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Potentialities and Limitations of Cross-National Problem-Solving Discussion using Technology

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Abstract

Problem solving in mathematics requires students to apply mathematical competencies, including effectively communicating their reasoning. Here, we consider the use of technologies in mathematics education to promote cross-national collaboration between students in discussions triggered by problem-solving activities. We focus on a novel form of mathematical discussion facilitated by the online platform Padlet. This discussion begins in Padlet, where students propose their solutions to a mathematics problem using posts that might incorporate various communication registers. In our experiment, this platform facilitated collaboration between classes from different countries, as paired classes from Argentina, Canada, and Italy exchanged their Padlets with each other. This promoted collaborative efforts between students from different countries. Thus, Padlet became a medium for multilevel classroom discussions. In this snapshot, our aim is to consider the perspective of the teachers involved in this collaboration. Thus, we conducted a SWOT analysis based on teachers' voices to highlight the potentialities and limitations of promoting such international mathematical collaboration and discussion. This prompted the formulation of new strategies to enhance the achievement of such transnational mathematical discussion.

Keywords Cross-national collaboration · Digital technologies · Mathematical Discussion · Padlet · Problem-solving

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Introduction

The extensive use of technologies in mathematics education over the last few decades has led to the exploration of several possibilities. In the meantime, new questions have emerged, for instance, regarding the reasons behind teachers' and researchers' choices in integrating technologies into teaching practices (Drijvers & Sinclair, 2024). One of the possible purposes of using technologies is to more precisely enact teaching goals. Bray and Tagney (2017) observe that the introduction of technologies could be proposed to improve collaboration and mathematical discussion. This is true both for out-of-class discussion, which develops through social media (Biton & Segal, 2021), and discussion in the classroom, but mediated by a digital platform (e.g., Gagliani Caputo et al. 2025; Giberti et al. 2022a; Maracci et al. 2024). In our previous works conducted in the Italian context (Giberti, 2022b, 2025), we reported on experiments in which Padlet[1] was used as an online platform for students to post their solutions concerning a mathematical problem. In those experiments, the students read and commented on their peers' ideas. Posts and comments on the Padlet were submitted anonymously and were initially visible only to the teacher, ensuring that students took the necessary time to think and write their own ideas. This fostered comments from a wider audience than usual. All students participated in the activity without being afraid of being judged for the ideas they posted. Afterwards, the teacher orchestrated a discussion which was *hybrid* (meaning both in the classroom and in the Padlet) and *multilevel* (meaning it was designed to have multiple steps to collect students' interactions in the class and in collaboration with other classes) (Giberti et al. 2022a). In this mathematical discussion we observed a broader participation, in which a positive culture of errors (Borasi, 1994), the enhancement of a variety of resolution strategies, and the inclusion of students who do not usually participate emerged. Padlet enriched the discussion by providing explicit elements used by both the teacher and the students (Lemmo et al., 2024), offering external inputs, and facilitating a critical analysis of statements and arguments (Giberti et al. 2022a, 2025).

These previous experiments prompted our international dialogue and motivated a collaboration to connect students in mathematical problem solving across national borders. We hypothesized that cross-national collaboration could offer several benefits. It broadens perspectives, providing teachers and students with a wider range of mathematical concepts and problem-solving approaches. Besides promoting cultural exchange (across different national and classroom cultures), it allows teachers to adopt innovative teaching practices from international peers, improving their instructional methods and fostering student engagement. In addition, accessing different problem-solving methods encourages students' critical thinking and adaptability, enhancing collaboration and communication across cultural and language differences (see, for instance, Atweh et al., 2007). Our experiment aimed to understand how Padlet could promote a multilevel hybrid mathematical discussion across diverse contexts when used to support an open problem-solving activity, thus an activity based on a task that invites multiple solution strategies and different representational forms. Our hypoth-

[1] https://it.padlet.com/.

esis is that this kind of discussion supports the engagement of students with culturally meaningful themes and promotes a fruitful collaboration among researchers, teachers, and students at the international level. Indeed, we argue that problem solving in mathematics requires students to enact their mathematics competencies, as defined by Niss and Højgaard (2019) in the KOM framework, including communicating about math with their peers. A problem-solving activity could then be an optimal starting point for a rich balance discussion (Bartolini Bussi et al., 1995), that is, the process through which the proposed solutions to a problem are explained, examined, compared, and evaluated. Nowadays, students are comfortable with communication through social media; thus, they have the means to communicate cross-nationally and cross-linguistically using technologies. These are the primary motivations behind promoting and investigating mathematical discussions across national borders. Previous research on cross-national or culturally diverse mathematics education contexts has shown that technologies can foster new forms of interaction and reflection for both teachers and students (Llinares & Olivero, 2008; Llinares & Valls, 2010). In particular, digital platforms can support meaningful communication and the development of professional and mathematical discussion. Moreover, studies on multicultural classrooms highlight how cultural and linguistic diversity can enrich students' mathematical practices and broaden perspectives (Barwell & Kaiser, 2005). These insights strengthen the motivation for engaging students in international mathematical exchanges.

