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ORIGINAL PAPER

The key-roles of the expert during classroom discussions aimed at fostering formative assessment processes through the use of digital technologies

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Abstract
We study the experts' practices developed with the support of digital technologies (DT), when they take aware in-the-moment decisions during classroom discussions to promote the development of effective formative assessment (FA) processes. In this investigation, we complement a macro-analysis of paradigmatic examples of classroom activities, focused on the functionalities of DT and on the implemented FA strategies, with a micro-analysis, developed with reference to a theoretical construct useful for interpreting and analysing expert teachers' roles during classroom discussions (the Model of Aware and Effective Attitudes and Behaviours, $M_{AE}AB$). More specifically, we explore how the expert uses DT to empower these roles with the aim of promoting FA processes. This study has two implications: (1) at the theoretical level, the study will introduce a model aimed at characterising the ways in which the expert can promote FA during classroom discussions when they are mediated by the use of DT; (2) at the pragmatic level, the use of this model to analyse paradigmatic examples from teaching experiments will introduce potential guidelines for teacher professional development aimed at promoting teachers' autonomous use of DT to carry out effective FA practices.

Keywords Formative assessment · Digital technologies · Roles of the expert

1 Introduction

Scholars agree on the importance of promoting formative assessment (FA), conceived as an integrated part of the teaching–learning process and characterised by a continuous teacher-learners interaction, to meet students' needs (Schildkamp et al., 2020). However, research has shown that FA does not always have clear positive effects, and this is linked to the fact that implementing FA in the classroom is a complex task and requires teachers to move from the mere application of "principles" in a mechanistic way to the integration of FA into teaching, thus changing the teacher's role in the classroom (Schildkamp et al., 2020).

Following this suggestion and adopting a socio-cultural perspective, we address the key role of the expert in promoting FA in the classroom.

We conceptualize expertise in teaching with reference to Mason and Spence (1999). Specifically, in our perspective, an expert design and implementation requires both knowing-to and knowing-how "to create suitable conditions and then to direct student attention effectively" (p. 147). Based on this assumption, in the teaching experiments documented in this paper, the role of the expert during classroom activities is played by the researcher, who is always present in the classroom together with the teacher. This choice has a twofold aim: on the one hand, focusing on a researcher makes it possible to investigate the actions of someone who is fully aware of the roles he/she can play in promoting FA processes in the classroom; on the other hand, in this way, the researcher can act as a model for the teacher (Cusi & Morselli, 2017), thus promoting the growth of the teacher's expertise.

This choice is in line with the Italian paradigm of research for innovation (Arzarello & Bartolini Bussi, 1998), which is characterised by a close collaboration between teachers and researchers, both as designers of classroom activities and as participants-observers, and by the elimination of the classical distinction between observer and observed (represented,

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in educational research, by the class, including the teacher, and the researcher, respectively).

Our study is situated within a broader research project focusing on the use of digital technologies (DT) to foster FA processes (the European project FaSMEd, cf Cusi et al., 2017).

Within the FaSMEd project, we adopted a Vygotskian perspective (Vygotsky, 1978), in which peer and expert's interactions play a crucial role in teaching–learning processes. In addition, special emphasis was placed on metacognitive factors (Schoenfeld, 1992). Accordingly, we set up activities where students (usually working in groups) share their thinking processes with researchers, teachers and peers and reflect collectively on their thinking processes. The activities included sets of digital worksheets (problem worksheets, helping worksheets, poll worksheets, see Cusi et al., 2017 for more details), which were used through a connected classroom technology (Irving, 2006) to assign tasks, collect group responses and reflections and launch polls. Key steps in this approach were the classroom discussions, orchestrated by selecting and grouping students' answers to be displayed on the interactive whiteboard (IWB) or by launching on-the-spot polls and sharing their results with students by means of the IWB.

The expert's roles in monitoring and selecting the answers to be displayed and discussed was investigated in a previous paper (Cusi et al., 2017). Here we focus on the expert's roles *during* classroom discussions and explore the ways in which he/she could use DT to empower his/her roles with the aim of promoting FA strategies.

2 Background of the study

In outlining the potentialities of DT in mathematics education, the crucial role of the teacher in carrying out a fruitful integration of DT in teaching has been pointed out (Trigueros et al., 2014). Drijvers et al. (2010), who investigate the teachers' practices that characterise instrumental orchestrations (Trouche, 2004) in technology-rich environments, propose a list of six orchestration types, some of which are teacher-centred, such as technical-demo, and others are student-centred, such as sherpa-at-work. The authors note that some types of orchestration, such as spot-and-show, can be seen as technological variants of the usual teaching practices, while other types, such as discuss-the-screen, arise when DT is adopted.

