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Mathematics Education in the Digital Age

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Orchestrating mathematical discussions with and through Padlet

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The role of the teachers is central in orchestrating classroom discussions to support students' engagement and highlight connections between emerging mathematical ideas. Literature shows many practices that could support teachers in dealing with this role, and some recent studies show that digital tools shape teachers' practices. In this paper, we discuss an example of a structured educational activity conducted with a shared and collaborative digital platform (Padlet); the aim is to identify the Padlet affordances that may support productive discussion orchestration. In the discussion presented here, Padlet appears to be a valuable tool: students' posts on Padlet allow the teacher to monitor the different approaches proposed by students to solve a given task and their achievements. Moreover, the possibility of having all students' posts together permits students and the teacher to recognize similar strategies and connect emerging ideas.

Keywords: Padlet, educational technology, mathematical discussion, mathematics activities

Introduction

In promoting a deeper understanding of mathematics, teachers orchestrate whole-class discussions that use students' responses to instructional tasks to advance the whole class's mathematical learning (e.g., Bartolini Bussi, 1996). Effective facilitation of classroom discussions poses a considerable challenge for educators, especially in the domain of mathematics. Stein and colleagues (2008) introduced a pedagogical model comprising five practices (anticipating, monitoring, selecting, sequencing, and connecting) that help teachers orchestrate meaningful mathematical discussions. In this paper, we explore the integration of Padlet in a mathematical discussion concerning problem solving. We use the model of Stein and colleagues as a theoretical framework to design an experimental plan for investigating whether and how Padlet is used in the planning (anticipating, monitoring), execution, and management (selecting, sequencing, and connecting) of such discussions.

Padlet, a versatile digital tool, enables the posting of various content types, such as images, links, videos, and documents. Utilizing Padlet in education facilitates the creation of a collaborative digital space between teachers and students. Accessible to all, this virtual wall allows viewing and adding diverse content seamlessly. Padlet is adaptable in educational contexts (Shuker & Burton, 2021), and particularly in mathematics education, suggests the need for further exploration to enhance mathematical discussion effectively. A previous study (Giberti et al., 2022), focused on grade 7 Italian students, highlighted that mathematical discussion in a classroom is a complex phenomenon wherein different factors interweave, and the use of Padlet highlights some of these aspects and promotes a more inclusive discussion. Nevertheless, the role of the teacher is fundamental because he/she acts as a mediator in raising turning points and catalysts of these different variables and processes.

In this contribution, we focus on this role, using a specific theoretical framework concerning mathematical discussion orchestration. The research question we aim to answer is: When and how does the teacher use Padlet in the process of orchestrating the discussion? To this end, we discuss an experimentation that illuminates the role played by Padlet's affordances while a teacher orchestrates a discussion concerning a mathematical problem.

Theoretical Framework

The metaphor of the "orchestra" is shared in the literature to refer to whole-class discussions and the management of the polyphony of voices involved (Bartolini Bussi, 1996). Stein and colleagues (2008) use the term *orchestration* to refer to the teacher's role in managing students involved in a discussion. The authors designed a pedagogical model of five practices for discussion facilitation starting from a mathematical task. The model's practices support both the planning phase of the discussion by the teachers and the orchestration phase involving both students and teachers. These practices are anticipating, monitoring, selecting, sequencing, and connecting.

Anticipating students' responses means imagining or predicting how students might tackle the tasks. Tackling the problem may mean how they interpret the text or the task situation, the set of strategies they might use, the difficulties they might encounter, and so on. *Monitoring* students' responses means observing and following the resolution process that students are employing as they attempt to answer the task. In this practice, the teacher observes students at work to gather information on the activated processes. Anticipation and monitoring play crucial roles before and during task resolution, providing valuable support to teachers during the discussion. In contrast, the practices of *selecting* and *sequencing* are integral to the overall management of the class discussion, with the former two practices serving as foundational elements for the latter two.