A Cross-National Problem-Solving Activity with Padlet

Here we report the first results of our international collaboration, which involves mathematics education researchers and teachers from Argentina, Canada, Israel, and Italy. The project lasted 8 months (April to December 2023); during this period, seven international meetings were held online involving teachers and researchers. The research focuses on the situations that Padlet creates in a cross-national mathematical problem-solving discussion (considering the discussion on Padlet and in the classroom, thanks to Padlet support).

The question that guides this investigation into our practices is: What potentialities and limitations do teachers attribute to Padlet in supporting mathematical discussion during an open problem-solving activity in a cross-national context?

Experimental Plan

The experiment involved pairs of classes in Argentina, Canada, and Italy (owing to the war that started in the autumn of 2023, it was impossible to involve classes from Israel). Thus, six classes spanning Grades 9 to 11 were involved. We paired classes based on curricular considerations and on teachers' contextualized descriptions of how students typically engage in collaborative work:

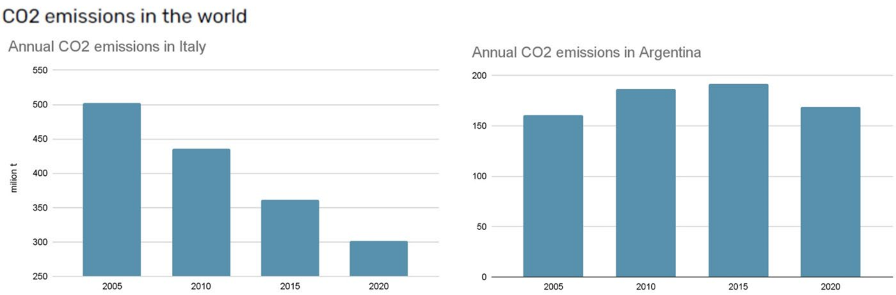
- Grade 9 class in Italy - Grade 9 class in Argentina.
- Grade 9 class in Canada - Grade 10 class in Italy.

- Grade 10 class in Italy - Grade 11 class in Canada.

The class pairing was discussed among teachers and researchers in relation to classroom practices, students' approaches to problem solving, and shared sociomathematical norms (Yackel & Cobb, 1996). In this sense, the pairing was informed not only by curricular considerations but also by teachers' descriptions of how students typically engage in collaborative work, use representations and strategies, and participate in whole-class discussions.

In groups of three to four, students faced the same math problem. Selecting an appropriate problem was a crucial and challenging step for the international team; the chosen problem emerged from an extensive discussion in which we examined and compared a wide range of ideas and proposals. We ultimately agreed on broad, non-routine problems that are capable of eliciting multiple solution strategies, requiring justification, making students' thinking visible, and offering a "low-threshold, high-ceiling" structure (Canogullari & Radmehr, 2025) to ensure that all students can meaningfully participate. This choice would be particularly important in a cross-national setting, as the task needed to be accessible across different curricular traditions while still allowing for diverse interpretations, approaches, and strategies.

The problem was inspired by the 2003 PISA problem, the Robberies (problem M179), which requires students to analyze and interpret a misleading graph (OECD, 2006, pp. 34–35). In our adapted version of the problem (Fig. 1), two graphs illustrate the annual CO_2 emissions in two different countries (those of the classes involved in



A TV reporter showed these two graphs and said: *"The graphs show that there is a huge decrease in the annual CO2 emissions in Italy from 2005 to 2020 while the situation is more critical in Argentina where the amount of CO2 is not decreasing"*.

A few days later, in a newspaper, the same two graphs were reported. The title of the paper is *"Argentina as a model to reduce CO2 emission: lower annual CO2 emissions than Italy and other countries"*.

Data from both the two graphs belongs to the same website: ourworldindata.org

- **Which of the two statements do you think is a reasonable interpretation of the graphs? Give an explanation to support your answer.**
- **Please, write a short post, possibly using graphs, aimed to give an unequivocal and clear explanation of the two given graphs.**

Fig. 1 Problem used in the collaboration between Italian and Argentinian classes the cross-national discussion), revealing different trends. The socio-environmental theme could also provide a common yet locally meaningful reference point for students from different countries.

The problem used (Fig. 1) exemplifies the principles that guided our selection process. Although it presents two statements that can be interpreted differently from the graphs provided, it invites students to decide which interpretation is reasonable and justify their choice. The research team agreed on this task because, while it is accessible to Grade 9 students, it still offers substantial challenges for Grade 11 students. It encourages students to explore the given data, compare it with information they find online, and engage with a socially and ecologically relevant issue. In this way, the problem maintains a “low-threshold and high-ceiling”, supporting diverse solution paths (e.g., directly interpreting graphs, rescaling axes, and creating a new graph merging the two provided) and meaningful participation for all students.