Other studies address specifically the ways in which DT can support assessment. Following Stacey and Wiliam (2013), we distinguish between assessment *with* DT, where students use technology in the mathematical performance that is being assessed, and assessment *through* DT, where technology is used to carry out the assessment processes. Here we refer to assessment *through* DT, with a particular focus on FA practices, understood as practices through which evidence of student achievement is elicited, interpreted, and used by the three main agents of FA (teachers, learners, or their peers) to make decisions about the next steps in instruction (Black & Wiliam, 2009). In the last decade, FA *through* DT has been addressed by many scholars (Aldon & Panero, 2020; Cusi et al., 2017; Dalby & Swan, 2019; Olsher et al., 2016; Ruchniewicz & Barzel, 2019). Differing views of the role of the teacher when implementing FA through DT appear to emerge, shifting from a central role to a role of "guide on the side" (Dalby & Swan, 2019).

Our research focuses on connected classroom technology (CCT), which is "a networked system of personal computers or handheld devices specifically designed to be used in a classroom for interactive teaching and learning." (Irving, 2006, p.16). As Clark-Wilson (2010) argues, CCT can support FA by providing the teacher with information on students' sense-making processes, and with the opportunity to share responses and screens to break up classroom discussions; at the same time, effective use of CCT for FA requires that teachers are able to quickly make sense of the variety of students' screens that are visible. This is specifically discussed by Edson and Difanis Phillips (2021), who explore the use of dashboards and the role of teachers in planning, implementation, information gathering, and real-time decision making.

Recently, the UNESCO report on the role of technology in education (2023) denounces that, despite the rapid spread of DT and the spotlight that was shone on the importance of teacher professional development in the use of DT by the experience of distance teaching during the Covid-19 pandemic, various barriers still prevent teachers from making the most of what technology can offer. Among these barriers, a crucial role is played by teachers' lack of confidence in using technology to teach, even in the case of widespread DT, such as interactive whiteboards and other basic digital tools (UNESCO, 2023). Research has highlighted that this aspect is even more relevant when the focus is on the integration of DT in teachers' FA practice, since teachers' expertise in using DT for teaching does not necessarily imply a corresponding expertise in using DT to promote FA processes, due to the profound change in classroom culture that this integration requires (Feldman & Capobianco, 2008). Foshayla and Bellman (2012) have introduced a three-level developmental progression for teachers' full transition to the highest level of expertise in this field: (1) the *first level*, which describes many teachers at the beginning of their use of DT for FA, who usually examine students' feedback after class and take decisions about "what to do next" from day to day, informed by this feedback; (2) the *second level* is typical of teachers who feel comfortable with the mechanism of obtaining frequent student data and are able to use

these data to make "real time" decisions; (3) the *third level* is characterised by the teacher's command of the full range of advanced interactive capabilities that DT offers.

In this paper, we deepen the reflection on expertise, by investigating how the expert could use DT to empower his/her roles with the aim of promoting FA strategies during classroom discussions. To do so, we complement a macro-level analysis, which aims to study paradigmatic examples of classroom activities where DT supports FA strategies, with a micro-level analysis, which focuses on the expert's key roles and how DT can empower these roles. To this end, the theoretical tools already used for the macro-analysis (the FA strategies and functionalities of DT, see below), are complemented by the $M_{AE}AB$ construct (Cusi & Malara, 2016), originally developed to study the expert teachers' roles during classroom discussions.

3 Analytical framework

The analytical framework is organised around three main theoretical lenses: FA strategies, the functionalities through which DT support FA, the $M_{AE}AB$ construct.

3.1 FA strategies and the functionalities through which DT supports FA

The first two lenses are part of the model that was introduced within the European project FaSMEd (Aldon & Panero, 2020; Cusi et al., 2017; Ruchniewicz & Barzel, 2019) and futher developed in the last years (Cusi et al., 2024, to appear), which includes three dimensions: FA key-strategies, three main agents, and the functionalities through which DT can support the agents in developing the FA strategies.

Wiliam and Thompson (2007) outlined five FA key-strategies: (A) clarifying and sharing learning intentions and success criteria; (B) engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding; (C) providing feedback that moves learners forward; (D) activating students as instructional resources for one another; and (E) activating students as the owners of their own learning. These strategies involve three different agents: the teacher, the students and the peers. In the present study, we focus mainly on the *teacher*.

In studying how DT could support FA processes within the FaSMEd project, three different functionalities were identified (Aldon et al., 2017): (1) sending and displaying; (2) processing and analysing; and (3) providing an interactive environment. The new possibilities offered by the rapid evolution of DT led Cusi et al., (2024, to appear) to extend the three functionalities to best capture the ways in which DT can support the FA processes. The result of this extension are the following three functionalities: (1) *communicating* between the different agents of FA, which involves all forms of communication with, through or of technology[1] (Ball & Barzel, 2018); (2) *analysing*, which involves different levels, from providing just an overview of the work progress, to providing information on the learning status, to allowing first insights in students' thinking; (3) *adapting*, which is related to the support that DT could provide to teachers in making decisions about the next steps in instruction.