The five practices are interconnected with each other, benefiting from the outcomes of the preceding ones. For instance, the information gathered in the monitoring practice can serve to select students' responses. Similarly, insights gained through the anticipation practice can guide the teacher in sequencing these responses. Lastly, the *connecting* practice aims to establish links between emerging mathematical ideas derived from collective solutions. Stein and colleagues (2008) underlined the role of these practices in fostering the development of robust mathematical concepts by emphasizing the significance of valuing students' responses and products.

Methodology

Experimental Plan

We structured a problem-based activity in four phases, following the theoretical framework, to involve students in a mathematical problem and observe the teacher orchestrating a whole-class mathematical discussion.

The first lesson consisted of phases 1, 2, and 3, during which students were engaged in group activities to deal with the problem and share and comment on other groups' strategies. In phase 1, the teacher posed the problem to the students by opening the Padlet. Then, she described the problem verbally and asked the students to observe it directly on their smartphones. Then, the teacher asked students to post their strategy and reasoning in detail on Padlet. The reasoning needed to be clear to their classmates belonging to other groups, as then they would have to comment on it. This phase concerns a part of the anticipating practices. Indeed, in these 5 minutes, the teacher could anticipate possible difficulties regarding the text or the context comprehension, and he/she could ask students if they understood what they were asked to do. In phase 2, each group posted its hypotheses/strategies in the Padlet. In this phase, Padlet was set up with the 'request approval' mode for comments and reactions (so each group did not see other groups' posts but only their own). Finally, in phase 3, the teacher made posts visible and allowed comments on posts so that each group could read and comment on posts from other groups. Phases 2 and 3 regard the monitoring practice: in the first, the teacher could observe groups' work, strategies, and attempts through the posts; in the second, she could realize what students think about their classmate strategies: whether they appreciate or not their mate strategies, if they compare the solution and so on.

Finally, phase 4 focused on the mathematical discussion, which started by visualizing the posts on Padlet. In the final discussion, the teacher could activate the connecting practice. Selecting and sequencing practices could be used in both phases 3 and 4; precisely, the teacher could select and sequence students' strategies before the beginning or during phase 4. The comments in phase 3 could support selecting and sequencing practices because they allow the teacher to go beyond the collection of groups strategies. The ongoing discussion (phase 4) could permit the teacher to release new information about emerging mathematical ideas and change some selecting and sequence choices.

Participants, data collection, and data analysis

We collected data in a grade 9 class composed of 27 students from a scientific high school in Italy. The teacher is an expert teacher who collaborated on several mathematics education projects. She had already used Padlet to promote mathematical discussion in other classes, but this was the first time she used Padlet in this classroom. She was informed about the main aim of the project, but she did not know Stein and colleagues' model. She described her students, stating that half of them have strong skills in mathematics while the others have difficulties, and two of them have a diagnosis of dyscalculia. Students are used to working in groups and discussing their ideas during mathematics lessons. In our experiment, students divided autonomously into groups of three people each. Each group chose a nickname and communicated it to the teacher; only the teacher was aware of the nickname-group correspondence.

The data collected consists of the Padlet wall used in the experiment. Thus, we have access to the groups' posts and comments in their final position, the one set by the teacher to orchestrate the final discussion. This discussion was video-recorded. Next, we interviewed the teacher, showing her pieces of video and asking her which strategies she was implementing at that given moment and why.

The mathematical problem

The mathematical problem to consider in order to implement a problem-based activity must be wide-ranging (van den Heuvel-Panhuizen & Becker, 2003), allowing students to express themselves and show what they know and can do with greater freedom. To this end, we started considering problems from the OECD-PISA test; we chose the "Continent Area" problem. To answer, students have to estimate the area of a continent using the map scale and explain their strategy. We considered this item because it can be tackled using different strategies (e.g., constructing grids or decomposing the figure using simpler shapes such as rectangles and circles), and thus it can be considered a wide-ranging problem.