The experiment was designed in different phases (Fig. 2): phases 1 and 2 formed the initial part of the experiment and were conducted for each class on the same school day, while phases 3 and 4 were conducted in the following days. In particular, the students of each class, working in groups, posted on the Padlet their solution to the problem and their reasoning without having the opportunity to see the solutions of the other groups (phase 1: 30–40 min). Students worked in the Padlet using the nicknames of their groups; none knew which students were in which group except the teacher. Then, the teacher made all the class posts visible, and groups were asked to comment on their classmates’ proposals (phase 2: 30–40 min). The Padlet was then shared with the parallel class from the other country, and students from both classes commented on each other’s posts (phase 3: 30–40 min). Students then read

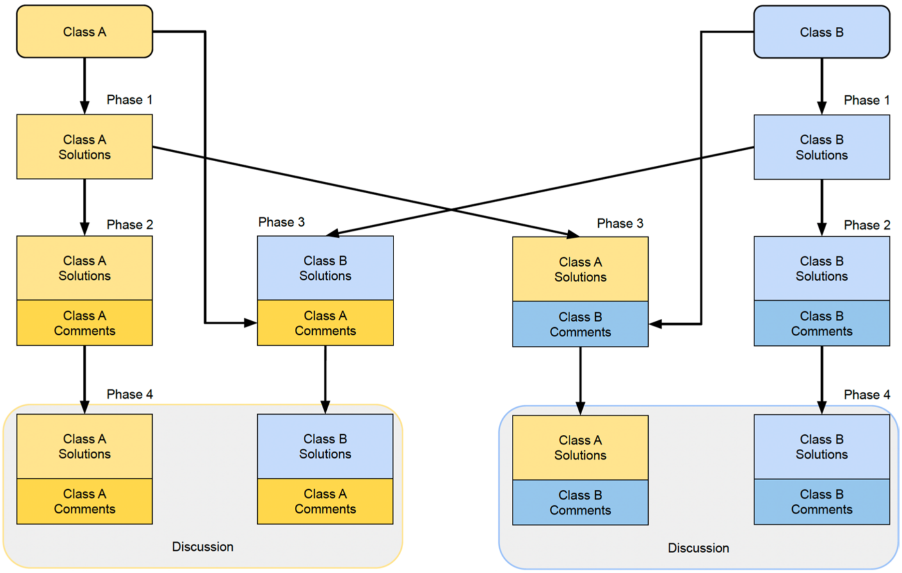


Fig. 2 Schematic representation of the experiment

and considered the comments and feedback from their peers in their paired class and participated in a final discussion with their teacher (phase 4: 60–80 min).

Data Collection and Methods

To highlight the potentialities and limitations of a mathematical discussion beyond national borders, we will focus on the participant teachers' reflections elaborated based on a SWOT analysis. SWOT analysis (Helms & Nixon, 2010) is a strategic management tool based on a 2 × 2 grid (Fig. 3). It helps describe the situation under examination by identifying internal factors within an organization (Strengths and Weaknesses) and external factors in the surrounding environment (Opportunities and Threats). In general, this analysis supports strategic decision-making by highlighting how strengths can be leveraged to capture opportunities and how weaknesses may expose the organization to external threats.

Given the exploratory nature of our study, we adopted the SWOT analysis to foreground teachers' perspectives on the potentialities and limitations of using Padlet in cross-national problem-solving discussions. Specifically, in the SWOT analysis we conducted, the organization refers to each class engaged in the activity. Internal factors include elements inherent to the classroom setting during the experiment, such as available resources, teachers' and students' competencies, teaching practices, and the ways in which the task and Padlet were enacted. These factors fall within the sphere of classroom practice, where teachers exercise agency. Mathematical aspects of the activity are considered internal insofar as they emerged within classroom practice and were addressed through teachers' orchestration of the task and discussion. External factors refer to broader contextual conditions that shape or constrain classroom activity, including national educational policies, institutional frameworks, technological infrastructures, and socio-economic contexts. This distinction is particularly relevant in a cross-national setting, as it enables us to analyse how similarities and differences across contexts influenced the development of mathematical discussion.

As not all teachers and researchers were familiar with SWOT analysis, an initial meeting was held to clarify its structure and to agree on the interpretation of internal and external factors within this specific experiment. The four participating teachers (one from Argentina, two from Italy, and one from Canada), each supported by a researcher from their country, independently completed a SWOT grid. Their reflections were then shared with the international team, and collectively discussed and refined. The data from the SWOT analysis were subsequently explored induc-

Fig. 3 Schematic representation of the SWOT analysis

tively using thematic analysis (Braun & Clarke, 2006) to identify recurring themes across the four dimensions. The SWOT analysis provided the structural organization of teachers' reflections (strengths, weaknesses, opportunities, and threats), while the thematic analysis allowed us to identify patterns within and across these dimensions.

To go one step further, the researchers' team observed that, within these themes, teachers described aspects related to students' mathematical competencies, which we frame in light of the eight competencies proposed in the KOM framework (Niss & Højgaard, 2019): mathematical thinking, problem handling, modelling, mathematical reasoning, dealing with different representations, handling symbols and formalism, communicating, and handling aids and tools. The KOM framework was not used as a predefined coding scheme; rather, it was employed a posteriori as an interpretive lens to examine how the themes emerging from the analysis relate to different mathematical competencies. Thus, the identification of competencies did not guide the coding process but resulted from an interpretive alignment between the emergent themes and the KOM framework.

Results of SWOT Analysis and Analysis of Teachers' Perspectives

In presenting the results, teachers' reflections are organized according to the SWOT dimensions (strengths, weaknesses, opportunities, and threats), while the themes emerging from the analysis are also interpreted in relation to the KOM competencies.