3.2 The $M_{AE}AB$ construct

Classroom discussions play a crucial role in FA, since they represent a fruitful context within which it is possible to foster the effective activation of FA processes, such as feedback, questioning and self-assessment (Lee, 2006) and monitoring of students' learning processes by directing students to talk about their understanding (Black & Wiliam, 1998; CERI, 2005).

In order to address the role of the expert in promoting FA through DT, we, therefore, combine theoretical tools on DT and FA with a model of expert teacher's interventions during discussions. We refer to the $M_{AE}AB$ construct (Cusi & Malara, 2016), developed to describe the key-roles played by the expert teacher in orchestrating discussions that support students in making their thinking visible (Collins et al., 1989) and in developing metacognitive reflections. The use of this model to analyse the expert's interventions in a FA activity focused on argumentative processes (Cusi & Olsher, 2021) showed the importance of the expert assuming roles that bring the discussion to a meta-level.

Table 1 summarises the expert teacher's roles in the $M_{AE}AB$ construct, together with indicators that may support the coding process.

4 Research questions

The aim of our study is to explore how the expert uses DT to empower her/his roles during classroom discussions to foster fruitful FA processes.

We address the following research questions:

1) How does the expert use the functionalities of DT to empower specific roles?

[1] *Communication through technology* is the one developed by students and teachers when technology supports their interactions face-to-face inside the classroom or when they are not at the same location. *Communication with technology* refers to the interplay between user and technology. *Communication of technology* is the one that is fostered when what is shown by technology is taken as a stimulus for discussion and further development of students' performance.

Table 1 The roles within the $M_{AE}AB$ construct (Cusi & Malara, 2016)

Roles of an expert teacher in the $M_{AE}AB$ construct	Characterisation of each role	Indicators
Investigating subject and constituent part of the class	She/he encourages students to take an inquiry approach to problems and to feel involved in the activity as a group	She/he uses the first-person plural when asking questions and she/he accepts the different proposals without judging them
Practical/ Strategic guide	She/he stimulates research into strategies for approaching a problem to be solved and acts in order to clarify how an expert might pose her/himself when analysing such a problem	Typical questions: - What does this question mean? - What are we being asked to do? - What might be useful to find in order to answer this question? - Is this the only possible way to solve the problem?
"Activator" of interpretative processes	She/he aims at clarifying the meanings of the representations that are constructed or transformed by the pupils and at stimulating a continuous interpretation of the representations and results that are obtained	Typical questions: - What does this symbol/expression/graph mean? - How can we represent this information? - How can we interpret this result? - Is this solution acceptable?
"Activator" of anticipating thoughts	She/he focuses students' attention on the objectives (or specific sub-objectives) of the activity the class is undertaking, or she/he makes them explore hypotheses and identify the effects of a possible change undertaken or a possible strategy activated	Typical questions/interventions: - What is the objective? - Remember that the objective is… - Are we achieving the objective? - What result do we expect to achieve? - If we made this choice, what could we achieve?
Guide in fostering a harmonized balance between the syntactical and the semantic level	She/he makes students reflect on the syntactic correctness of certain transformations carried out and make connections between the processes that characterise the solution of a problem and the corresponding meanings	Typical questions: - Is this transformation correct? - Is it legitimate to simplify this expression? - Why did you make this transformation? - How did we get this result?
Reflective guide	She/he helps students to make explicit the meaning of effective strategies/approaches used in class activities to encourage reflections on them, so that students can identify effective practical/strategic models from which to draw inspiration in tackling problems	Typical questions/interventions: - Could you explain your reasoning to your classmates? - Is there anyone who could explain his/her reasoning? - She/he argued in this way: "Since I want get this kind of result, I could…" (The teacher speaks as if she/he were the student, repeating the same words as the student or reformulating her/his argument) - Is it clear what she/he said? She/he noticed that… (the teacher repeats what a student said referring to her/him with the singular third-person)"
"Activator" of reflective attitudes and metacognitive acts	She/he stimulates and provokes meta-level attitudes, by helping students exchange and compare different arguments/strategies to reflect on their strengths/weaknesses	Typical questions: - Do you agree with what she/he said /what is written? - Do you think this is an effective choice/strategy? Why? - What are the differences between theses answers? What do they have in common? - Was this task difficult for you? Why?

2) What are the effects of empowering these roles in terms of activating specific FA strategies?

