DESIGN OF DIGITAL ENVIRONMENTS AIMED AT FOSTERING ASYNCHRONOUS WORKING GROUP ACTIVITIES: EMERGING CATEGORIES OF STUDENTS' COLLABORATIVE PROCESSES

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In this study we focus on the collaborative processes developed within an asynchronous small group activity carried out through an instant messaging platform. To investigate the ways students communicate and collaborate during the asynchronous activity, we refer to the theoretical lenses provided by the dimensions introduced by Weinberger and Fischer (2006) to study the processes realised within computer-supported collaborative learning environments. In particular, we develop a combined analysis that takes into account both the quantity of students' interventions and their social modes of co-construction. This analysis has revealed two main macro-categories of collaborative processes activated by the groups of students who participated in the study, which mainly differ in the level of sharing and comparison within the groups and in the aim that guided their work.

Keywords: Asynchronous discussion, collaborative processes, instant messaging communication

INTRODUCTION

The pilot study presented in this paper is part of a wider research project aimed at investigating the potentialities of digital environments in supporting mathematical discussions conducted in an asynchronous way. Asynchronous discussions are characterised by a communication between participants that are separated in space and time (Andersen, 2009) and are structured as linked messages relating to a common discussion topic. They have become an emergent field of research in the last two decades (see, for instance, Johnson, 2006; Gao et al., 2013). Digital environments play a role in mediating asynchronous mathematical discussions in terms of both stimulating different modalities of students' engagement and communication, and of supporting the teacher in the orchestration of the discussions. In fact, the asynchronous nature of the discussions enables students (and teachers) to take their own time in reading others' posts and comments, preparing thoughtful responses and reflecting upon their contributions (Andersen, 2009). Moreover, by providing a transcript of the discussion and making all communication elements explicit, the use of a written form of communication makes the discussion more transparent for those who are involved within it, turning it into an effective support for students in both studying and reflecting (Meyer, 2004).

The digital environment investigated in our study involves the combined use of two different platforms, aimed at two main purposes: (a) supporting students' collaborative processes when working in groups in an asynchronous way, and (b) supporting the teacher in orchestrating effective asynchronous mathematical discussions (Bartolini Bussi, 1996; Cusi & Malara, 2013). In this paper, we focus on the role played by this environment in fostering purpose (a).

THEORETICAL FRAMEWORK: COLLABORATIVE LEARNING ACTIVITIES WITHIN THE CONTEXT OF SOCIAL MEDIA

The role of online social media for improving collaborative learning among students has been widely reported and discussed especially during the Covid-19 pandemic (Bakker et al., 2021; Biton & Segal, 2021). The discussion on the use of social media for teaching and learning purposes has highlighted the potentialities related to the fact that learning can occur anywhere and at any time (Naidoo & Kopung, 2016), enabling students to take their own time in reading, reflecting and answering to other students' contributions and in giving them the opportunity to re-organise their knowledge and to express and communicate it in different ways (Biton & Segal, 2021). Moreover, research has shown the effective role played by social media in fostering students' engagement and in promoting their collaboration (Naidoo & Kopung, 2016). As regards this last issue, Weinberger and Fischer (2006) developed a framework to analyse different process dimensions of knowledge construction in computer-supported collaborative learning environments. They state that four dimensions should be taken into account when analysing the computer-supported collaborative learning environments: (1) the participation dimension, that consists of the quantity and the heterogeneity of participation; (2) the epistemic dimension, that refers to how learners work on the knowledge construction involved in the task they are working on; (3) the argument dimension, that concerns the construction of single arguments and the construction of sequences of arguments; and (4) the dimension of social modes of co-construction, that refers to how learners work on the task and formulate arguments referring to other learners' contributions or individually. The different social modes can be characterised according to the degree with which learners refer to the contributions of the other participants:

(a) Externalization (EX), when learners make contributions without (implicit or explicit) reference to previous contributions to the discourse. It occurs typically at the beginning of a discussion or when a learner does not comment on any other message present in the discourse.

(b) Elicitation (EL), when learners request information, feedback or specific actions from the other participants. It is important to observe that learners can rely on and abuse of elicitation, so it positively contributes to knowledge building only if the learner receives help but applies it on his own to the problematic situation.

(c) Quick consensus building (QC), when learners accept other participants' contributions just in order to move on with the discourse and without taking charge of it. The acceptance can be explicit, such as "That's right!", or it can consist of a rephrasing of the contribution without changing its meaning.

(d) Integration-oriented consensus building (IC), when learners' perspectives are taken over. It generally occurs when learners integrate their contributions during the discussion.