Strengths of Discussion with Padlet

The first aspect that emerged from our analysis is the general agreement between the strengths as identified by the teachers. Many comments addressed *Padlet's functionalities* that were used by students and teachers during the activity. Teachers from all countries commented on an "easy-to-use platform" that benefits both teachers and students. For example, the Canadian teacher highlighted several possibilities of expression for students, thus enabling students to use different semiotic registers to describe their mathematical ideas: "The interface was straightforward for students to use, and it was easy for them to post media, such as photos, to support their arguments". The Italian teacher and the Argentinian teacher also emphasized the strength of promoting the use of various registers and highlighted the benefits of solving the same problem in multiple novel ways, using videos, photos, links, and other media to present their solutions. This flexibility of media, which includes words, symbolic notation, and graphs, was perceived by teachers as significant for the students, who had the freedom to explore mathematical competencies such as dealing with different representations of mathematical objects and communicating in, with, and about mathematics. These strengths were reflected in students' work on the Padlet and enriched the classroom discussion. For instance, one Italian group (Fig. 4a) integrated a digital graph with an online source and a written explanation. Both in Italy and in Argentina, students enriched their argumentation with contextual information and external data. In several posts, students explicitly integrated hyperlinks or extended the temporal range of the dataset beyond the one provided in the original graphs, thereby expand-

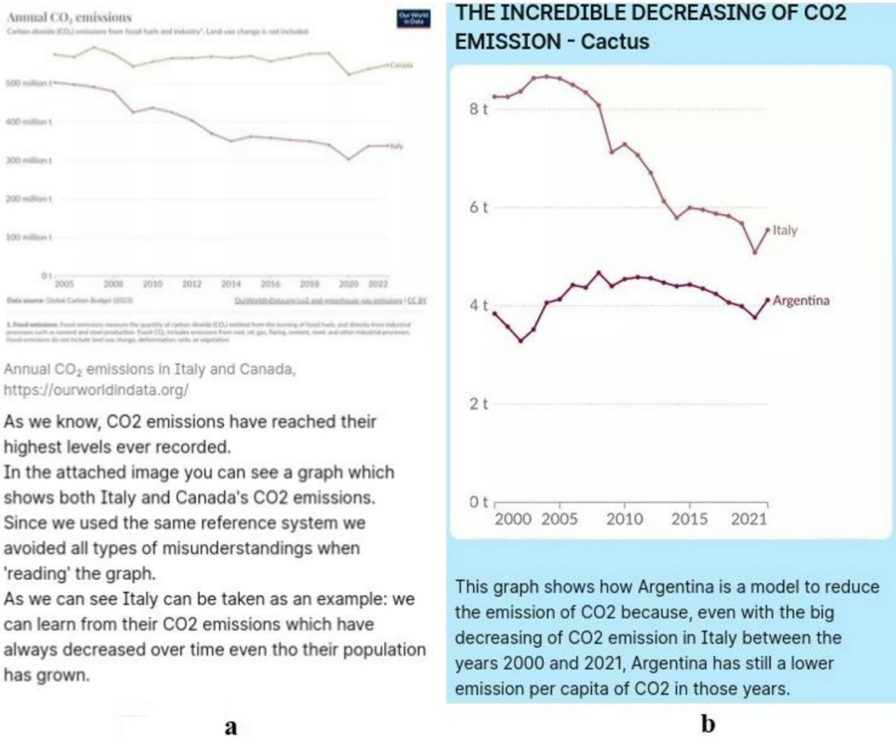


Fig. 4 Examples of posts from different classes and countries. Figure 4a and b were spontaneously written in English by the Italian and Argentinian students

ing the frame of reference of the task. An example is the post from an Argentinian group (Fig. 4b), which considers a wider year range.

Other groups, both Italians (Fig. 5a) and Canadians, combined digital or hand-drawn bar charts with a concise interpretation, or reported the graph of the task, adding new details (Fig. 5b). In some cases, students produced modified or merged representations in order to compare the two countries within a single visual frame. The specificities of the problem proposed required to read, create, modify and share data representations, and the discussion in the classrooms started considering the posts created by the students and posted in Padlet. This possibility of integrating external sources within the same discussion space was perceived by teachers as a strength, as it allowed students to situate their interpretations within a broader informational context.

The Italian teacher stated that the use of Padlet guarantees continuity in classroom discussion as "its dashboard features allow the teacher to start the lecture without making the effort of recalling everything that was said in the previous one." Other teachers' reflections concerned the different timing guaranteed by the Padlet in terms of "speed/efficiency" and easily managed by the teacher: as highlighted by the Argentinian teacher, Padlet gives the possibility to make a "production of a conjectural script containing the details of the relationships and links between the different

