individuals), **activity presentation graphs, both individual and for the group should be mentioned**. In second place, participants selected **bar charts showing individual performance**: number of messages by category. Before adding these charts, the data tables used to generate them were presented. This information was also valued by students. Finally, the use of **text as integration, explanation and contextualization element was found valuable** as well. As regards as the reasons for selecting different visualization types, the following were given: *"Charts represent data in a clear and accurate manner," "Personally, I prefer to analyze charts rather than numbers," "I prefer graphs because I can see the connection between members and actions and types of messages."* Data tables were also mentioned: *"I found the individual breakdown of participations and the data table and its subdivisions to be useful to me."* Both the text and the integration of different types of information in the site were valued as well: *"All reports were read carefully. Charts, tables and graphs were easier to interpret, but a textual description is always useful to have"* and *"Every element enriched process statistics in its own way and complemented the other elements."*

To point to the initial hypothesis, the following was asked: What decisions were changed as a result of the information presented in the site? (options are divided in three aspects: emotion, contents, organization). The answers obtained are presented in Figure 5.

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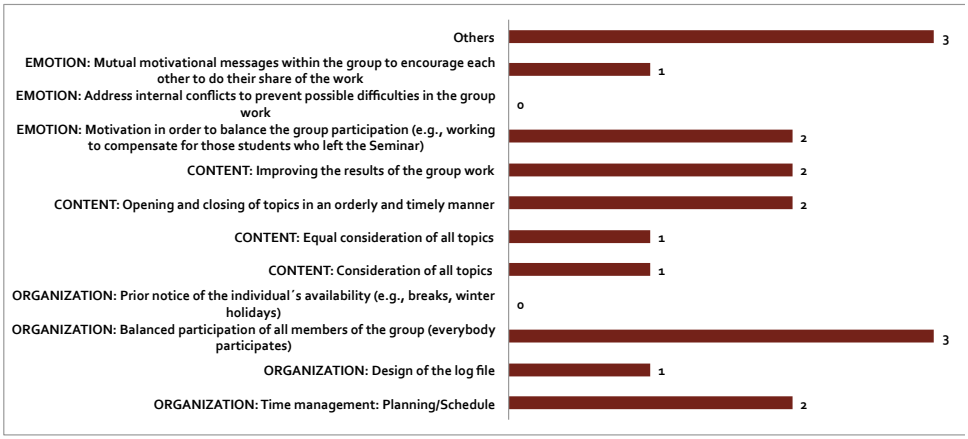

Fig. 5. Decisions made based on the mirroring strategy

Figure 5 shows that **organization decisions** were affected the most by knowledge obtained through the mirroring strategy. Within organization decisions, two key components can be identified: time management and balanced participation of all group members. As regards member participation, it could be tracked through the site using the individual information component. As regards **content decisions**, all of them were identified as having been affected by this strategy. **Emotion-related decisions** affected by information obtained through the mirroring strategy were motivation-related: knowing what each participant had done on the individual and group levels helped create messages aimed at achieving higher involvement and level of activity from everyone. As regards organization-related issues, students mentioned the following*: "I think the main goal was to organize member time management to finish as soon as possible with individual responsibilities. It allowed us to organize taking into account the time we had in order to be able to finish the task within the expected time. We also had to take into account the creation of a summary for the topic assigned to a member that dropped the course." "It was also useful to reinforce meta-knowledge about individual performance: Seeing the data made me realize that at points my contribution had been really low".*

5 Conclusions

The governing idea behind this work is the importance of information in a collaborative work process as a metacognitive component of performance, both individual and collective. Knowing how each individual and their peers work is seen as a valuable contribution, both to the process as well as to the result of group work. This knowledge of metacognitive nature is important both for group members as well as for the coordinator, whose job is to guide students and intervene if required. In this article, a mirroring strategy that was designed and implemented with a group of postgraduate students as metacognitive experimentation space was described. The results

obtained support the idea presented in [13] as regards the visibility, awareness and responsibility that having this information about their own performance promotes among the members of a group. Among the findings of our experience, the following can be mentioned: a) the number of organization-related messages changed; as soon as message type-related data were included in the mirroring site, the group started communicating in terms of task planning and organization; b) most participants monitored the information shown on the site about their individual tasks, and each of them made sure that the site showed accurate information about what they had done. They even sent private messages explaining why they had not been able to carry out a specific task. From this visualization, it was observed that group members monitored what they did (and what they did not do) individually, and what their peers (from both groups) produced during the 6-week period assigned for this task. In this sense, we believe that the implemented strategy is relevant, since it confirms several of the hypotheses reviewed as background information. It also opens up new study paths, since it presents new findings about the types of visualization that affected the process the most. In the future, we will continue to carry out experiences to increase the number of participants and thus produce more conclusive results.

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