(e) Conflict-oriented consensus building (CC), when learners do not accept the contributions as they are, but they replace, modify or supplement them.

DESIGN OF THE ACTIVITY

The activity implemented in the pilot study documented in this paper, called "Digital Mathematical Discussion" (DMD), is set within a digital environment characterised by a combined use of two digital platforms and it consists of two main phases. First, students, divided into small groups, work within chats of an instant messaging platform (Telegram in this study) to collaboratively face a mathematical problem. In each chat, the teacher is present only to answer students' questions on practical aspects, if needed. Students are given a few days (in our study, 4 days) to collectively solve the problem communicating only through the chat and to send to the teacher (by email or

through a shared e-learning platform, such as, for example, Moodle) the written solution agreed by the members of the group. In order to limit additional interactions between the participants on the problem they have to face, it is advisable to set this part of the activity in a moment of the week within which students have a limited amount of presential classes. The second part of the activity consists in a collective discussion conducted on a collaborative web platform, Padlet (https://padlet.com/) in this study. The discussion is designed by the teacher starting from selected excerpts from the groups' solutions (Cusi, Morselli & Sabena, 2017) and from significant interactions that emerged in the Telegram chats. The Padlet link is shared with students as soon as all the groups submit their solutions and students can insert their comments within a period of about 4 days (more days can be considered if needed). Finally, a collective discussion is conducted in presence to resume and deepen the reflections emerged on the Padlet.

Since research has documented pitfalls related to the distracting nature of social media, in particular when students work with mobile instant messaging platforms (Naidoo & Kopung, 2016), we decided to design the activity with an accompanying set of indications to regulate the use of the social media for educational purposes: (1) interact only on the Telegram chat and on the Padlet devoted to the activity, trying to avoid any other form of communication regarding the mathematical problem under discussion; (2) make all the thinking processes explicit, including the ones regarding the resolution of the problem, doubts, ideas, difficulties, individual explorations, etc. in order to let the thoughts become visible to all the participants; (3) share all the used materials, such as pictures of what is written (if paper and pencil are used to develop the reasoning); (4) do not use vocal messages in order to maintain the communication written.

RESEARCH CONTEXT AND CHOICE OF THE TASK

The students involved in this study are preservice primary school teachers enrolled at the first year of the master-degree course "Primary education sciences" at Sapienza University of Rome. The activity DMD was implemented within a 48 hours course aimed at making students develop reflections, in an integrated way, on specific mathematical contents, mathematical processes and on specific pedagogical aspects of mathematics teaching-learning. This sample was chosen since, during the course, the students got used to a teaching methodology characterised by small group collaborative problem solving activities, followed by classroom discussions designed by the teacher educator (one of the authors) starting from groups' written productions and orchestrated with the aim of fostering comparison between different approaches and reflections on the thinking processes activated to face the given problems.

31 students, divided into 5 groups of 5-7 students, participated in this study. The task (Fig. 1) proposed to the groups within the Telegram chats was in tune with other problem solving activities faced during the course, which were aimed at making them experience the use of algebra as a thinking tool by means of tasks focused on numerical explorations, conjecture, argumentation and proof.

Observe carefully this table. Do you notice any regularities?

After listing all observed regularities, try to justify them.

1	3	3
2	4	8
3	5	15
4	6	24
5	7	35

Figure 1. The task faced by students within the Telegram chats

RESEARCH QUESTIONS AND RESEARCH METHODOLOGY

The research question that guided the pilot study documented in this paper is the following: What kind of collaborative processes are fostered, within the phase of the DMD devoted to asynchronous small group activities, by the design of the digital environment where the DMD activity is set?

The data collected to investigate the collaborative processes developed by the groups of students within the instant messaging platform were: all the messages written by students within the Telegram chats; all the files uploaded by students within the chats; the written answers uploaded by each group of students within the e-learning platform of the course. To investigate the ways in which students communicated and collaborated with each other within the chats, we analysed these data by referring to the theoretical lenses provided by Weinberger and Fischer (2006). In particular, we focused on two of the four dimensions introduced by Weinberger and Fischer, that is the participation dimension and the dimension of social modes of co-construction. We developed our analysis by combining the quantity of students' participation with the qualitative analysis of students' interventions. The quantity of students' participation was investigated by counting the number of interventions that each student proposed within the chats. The qualitative analysis of students' interventions was developed by coding them according to Weinberger and Fischer's categories of social modes of co-construction. To better determine the category to which each intervention refers, we also distinguished between the interventions that are focused on content (the problem under investigation, the argumentations to be developed, the mathematical knowledge at stake…) and the interventions focused on organisational aspects (the roles to be played by each student, the ways in which to organise the answer to be sent to the teacher…). We also counted the number of students whose interventions refer to specific categories.