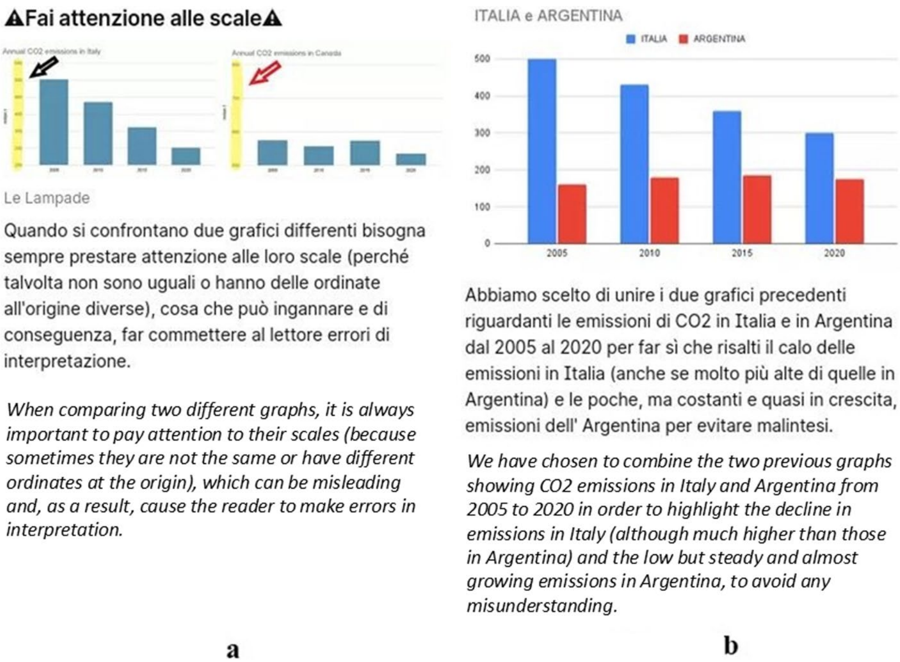


Fig. 5 Examples of posts from different classes. The translation is provided below each post

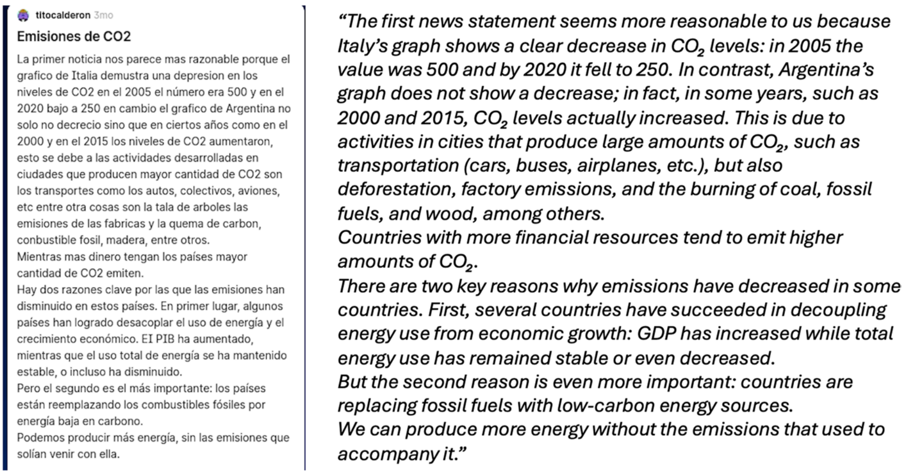


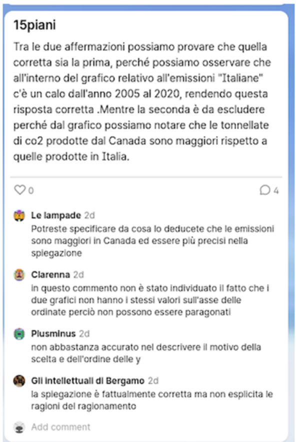
Fig. 6 Example of an extended post from the Argentina Padlet, featuring a detailed explanation supported by external information. The translation is provided on the right side

students' answers before the class debate" that "allowed for a smooth running" of the class mathematical discussion. In line with these statements, in all the contexts involved, teachers state that Padlet appeared to support mathematical reasoning competency, particularly by making students' argumentations visible and comparable.

For example, in the Argentina Padlet, a group produced a long, detailed explanation enriched with external information (Fig. 6), illustrating the considerable variation in the length and structure of students' contributions across the Padlet. This visible variation in the length and structure of contributions made different approaches simultaneously accessible to the whole class. Such extended posts enabled the teacher to anticipate the mathematical links among students' ideas and to prepare a conjectural script before the in-class discussion.

In addition, the Italian teacher stated that "Padlet offers immediacy in posting content and receiving comments and feedback. Padlet uploads easily: anyone can see immediately what was written (Fig. 7), and several devices [also from the same group] can access and work on Padlet at the same time.". Speaking about students' comments to the posts, the Canadian teacher underlined that "Their counterparts could copy and paste their solutions and edit them (maybe using a different font colour) to provide feedback easily." and this was helpful in providing useful feedback in the Padlet discussion and promoting problem solving.