5 Context

We refer to a teaching experiment carried out in grade 5, in a primary school located in northern Italy. The class consisted of 27 students (11 males, 16 females) and the teacher had more than 30 years of teaching experience. The experiment concerns a set of FaSMEd activities consisting in a series of 7 worksheets that were created by adapting paper and pencil time-distance graph activities from the Mathematics Assessment Program, developed by the MARS Shell Centre team [http://map.mathshell.org/materials/lessons.php].

The class had at disposal a CCT: students (working in pairs) were provided with tablets and the teacher and the researcher were provided with a computer, connected to an IWB. One author (referred as "Researcher" or R), who is familiar with both the $M_{AE}AB$ construct and the FA strategies to be activated, orchestrated the classroom discussions. This choice is consistent with our aim to explore how DT can be used by an expert to empower specific roles to promote FA. The teacher, who had been involved in designing the activities, was always present in the classroom and took part in the discussions.

6 Methodology

During the teaching experiments, we collected lessons' video recordings, researchers' notes and students' written answers (on the digital worksheets). Video recordings and their transcripts form the data corpus for the current study. Among the wide corpus of data, we performed a double-level selection, aimed at identifying paradigmatic examples of classroom activities, the analysis of which can lead to generalizations that are meant to be analytical rather than statistical, in line with design-based research (Cobb et al., 2003).

A first level of selection was related to the choice of two paradigmatic examples of classroom activity in reference to the functionality of DT, while the second level of selection led to identify excerpts to be analysed with a focus on expert's interventions.

Within each paradigmatic example, we chose excerpts where the expert used the DT (in our case, the CCT and the IWB) during the discussion by exploiting its specific affordances (such as the possibility to zoom or scroll, or the activation of polls) and explicitly mentioned the DT during the discussion.

The videos related to the selected paradigmatic examples were transcribed and analysed separately by the two authors, combining:

- a macro analysis, which focuses on the whole presented example as the unit of analysis and characterises the paradigmatic example according to the DT functionalities used for FA (Cusi et al., submitted) and to the main FA key-strategies that are activated; and
- a micro analysis, which focuses on specific excerpts within each example and zooms in on the expert's interventions, analysed according to the $M\text{-}_{AE}AB$ construct (Cusi & Malara, 2016), then linked to their effects in terms of the FA key-strategies (Wiliam & Thompson, 2007) activated by means of these interventions. Concerning the micro-analysis according to the $M\text{-}_{AE}AB$ construct, Table 1 provides a guide for coding the interventions.

A few non-converging elements of the analysis developed separately by the two authors were discussed further so as to reach an agreement. We then discussed the relationships between the dimensions in order to address the research questions.

7 Data analysis and results

In this section we present two paradigmatic examples. The first one refers to a discussion concerning students' written answers, that are selected and displayed at the IWB so that all the class can comment them. Here the focus is on the *communicating* functionality of DT.

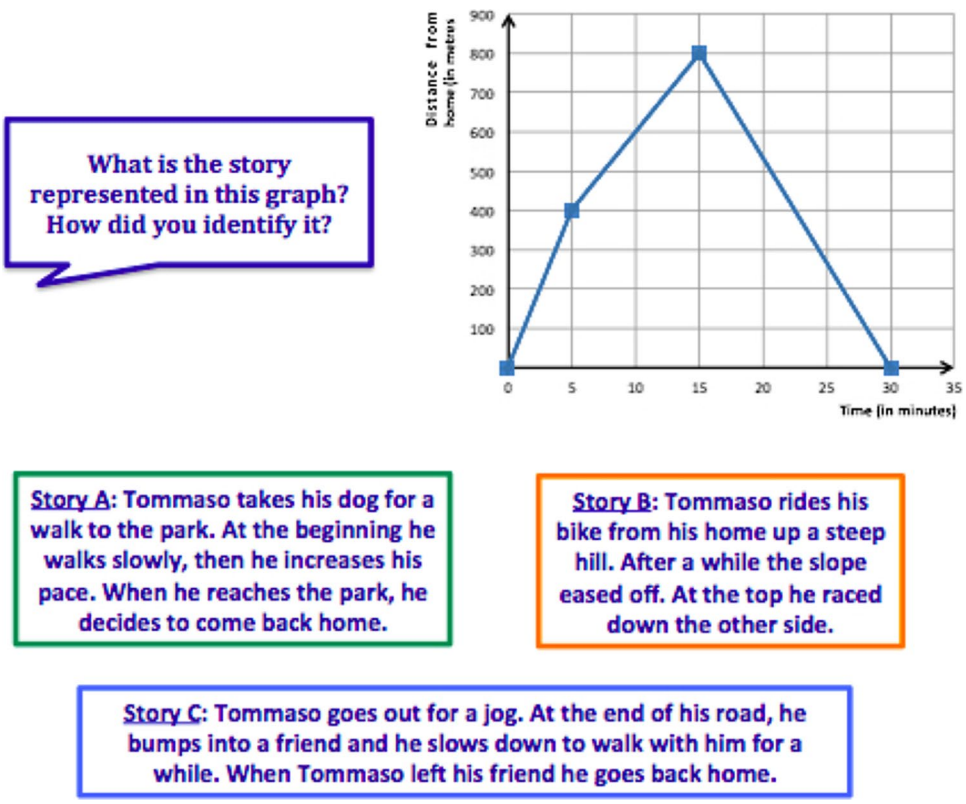
The second paradigmatic example concerns the use of four on-the spot polls and the consequent discussions on the results of the polls, that are displayed on the IWB. Here both the *analysing* and *communicating* functionalities are addressed.