Moreover, in order to investigate students' perspectives on their experience of participating in the DMD as further evidence of our interpretation of the processes developed throughout the whole activity, we asked them to answer a written questionnaire. The questions asked in relation to the small group collaborative activity within the Telegram chats were aimed at investigating aspects such as students' difficulties in respecting the given guidelines for the activity, students' opinion about the number of messages written within the chat, students' feeling of being listened by their mates during the small group activity, the usefulness of having their mates' written messages at disposal, the usefulness of working in an asynchronous way, their reflections on the comparison between working in groups in presence or within the Telegram chats.

ANALYSIS

Table 1 exemplifies the ways in which we developed the qualitative analysis of students' interactions within the Telegram chats. The students' interventions within the transcript (column 1) are coded (in column 2) in terms of social modes of co-construction, distinguishing between EX (externalization), EL (elicitation), QC (quick consensus building), IC (integration-oriented consensus building) and CC (conflict-oriented consensus building). In column 2 the coding process is made explicit. We chose this specific transcript (belonging to group C's chat) due to the variety of categories of social modes of co-constructions that can be referred to students' interventions within the chat.

Excerpt from the transcript of a chat	**Coding of the interventions according to**

	Weinberger and Fischer categories of social modes of co-construction
11:08 I: Good morning! Have you noticed any other regularity beyond the ones already written? So, if you agree, in the meantime we can reformulate the regularities and write them in order, so that then we can focus on the missing generalisations	EL – Student I implicitly requests some actions from the group in order to organise the following work. The focus is on organisational aspects.
11:10 E: Good morning, I agree with the regularities you identified. I haven't found any different regularity. So, we can stop here and put them all together.	QC – Student E agrees with the issues proposed by student I and reformulates her message. The focus is on organisational aspects.
11:22 C: I agree, I would start from the more "trivial" observations, that is the relationship between the first and the second [columns], second and third [columns] and first and third [columns], then I would move to the more articulated ones, such as the difference between results, etc…	IC – Student C proposes her point of view on the ways in which the observed regularities should be listed in the collective document.
11:28 I: Perfect!	QC – Student I explicitly agrees.
11:29 I: How do we want to organise ourselves for the file we have to submit? Is one person writing it and then sharing it here in the chat?	EL – Student I asks her mates how to organise the writing of the collective document.
11:31 A: It can be done this way	QC – Student A explicitly agrees.
16:23 *I shares a document with the collection of all the regularities emerged in the group*	
16:23 I: Girls, I decided to write in a unique file all the regularities we found. Just generalisations are missing. Let me know what you think about it.	EL – Student I is leading the writing of the document, but she wants to involve her mates, by explicitly asking them feedback on the file she started creating.
16:25 A: Excuse me, according to me the first two regularities are not essential, but I don't know	IC+EL – Student A is pointing out her perspective on the content of the document; the final "but I don't know" can represent an implicit request for feedback.
16:26 I: Indeed, on the first [regularity] I had your same doubt because I wasn't sure to write it	IC – Student I is boosting the discussion with A expressing her accordance and her point of view.

Table 1. Qualitative analysis of an excerpt of the Telegram chat of group C

We summarised the results emerging from our combined analysis within 5 tables (one for each group) with the aim of supporting the comparison between the collaborative processes that characterised each group's interactions. A first comparison between these results enables to highlight two main macro-categories of collaborative processes developed by the groups of students involved in this study: (1) interactions characterised by a widespread lack of shared reflections on each other's proposals and mainly aimed at producing a written answer to be sent to the teacher; (2)

interactions characterised by a constant comparison between each other's proposals and mainly aimed at developing a really shared answer to the given task.

Table 2 and 3 summarise the results of this analysis for two groups (group A and group C), belonging, respectively, to category 1 and category 2.

The interactions observed within the chat of group A (Table 2) are characterised by a predominance of QC and EL interventions focused on organisational aspects. Table 2 also highlights that the work is guided by few leaders, since EX and EL interventions are proposed only by 3 students among 7. What is not evident from the table, but was observed through the qualitative analysis of the chat, is that, although students do not propose reflections on what their mates write in the chat and limit themselves to agree or to add further proposals, there is an effort to take all these proposals into account to be integrated into the written document to be uploaded within the e-learning platform.