The Italian teacher also highlighted a new strength of Padlet, which teachers from all countries emphasized: its collaborative nature. Indeed, she stated that "Padlet makes it possible to log in with the same user, and this feature makes group work easier". This aspect supports mathematical thinking competency by engaging students in mathematical inquiry. Furthermore, the Canadian teacher highlighted that "Students were able to collaborate effectively with their counterparts in Italy" and that Padlet facilitated collaboration at an international level, also because it "allowed for easy translation between the two languages". Indeed, the collaboration between classes from different countries did not limit students' participation in the Padlet discussion: Argentinian students wrote their posts in their language, as many Italian students did, and the use of online translation tools allowed the understanding of dif-



"Between the two statements, we can show that the correct one is the first, because in the graph for 'Italy' we can observe a decrease from 2005 to 2020, which makes this answer correct. The second statement should be excluded because, from the graph, we can see that the tonnes of CO_2 produced by Canada are higher than those produced by Italy."

Comments
Le lampade: "You could specify what exactly makes you conclude that Canada's emissions are higher, and be more precise in your explanation."

Clarenna: "In this comment you did not point out that the two graphs do not have the same scale on the vertical axis, so they cannot be compared directly."

Plusminus: "Your explanation is not precise enough in describing the reason for your choice and the order of the data."

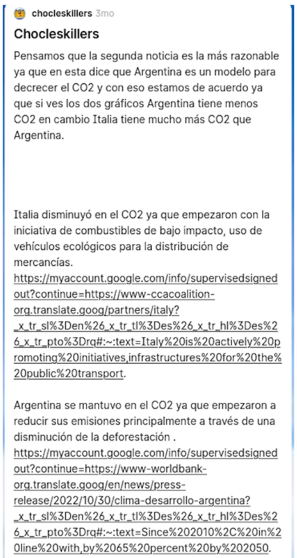
Gli intellettuali di Bergamo: "The explanation is factually correct, but it does not clearly justify the reasoning behind it."

Fig. 7 Example of a Padlet post displaying multiple student comments arranged sequentially beneath the original contribution. The translation is provided on the right side ferent languages; furthermore, some Italian groups, engaged in the collaboration with Canadian students, wrote their posts spontaneously in English.

Opportunities for Education

The teachers highlighted numerous opportunities for mathematics education, particularly in relation to Padlet's functionality and its collaborative nature. In this case, each context highlighted distinct yet important aspects. The Italian teacher focused on aspects of *inclusion and equity*, which are particularly relevant in the Italian school context, characterized by inclusive classroom settings, where students with special needs learn alongside their peers and where classes display heterogeneous learning levels. She argued that "the functionality of Padlet of keeping posts hidden and publishing them only after everyone has reflected on their strategies allows everyone to think without being influenced by others." The different timing in participating in the Padlet discussion also emerged as an opportunity given by Padlet. The Argentinian teacher remarked how the "Availability of the school's technology and infrastructure (Wi-Fi connection and digital whiteboard) and students' personal technological devices (mobile phones, tablets, and notebooks) to post on the Padlet and then project the students' resolutions and comments" contributed to the success of the experiment. Argentinian students frequently integrated external sources in their Padlet posts. For instance, a group included multiple hyperlinks to news portals and energy reports (Fig. 8), something that was only possible because students had immediate access to devices and a stable Internet connection during the activity.

The Italian teacher also mentioned the importance of using Padlet during the classroom discussion to improve *students' independence*: "The fact that the Padlet



"We think that the second statement is the most reasonable one, because it says that Argentina is a model for reducing CO_2, and we agree with this since, if you look at the two graphs, Argentina has lower CO_2 levels while Italy has much higher emissions than Argentina.

Italy's CO_2 decreased because they began using low-impact fuels and ecological vehicles for freight transportation. (link)

Argentina's CO_2 remained stable because emissions were mainly reduced through a decrease in deforestation." (link)

Fig. 8 Example of an Argentinian group's Padlet post featuring multiple external hyperlinks to news sources and energy reports. The translation is provided on the right side is accessible to students during the discussion and that they can navigate it independently during the discussion multiplies the connections between the answers." She also stated that her students appreciated "the idea of comparing [them]selves with other classes, near and far," and this led to interactions that "can go beyond mathematical content."

Teachers were also keenly interested in how *anonymity* impacted students' comments in the Padlet. In particular, in the Italian context, the teacher reported that "Anonymous posts allow students to focus on the content and not on the person who writes." Furthermore, they observed that while some students felt a new freedom to conjecture without fear, others, accustomed to the trust of their peers (based on their developed mathematical competencies), had to justify their claims: they could not rely on their authority. The anonymity of posts and comments had a significant influence, as the Italian teacher stated, "Somehow, the social and non-social differences between students are eliminated."

Weaknesses of the Discussion with Padlet

Any technology has weaknesses, but they can be difficult to identify, as they also relate to the competencies of users (Lagrange et al., 2003)—in our case, teachers and students. Nevertheless, we identified some weaknesses or challenges connected to the technology. In our adaptation of the SWOT analysis, these technological features are considered internal insofar as they directly shaped classroom interaction during the activity, even though they originate in the platform design.