Taking a cue from the “Continent Area” problem, we designed a new one: “Oil spill in the Gulf of Mexico” (Figure 1). To solve the problem, students have to consider two figures representing a map of the Gulf of Mexico and a satellite photo of the oil spill. The distance between two cities in the geographical map is the only numerical data given.

An oil rig explodes in the Gulf of Mexico. A month later, a NASA satellite photo shows the ecological disaster. Figure A is a map of the Gulf of Mexico. Figure B is a satellite photo of the oil spill made a month after the explosion, with its edge marked. The rectangle with red edges in Figure A corresponds to the satellite photo in Figure B.

Estimate the extent of the ecological disaster by calculating the area of the ocean polluted by the oil spill.

- Consider that the distance between Austin and Jacksonville is 1600 km, as the crow flies.
- You can draw on the printed map if it helps; if so, upload a photo of it to Padlet as well.

Show your work and explain how you made your estimate.

Figure 1: Problem “Oil spill in the Gulf of Mexico”

Results

In phase 1, the teacher presented the problem in Padlet and read it aloud. She described the problem verbally and asked the students if everything was clear. This phase pertains to the *anticipating practice* because the teacher ensures the assignment is clear and checks if the students have doubts about the text, the stimulus, and the images presented. In this first phase, Padlet is only used to present the problem; therefore, we cannot identify it as a support for anticipation. In the second phase, the teacher asked the students to post their hypotheses/strategies in the Padlet. This is the moment for the teacher to *monitor* students’ work. In fact, the teacher observed the work of each group and followed the attempts made and the strategies used. In her words, “The functionality of Padlet permits posts visible only for me; this allows every group to reflect on their strategies and allows everyone to think without being influenced by others.”

Through Padlet’s posts, it is possible to realize that many groups approached the problem with graphical strategies. In the post reported in Figure 2a, the students determined the area of the rectangle circumscribing the oil spill. They copied the image onto tracing paper, subdividing the rectangle into small squares. They identified the estimated area of each square and finally counted the number of squares contained in the oil spill. Three other groups chose to approximate the ground surface through rectangles and removed it from the total rectangle surface. In this way, they identified an estimation of the sea surface depicted in Figure 1 (Figure 2b).

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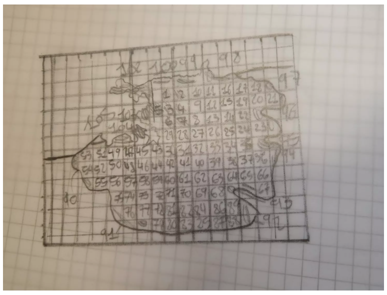
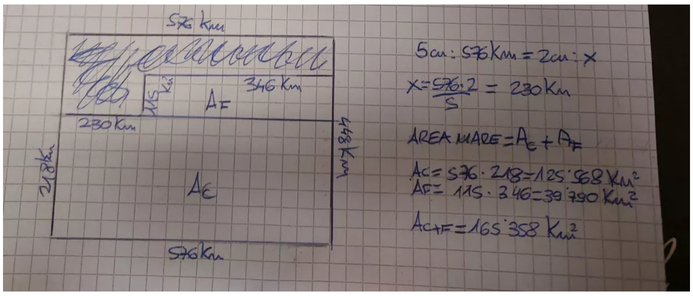


2a. Example of subdividing into small squares



2b. Example of subtracting area

Figure 2. Example of students' strategies

It can be noticed that other two groups of students identified the sea area by estimating the ratio of land and sea area. In this last example, students did not use pictures but only written argumentations:

> "We started looking for the solution by estimating the base of the rectangle (here Figure 1- Figure B), and we did this by taking the distance from Austin to Jacksonville, which is 1600 km, and assumed that the base was about 2/5 of this distance. Next, we assumed that the height of the rectangle was about 2/3 of its base because by imagining taking the height segment to the base, it appeared to be about this size. Finally, we estimated the area of land in the rectangle, which is about 1/3 of the area of the square, because to obtain the solution, we only needed the area of the ocean contaminated by oil, so the area of the piece of land was not needed. Consequently, the result of the water area was 2/3 of the total area."