Types of interventions	Number of interventions	Number of interventions focused on content	Number of interventions focused on organisational aspects	Number of participants who propose this type of interventions
EX	1	1 (EX+EL)	0	1/7
EL	23	2 (1 EL+EX)	21	3/7
QC	28	4	24	7/7
IC	9	6	3	5/7

Table 2. Summary of the combined analysis of the interventions within the chat of group A

The fact that the interactions observed within the Telegram chat of group C belong to category 2 is evident both from Table 3 and from the results of the qualitative analysis of the excerpt presented in Table 1. In fact, even if the work is led by only 3 of the 7 students (lines 2 and 3 in Table 3), all the students (except one of them, who never participated) proposed IC interventions, mainly focused on the content under discussion.

Types of interventions	Number of interventions	Number of interventions focused on content	Number of interventions focused on organisational aspects	Number of participants who propose this type of interventions
EX	8	8 (3 EX+EL)	0	3/7
EL	16	6 (3 EL+EX, 1 EL+IC)	10	3/7
QC	25	5	20	6/7
IC	20	19 (1 IC+EL)	1	6/7

Table 3. Summary of the combined analysis of the interventions within the chat of group C

DISCUSSION

The results of the analysis presented in the previous section enabled us to highlight two main counterposed collaborative dynamics within the groups that interacted in the Telegram chats. On one hand, two groups activated effective collaborative processes, characterised by many integration-oriented consensus building interventions proposed by most of the participants and aimed at developing a shared solution to the problem (category 2). On the other hand, the interactions that characterised the collaborative processes activated by three groups proved to be less effective, since we observed a widespread lack of shared students' reflections on each other's proposals and a predominance of quick consensus building interventions focused mainly on organisational aspects (category 1).

Although the ineffective collaborative processes observed within some of the Telegram chats, students' answers to the final written questionnaire highlight a general positive perception of the work developed with their mates in the chats, due to the opportunity to use the flexible time at disposal to better reflect on each other's proposal and to the potentialities of focusing on a written form of communication as a way to make thinking more visible, as these two excerpts from the questionnaire testify:

> "The fact that everything was written allowed me, first, to read all the proposed observations taking my own time and, then, to verify and interpret them calmly."

> "If others express their thinking or even a thinking that does not have a clear form, when it is written, this thinking becomes more visible and it is possible to develop it and deepen the work."

We hypothesise that the reason why some students share a positive perception of their experience of group work within the Telegram chats even if the collaborative processes developed within their groups are not effective could be ascribed to the fact that, in some cases, the dynamics activated within the chats do not differ from those activated during in-person group work (especially when some students set themselves as leaders and the other participants limit themselves to follow what the leaders suggest). We plan to assess this hypothesis in a future step of our research.

Moreover, we think that the ineffectiveness of the collaborative processes observed in some of the groups could be also related to the difficulties due to the impossibility of looking at interlocutors during the interactions within the Telegram chats. Being not able to grasp typical aspects of para-verbal communication and the gaze of the group's mates when sharing their thinking within a chat prevents the participants from understanding the unwritten, making them possibly not realise the need of reformulating their thoughts to make them better understandable to others. This hypothesis has been confirmed by some students' reflections, who stress that within digital environments "there is less emotional involvement" and define the digital chats as "aseptic and detached situations".

In spite of the difficulties related to these last aspects, most of the students stated that their participation and engagement in the DMD activity were higher than within in-presence activities implemented during the course. This result is in tune with other research studies, which showed that, within text-based computer-supported collaborative learning environments, the quantity of participation is higher than in traditional classrooms (Weinberger & Fischer, 2006). The students who declared that their engagement has increased during the DMD activity identified the greater amount of time at disposal for developing reflections as a factor that influenced their way of participating, as the following reflection testifies:

> "Having more time at disposal for reading and formulating observations and answers to my mates encouraged me to participate"

Another aspect highlighted by the qualitative analysis of the interactions within the Telegram chats is the complete lack of conflict-oriented consensus building interventions. This is certainly due to the explorative nature of the task, which makes almost all the students' statements on what they observe meaningful and useful for the development of the activity. However, we hypothesise that this result could also be due to the ways of working and interacting within the chats, which prompts most of the students to meditate on their interventions for a long time before writing them. This is testified by the following reflection written in the questionnaire:

> "I noticed that, differently from what happens in class, I thought a lot more before sending my comments since I was afraid of making mistakes, so I made sure that what I was about to send was correct."

As a future step of this research, we plan both to implement a further study aimed at verifying the hypothesis we developed and to work on the re-design of the digital environment with the aim of trying to overcome the difficulties in developing effective collaborative processes highlighted by the analysis presented in this paper.

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