8 Paradigmatic example 1: the use of CCT and IWB to encourage sharing and comparison

The first example refers to Problem Worksheet 6 (Fig. 1), where a graph and three possible corresponding stories are presented and students are asked to identify the story that could correspond to the graph and justify their choice.

Stories A and C are very similar. In order to choose the correct one (C), the students should notice that the graph shows a decrease in speed because the slope decreases from the first to the second stroke of the graph. Therefore, story

Fig. 1 Problem worksheet 6



A is not the correct choice because it contains the sentence "he walks slowly, then he increases his pace".

In story B, the distance from home should be increasing, whereas the last part of the graph represents a return to home, i.e. a decrease in the distance from home. Hence, story B is not correct. A student, erroneously interpreting a time-distance graph as a drawing (Clement, 1989), could choose story B because it contains the word "hill".

Before making the students work in pairs/groups, the teacher reads the stories to the class and has the students look at the graph, noting that the distance is expressed in metres on the vertical axis, while the time is expressed in minutes on the horizontal axis.

The researcher clarifies the meaning of the request "Justify your answer": the justification should be correct, clear for those who will read it, and also complete from a mathematical point of view (it should be understood how, starting from the graph, the correct match was identified). We can say that this is an activation of *FA strategy A*, since the researcher clarifies the criteria for success.

Students work in pairs/groups for about 40 min. While the students are working and sending their answers, the teacher and the researcher select some answers and prepare a doc file, containing the text of the task and these answers, grouped and ordered to be projected during the discussion to encourage sharing and comparison. Therefore, we can say that the *communicating* functionality of DT is used (in the sense of *communication through technology*) in order to promote *FA strategy B*.

After summarising the reasons why story B could not be matched with the graph, the researcher (R) shows the whole doc file on the IWB, scrolling from top to bottom to encourage collective reading of the groups' answers.

> 457. R: Here is someone who answered "For me it is A", then almost everyone answered "For me it is C", "It is story C", etc. But do you think it is story A or C?
> 458. Noé (*raising his hand*): For me it is A because…
> 459. R: Come [*to the IWB*] to show it [*R scrolls to the top of the file to display the task on the IWB*].
> *Noè approaches the IWB and shares his doubts about the choice to be done, focusing both on the texts of the three stories and on the graph.*

At the beginning of the excerpt, R uses the available DT to *zoom out* and *scroll* the displayed document *from top to bottom* in order to promote an overall view of the groups' answers. In this way, she encourages the sharing of the students' productions, in which each perspective is taken into account and each answer can become a source of reflection for the class.

Therefore, the role of activator of *reflective attitudes and metacognitive acts* is empowered by the use of DT, which, by enabling students to grasp the variety of answers produced by the different groups, together with R's intervention

(line 457), stimulates a collective need to identify and justify the correct answer. As a result, Noè activates himself as responsible for his learning (*FA strategy E*) by proposing his point of view (line 458).

In line 459, by *inviting Noè to come to the IWB* to explain his thinking processes (the reasons why he chose an answer, his doubts, his interpretation of the graph), R fosters a focus on Noè's perspective and approach (line 460). In this way, R plays the role of *reflective guide*, which is empowered by the fact that, when Noè is at the IWB, he has the opportunity to combine his words with his gestures and to directly indicate both parts of the text and elements of the graph. In this way, Noè's thinking could be made visible to his mates and he is also activated as a resource for them (*FA strategy D*).

469. R: And what justification did you [*Noé and Andromeda*] write?
R scrolls through the file projected on the IWB, until she finds Noé and Andromeda's answer and projects it to show it to the class.
470. R [reading]: "In our opinion, A is the correct answer because, in the graph, the last part goes down, so Tommaso goes back to the park, while in the other [*stories*] he goes home."
R scrolls to the top of the file to display the task on the IWB.
471. R: That is to say, they had realised that, in both story A and C, he [*Tommaso*] comes back home anyway. And what is the difference between A and C?
R guides Noè in the reading of stories A and C to highlight the differences between them and to think about how these differences would affect the corresponding graph.