The free version of Padlet has *limited customization options*, and a weakness of the full version of Padlet, used in our project; its cost can represent a constraint for classroom adoption and sustained use. As teachers highlighted, Padlet allows text and basic formatting; however, as with many online platforms, messages are often brief, which could limit engagement with the problem-solving activity. While brevity can facilitate rapid exchanges and lower students' entry barriers, teachers highlighted that short posts may also constrain the articulation of complex mathematical reasoning. As noted by the Italian teacher, "In the brevity of the message, the complexity is sometimes lost." In this sense, brevity emerges as a structural weakness of platform-mediated discussion when the goal is to support sustained argumentation and the explicit development of mathematical reasoning. Without careful teacher orchestration, concise posts may privilege conclusions over processes, potentially limiting opportunities for deeper collective reflection. Brevity was not considered problematic per se, but became a weakness when it limited the explicit articulation of *mathematical reasoning*.

Padlet also lacks an extensive library of *math symbols*. This was a weakness identified by the Canadian teacher who commented on the lack of an equation editor: "If Padlet had an equation editor option (perhaps a simplified LaTeX editor), students would be able to type their mathematical steps and solutions." From the teachers' perspectives, the limited availability of mathematical symbols constrained the expression of the handling symbols and formalism competency: students were able to handle mathematical symbols and formalisms only when uploading pictures of written papers, but were unable to do so in their comments.

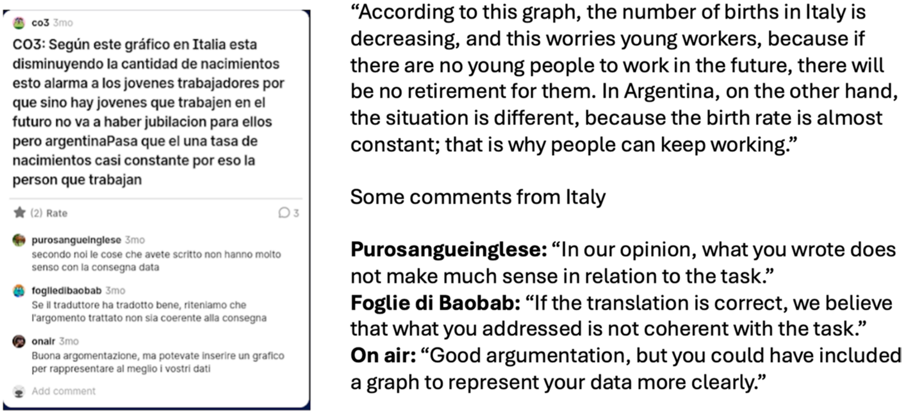


Fig. 9 Argentine students' Padlet post with social interpretations of the graph, alongside Italian students' comments focused on mathematical aspects. The translation is provided on the right side

Creating *graphs and diagrams* is not intuitive in Padlet; therefore, students often draw them on paper or other tools and upload them into Padlet as photos or screenshots. This limits the type of feedback peers or teachers can provide to written text rather than annotated graphs or other work that was uploaded as an image. This aspect appears to influence the expressive freedom in handling a broader range of representations. A few examples come from the Canadian Padlet, where students photographed a hand-drawn graph to compare the two countries' CO_2 trends.

Threats to Education

As explained, we considered the aim of our project a challenge and thus expected potential threats to emerge. The introduction of a technology, such as Padlet, is challenging for both teachers and students (Drijvers et al., 2013). In the experiment, a few threats related to technological issues emerged: the Italian teacher underlined that, given that Padlet is an online platform, it relies upon stable Wi-Fi for all participants and upon the students' *access to Internet-ready devices*; as noted by the Argentinian teacher, this aspect and the cost of the full license, lead us to a reflection also concerning equity issues related to access to technology.

Other challenges faced during the experiment execution were related to collaboration between classes from different nations. Collaboration is challenging because it is *difficult to identify a problem* for the student prompt when their curriculum and classroom culture contexts differ. Furthermore, the problem focus of the activity must foster dialogue and student motivation, which can vary depending on the context.

During the Italy–Argentina exchange, a few Argentinian students projected social meanings onto the mathematical graph—for example, interpreting a decrease in CO_2 as a decrease in birth rates and linking it to future pension costs. Italian students, however, did not show comparable divergences: their comments remained strictly focused on mathematical structure (scales, values, comparability)—see Fig. 9.

This asymmetry highlights a potential threat in cross-national activities: culturally grounded interpretations may arise, leading to unexpected misunderstandings in shared discussions due to different backgrounds and sensibilities, as in the case of the collaboration between Italian and Argentinian students. In fact, this asymmetry does not simply reflect individual differences in students' interpretations, but rather points to how Padlet's affordances interact with culturally and educationally situated ways of making sense of this mathematical task. While the platform enables students to externalize and share their interpretations freely, the nature of these interpretations appears to be shaped by locally established norms regarding the boundaries between mathematical reasoning and socio-contextual considerations. In this sense, Padlet does not merely function as a neutral medium for cross-national exchange, but as a space in which culturally grounded mathematical practices become visible and comparable.

The different organization of the school year and the varying time zones may also pose a threat to collaboration between classes during the experiment. For instance, the Argentinian teacher highlighted an important aspect that emerged also in the organization of the experiment within the research team: even if Padlet allows an asynchronous discussion, the international collaboration requires precise *coordination of the time schedules* of the different phases, which is not a trivial issue considering different peculiarities of national school contexts.

Conclusions and Further Perspectives

In our experiment, we investigated the role of Padlet in cross-national mathematical problem-solving discussions.