In summary, during the interview, the teacher shared that Padlet allowed her to observe the strategies chosen by the students before opening the discussion. She said: "Padlet works as a dashboard collecting and organizing all solutions at once: it provides an overview of all strategies and students' answers." The teacher could observe that most students preferred graphical rather than arithmetic/algebraic approaches. She also observed that there were different graphical approaches: the two strategies (subdividing into small squares versus subtracting areas) are similar because they make use of graphical representation but also differ in the implemented mathematical process (decomposition versus difference). She concluded by stating: "Students proposed strictly different approaches despite the fact they already worked together on polygon areas".

In the third phase, the teacher made all posts visible and asked each group to comment on the posts of the others. Being able to read the group comments provided the teacher with additional *monitoring* information to use in *selecting*, *sequencing,* and *connectin*g practices. She noted that the groups' comments suggested a preference for the graphic representation. In various comments on arithmetic approaches, we read: "In our opinion, the calculations performed are accurate and correct, but a graphical representation of what has been done is absent." And again, some students highlighted algorithmic errors; for example, in some comments, we read: "The estimation is quite right, but some calculations are wrong: $\frac{2}{3}+\frac{2}{5}$ is 16/15." The teacher also realized that those who chose graphical approaches were retained as inaccurate by their classmates and too approximate in their solutions. For example, "The final approximation is inaccurate because the method used is not precise." In addition, students pointed out the confusing argumentation and the lack of details in the post. In general, accuracy seemed to be a topic of great interest for students.

To summarize, students' comments provided the teacher with important information. For example, which strategies were welcomed by classmates, which were appreciated, and finally, which were contested. The teacher decided to start phase 4 based on the groups' comments: "Comments were articulated, and students were excited to comment on their classmates' works. It was an opportunity for me." At the first moment, she discussed them and highlighted that some were not so rich, whereas others were detailed. Then, she asked students if some strategies impacted them. No students answered, so she decided to change strategy, proposing "show and tell"; i.e., she asked: "Did you all give the same answer? So, let's start by explaining which strategy you chose to answer. Let's start with group 1. Let's take a look, and then we will discuss differences and similarities". In this case, the teacher undertook the *selecting* and *sequencing* practices following the order of the posts on Padlet, and this choice did not support her in the subsequent *connecting* practice. After this first "show and tell" moment, the teacher asked students to find the differences and similarities between the strategies used. She listed on the blackboard the three main strategies used, helped by students who were looking at the Padlet to check them. The teacher picked up on similarities in the students' comments and used them to *connect* emerging ideas about possible solving strategies.

Then, she asked students: "Now you have seen your classmate's strategies. Is there a 'better strategy' you would choose, or are you already sure of yours?". This question opened a discussion about what 'accuracy/rigor' meant: many groups responded that they would implement the same strategy using more accuracy or precision. This question moved students to discuss and compare the two arithmetic strategies. In particular, the teacher prompted students who used the estimated ratio of land and sea area to explain their strategy to their classmates. One group claimed they guessed the estimation with their hands rather than using the ruler as other groups did. With this answer, the teacher came back to the word 'accurate'. In the comments, students often underlined the lack of accuracy of the graphical strategy in favor of the arithmetic ones. The first arithmetic strategy brought out the use of eye estimation which was then recognized as inaccurate. The teacher asked: "Does accurate mean reaching the closest result, or measuring and not guessing?". In this way, the teacher came back to *selecting* and *sequencing* and moved her students to sort the groups' answers by accuracy. Padlet allowed everyone to see the posts commented on and discussed (both on the interactive whiteboard and their smartphones). This was also underlined during the interview: "The fact that Padlet was accessible to students during the discussion, and they can navigate it independently multiplies the connections between the answers."