R then *scrolls through the file* projected on the IWB and *zooms-in* on Noè and Andromeda's answer in order to foster a focus on what the two students have written. R plays the role of *activator of interpretative processes*, which is empowered by the fact that the graph and the stories are displayed on the IWB side by side with Noé's answer. At the same time, by displaying and reading the group's answer, the role of *reflective guide* is empowered, allowing Noè to combine his reflections with the visualisation of his answer and the text of the task and potentially activating the other students as resources for Noè and Andromeda (*FA strategy D*).

9 Paradigmatic example 2: the activation and combination of on-the-spot polls during a lesson

The second paradigmatic example refers to Problem Worksheet 7 (Fig. 2), where students are given five graphs and five stories (Fig. 3) and are asked to identify the story that could correspond to each graph and to justify their choice. Students are also warned that there may be graphs without a corresponding story. In this case, they are asked to invent one.

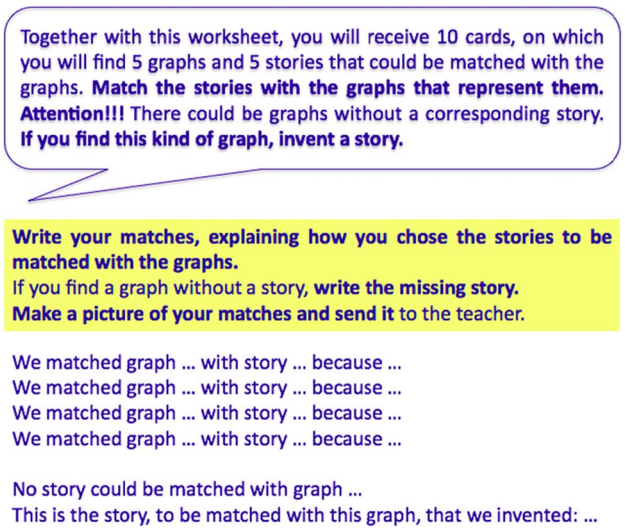


Fig. 2 Problem worksheet 7

Table 2 summarises the expected matches and some critical issues that could arise for each match.

9.1 First on-the-spot poll launched during the activity

At the beginning of the classroom activity, the students are asked to work in groups on the task related to problem worksheet 7. Afterwards, and before any discussion on the matching, the researcher uses the DT to launch an on-the-spot poll: "*Which graph required the most attention and reflection?*".

In designing and launching this on-the-spot poll, R uses the *analysing* functionality of DT to empower her role of *activator of reflective attitudes and metacognitive acts* since, through the poll, she stimulates meta-level reflections, aimed at promoting students' self-assessment and thus promoting *FA strategy E*.

Afterwards, R displays the results of the poll on the IWB as a starting point for a class discussion. In this way, *the communicating* functionality of DT is also used, since R activates a *communication of technology* to promote *FA strategy B*. Figure 4 shows the result of the poll displayed on the IWB: graphs 3 and 4 are indicated as those that required most attention and reflection.

We report here the introductory part of the discussion:

65. R: ok. Now I put it here [*she moves the results of the poll on the right side of the IWB, while the list of*

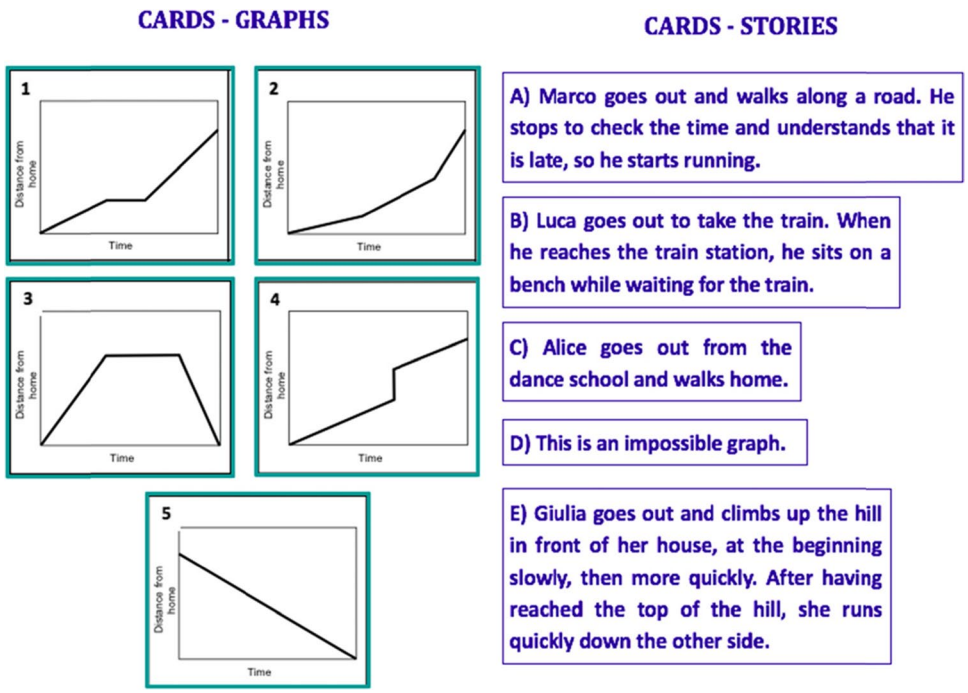


Fig. 3 Annexe cards to problem worksheet 7

Table 2 Expected matching graphs-stories and critical issues

Graph	Corresponding story	Potential critical issues
Graph 1	Story A	The horizontal segment could be interpreted in terms of movement
Graph 2	Story E	Students could find it difficult to interpret the slope in terms of speed
Graph 3	No corresponding story	Graph 3 could be erroneously matched with story B, linking the horizontal segment to the sentence "he sits on a bench while waiting for the train"
Graph 4	Story D	The vertical segment could be interpreted in terms of vertical movement
Graph 5	Story C	Students may have difficulty with the interpretation of the intersection with the y-axis in terms of departure from a place that is different from home

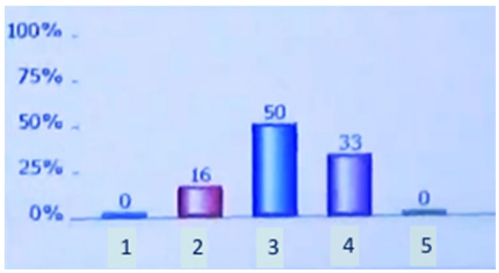


Fig. 4 Results of the first on-the-spot-poll

graphs is on the left side], so that we can discuss it a bit together. What is very evident, that we can say immediately? […] How many hands up! ...Elena?
66. Elena: that 3 was difficult for most of us.
67. R: For most of you graph 3 is the one that made you think more.

R starts the discussion (line 65) by posing herself as both an *activator of interpretative processes* and an *activator of reflective attitudes and metacognitive acts*, by asking the students to interpret the results of the on-the -spot poll by themselves. This role is empowered by R's choice of displaying both the results of the poll and the graph at the IWB. In this way, students are immediately invited to express their thoughts and reflections. In fact, a rich discussion starts in which the students share their comments on the graphs, describing their initial interpretations of the different graphs and the reflections developed during the former group work.

We summarise here the main crucial issues that emerged during the subsequent discussion, in order to

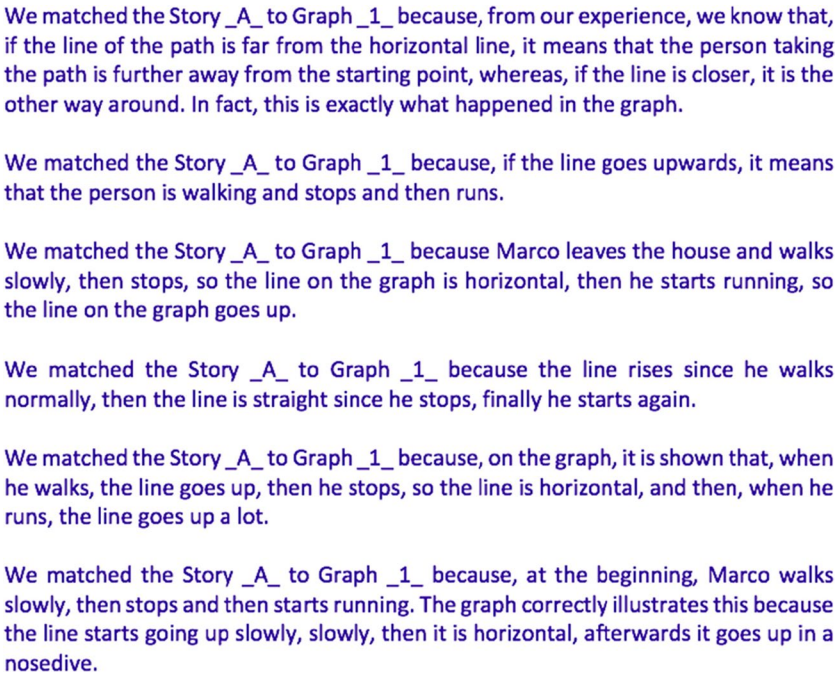


Fig. 5 The six argumentations as shown on the IWB (translation from Italian into English)

document the effectiveness of R's use of the DT functionality to activate *FA strategies B* and *E*:

- Graph 3 does not correspond to any story. This makes the task "open" and more difficult to address ("*We made a mes of graph 3 because it was supposed to have a story but in the end it didn't*"). Students report that this fact required more reflection, and they usually left graph 3 apart and returned to it at the end, after having done the other matches ("*We already matched all the others and we tried to leave it for last, but the remaining story did not match, then we tried with the others and we understood it was that one*").
- Graph 4 contained a vertical segment, which was reported to be very difficult to interpret ("*For us it was difficult because it is impossible for a person to walk some meters in zero seconds*").
- Graph 2 required an understanding of the slope in terms of speed, a concept that had not been deeply explored before ("*In graph 2 it was about speed and at first I could not understand it*").