We identified strengths, such as Padlet's user-friendly interface, its collaborative nature, which facilitated group work, and its different timing management. Indeed, Padlet enables "asynchronous" discussions: students have time to read and translate posts written in other languages by classes from different countries and then find the best words/ways to answer.

The multimodal nature of Padlet appeared to play a crucial role in shaping the mathematical discussions observed in this study. The possibility of combining written text, symbolic notation, graphs, images, and external digital resources allowed students to express mathematical ideas in ways that extend beyond linear textual explanations. This multimodality appears particularly significant in cross-national contexts, where linguistic differences might otherwise hinder participation. Visual and graphical representations functioned as shared semiotic resources, enabling students to communicate mathematical meanings even when working across different languages. From the teacher's perspective, Padlet's multimodal affordances were perceived by teachers as supporting competencies related to representing, communicating, and using tools, while simultaneously reshaping how these competencies are enacted in culturally diverse classrooms.

Opportunities focused on the inclusion of all students, the ease of providing feedback using Padlet, and the possibility for them to independently explore solutions and comments collected in the Padlet during the classroom discussion. Weaknesses included limited customization options in the free version and challenges in creating formulas or graphs directly on Padlet. Threats encompassed issues related to technology access, the influence of theoretical and conceptual tools on problem selection, logistics of international collaboration, and communication challenges. The interaction between Italian and Argentinian students can be considered an example of communication challenges that may arise, but also emphasizes the importance of students having these experiences. These findings align with previous studies that demonstrate how digital platforms can foster reflective and meaningful discourse in mathematics education, particularly when participants come from diverse cultural or linguistic backgrounds (Barwell & Kaiser, 2005; Llinares & Olivero, 2008; Llinares & Valls, 2010). Such contexts foster both new learning opportunities and communication challenges that can enrich the experience of mathematical problem-solving. Furthermore, the challenge posed by cultural misunderstanding reminds us that all mathematical interactions are mediated by students' perceptions of each other, and that these perceptions are subjective and culturally influenced. Communication challenges are part of the mathematical challenge. Therefore, our findings suggest that Padlet's affordances cannot be fully understood independently of the cultural and educational contexts in which they are enacted. In this sense, the pairing of classes—based on teachers' contextualized descriptions of their students and their classroom practices—also reflects the situated nature of cross-national collaborations and may have influenced the forms of interaction. In cross-national settings, the platform appeared to amplify differences in how students frame mathematical problems, what they consider relevant to mathematical argumentation, and how they connect mathematics to broader social meanings. Rather than being treated as a limitation, this interaction between technological affordances and contextual factors can be seen as a key resource for fostering reflective and comparative mathematical discussions across national borders. It is important to note that some of the affordances discussed in this study are closely connected to the specific characteristics of the mathematical task adopted—particularly its openness, its representational demands, and its socio-environmental theme. Other affordances, such as anonymity, asynchronous interaction, and persistence of contributions, appear to be more structurally linked to the platform itself. Therefore, while some findings may transfer to other contexts, such transferability is more plausible for problem-solving activities that share similar open structures and representational richness.

To go one step further, we also want to reflect on the nature of our research collaboration and its impact on classroom interactions. There exists a plethora of theoretical and conceptual tools available, most notably because each person on our team has a unique research trajectory. The theoretical insights guided our analysis of the data derived from the activity, as well as our decision to choose the mathematical problem and to guide the involved teachers. As noted, our challenges as a research team are also opportunities because they promote a rich dialogue.

For both our research collaboration and the cross-border dialogues, the challenges were readily addressed thanks to the team members' commitment. If teachers want their math students to collaborate, they need an idea and a medium (e.g., Padlet), perhaps inspired by accounts of others who have done so (such as ours). But most importantly, teachers will meet all the challenges if they find it important to promote such a dialogue. It is the same with our research team.

Reflecting on the weaknesses and threats highlighted in our SWOT analysis, we note that these could be called problems. Ironically, the collaboration was designed to give students problems—mathematics problems. School mathematics is designed to provide students with experience and guidance in problem-solving, but this is usually thought of as mathematics problems. We argue that problem solving in mathematics requires students to understand mathematics, but also to understand communication. In our increasingly digital world, communication is becoming multi-modal, cross-national, and mediated by technologies. The problems (weaknesses and threats) associated with technologies such as Padlet can be seen as a highly appropriate part of students' experience with mathematical problem solving. As we highlighted earlier, the experience with Padlet appears to support several of the competencies identified in the KOM framework (Niss & Højgaard, 2019). In particular, the possibility of posting problem-solving processes, reading and commenting on peers' posts (even from classes other than one's own), expressing opinions, and discussing deeply supports the competencies of *mathematical thinking*, *problem handling*, *mathematical reasoning*, *communicating*, *dealing with different representations*, and *handling* (digital) *tools*. On the contrary, the competency related to *handling symbols and formalism* seems to be hindered due to Padlet's limitations in embedding mathematical symbols.

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Data Availability The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Declarations

Ethical approval For this study was obtained from the ethical committee of the University of Bergamo (N. 03/2023–15th March 2023).

Competing interests The authors declare no competing interests.

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