Discussion and conclusion

In this contribution, we investigated the use of Padlet by a teacher for orchestrating a mathematical discussion. We presented a discussion in which an Italian teacher and her students dealt with a mathematical problem and discussed students' strategies supported by Padlet. The analysis of the whole activity focused on the use of Padlet throughout the different pedagogical strategies referred to the model by Stein and colleagues (2008). This contribution starts from an open issue raised in previous studies (Giberti et al., 2022) in which authors suggest investigating how dynamics in classroom discussion depend on the specific features of the teacher's teaching style.

In this example, the monitoring phase through Padlet offered the teacher the opportunity to discuss a topic of interest to the students, the accuracy of estimation, and to value shared ideas that emerged in students' comments. In this case, the use of Padlet was decisive in facilitating the activity and allowing students to post their responses, thoughts, and strategies directly as they engaged with tasks. The digital platform offered students the opportunity to comment on their classmates' strategies; without Padlet, the teacher would have had difficulty in observing this variety of strategies. Students also worked anonymously, and the teacher chose when and how to show the posts, avoiding any bias in the opinions on others' posts. In addition, Padlet allows time and space management in a different way: for example, groups could not see who had already posted the answers, and this may limit the so-called anxiety of having to finish first. The teacher also claimed, "Padlet guarantees continuity in the classroom activities: its dashboard features allow for restarting the next lesson without making the effort of recalling everything that was said in the previous one."

The possibility of viewing all posts together on Padlet during the selecting and sequencing practices led the teacher to distinguish graphical or arithmetic approaches, focusing on the different strategies that could be used within the same approach. However, other choices might have been adopted; for instance, she could have started from the most to the least appreciated strategy or vice versa, dealing with the problem of sharing strategies or discarding others. In any case, the data collected with Padlet seems to open up multiple possibilities for orchestrating discussion. Similarly, the teacher could collect the written answers on sheets of paper without the support of the technological tool. In this case, the potential of Padlet is to immediately display all answers together in one place, without scattered sheets. Considering our experiment, Padlet was useful to students when the teacher wrote the strategies on the blackboard because it allowed them to look at the Padlet and control that every post was considered. On the other hand, Padlet could have affected the teacher choices in the selecting phase: she decided to consider the order of the posts for a "show and tell" moment; if the post had been in a different position, the first phase of the discussion could have been different. Padlet revealed its suitability, even during the orchestration of the whole-class discussion. As a dashboard, it shows all posts together as on a wall, and in this way, both students and the teacher have the possibility to compare and discuss all strategies simultaneously. In the absence of the technological device, the students and teacher would only have been able to use the blackboard. This would have required more time for writing and fewer expressive possibilities.

In any case, it should be noted that any digital technology has weaknesses; for example, the posts in Padlet could suggest students use short and basic messages (as in many community platforms), which might limit students' engagement or deep strategy descriptions in the problem-solving activity. This is also confirmed by the teacher who said: "Padlet, as a digital tool, encourages a writing style that evokes other digital platforms (for example, Instagram, WhatsApp). I noticed short messages and replies. The complexity is sometimes lost in the brevity of students' messages." In addition, Padlet does not facilitate verbal exchanges between groups. This may limit the teacher's role in the monitoring practice. The versatility of Padlet's posts is held back by limitations: it does not have an extensive library of mathematical symbols and creating graphs and diagrams is not intuitive. This limits the type of feedback classmates or teachers can provide.

In conclusion, while summarizing when and how the teacher used Padlet, we also highlighted other modalities and other strengths for using such a digital tool. For instance, sharing the theoretical framework of Stein and colleagues (2008) with the teachers involved might highlight other and new potentialities of Padlet that are still to be explored. Actually, the teacher involved used well-established pedagogical practices in her orchestration even without being fully aware of them from a theoretical point of view. For less experienced teachers, it might be more complex, and introducing a new digital technology may require specific training to fully exploit all features essential for a successful orchestration of a classroom discussion.

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