9.2 Second on-the-spot poll launched during the activity

A discussion on the matching task is then encouraged. The first part of the discussion is devoted to reflecting on the reasons given for matching between Graph 1 with Story A. It is noted that all the pupils correctly matched Graph 1 with Story A, but that the argumentations given are different. The first five argumentations are displayed on the IWB and are read out by R. She has grouped them because they only present a reformulation of Marco's journey, without really explaining the connections between the graph and the story (Ex." *We have matched the Story A to Graph 1 because, when Marco walks along the road, he stops. Then he starts running*"). During this phase of the discussion, several pupils approach the IWB and reconstruct the argumentations for choosing story A. In particular, Vincenzo and Michele focus on the fact that the graph shows that the moving person first walks and then runs. The pupils also reflect together on the correct justification for the fact that a horizontal line means that the person is standing still.

R then reads the other six argumentations on the IWB (Fig. 5 presents what is shown on the IWB, translated from Italian into English).

At this point of the discussion, R launches another on-the-spot poll to encourage a reflection on a criterion for assessing argumentations, namely completeness. The following excerpt refers to this phase of the discussion.

340. R: Try to read them again and think, on the basis of what we said before, which of them we can consider the most complete. There might be something missing, but let's identify the one that is more complete than the others.
Several pupils raise their hands.
341. R: What do you think? Shall we take a poll?
342. Chorus: Yes!
343. R: Now think about it. Let's number them: 1, 2, 3, 4, 5, 6 [*as R says the numbers, she points to the six answers, one after the other*]. I will ask only one

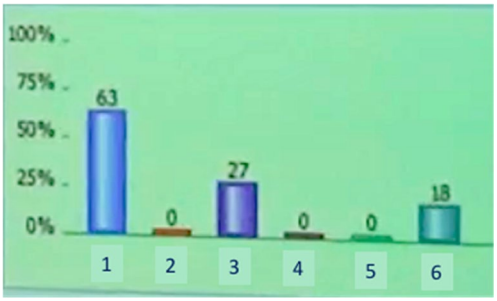


Fig. 6 Results of the second on-the-spot poll

question: "Which one of these is the most complete?" and you choose it. After that, you have to motivate, and that is important.

When designing and launching this on-the-spot poll (line 343), R again uses the *analysing functionality of DT* to empower her roles of *activator of reflective attitudes and metacognitive acts* and of *guide in fostering a harmonized balance between the syntactical and the semantic level*, since, through the poll, she stimulates the comparison of justifications and the reflection on their completeness. She also acts as a *reflective guide*, since the focus is on certain answers given by the students. The aim related to the activation of these roles is to promote *FA strategy A*, since the content of the poll concerns the ways in which specific argumentations can be assessed according to a criterion of completeness (line 340), and *FA strategy D*, since students are invited to assess their peers' argumentations according to this criterion.

The chart elaborated by the DT (Fig. 6) is then displayed at the IWB. R comments on it and notes that 63% of the groups chose the first argumentation, 27% of the groups chose the third argumentation and 18% of the groups chose the last argumentation. When looking at each bar in the chart, R moves the poll window in order to make the corresponding argumentation visible and reads it (Fig. 7).

Again, we can say that the *analysing* functionality offered by the DT plays a crucial role in bringing the focus of the discussion to the meta-level. Since the results of the poll are displayed on the IWB as a starting point for a class discussion, the *communicating* functionality of the DT is used to empower R's role of *activator of reflective attitudes and metacognitive acts* to promote *FA strategy B*. Indeed, R's aim to get the pupils to share their reflections on the reasons for the choices they have made and on the effectiveness of these choices.

After R has presented the chart to the students and asked them to explain their choices, Michele suggests that they first think about the argumentations that nobody has chosen. He starts reading the fourth argumentation and tries to explain why he thinks it is not complete enough to be chosen: "it doesn't describe what Marco does, nor does it refer much to the graph". Then Michele proposes to focus on the fifth argumentation, explaining that it lacks completeness like the fourth ("*This is like the one before*"). By sharing his reflections on argumentation 4, Michele activates himself as a resource for his mates (FA strategy D).

At this point, R asks to the other students to comment on Michele's observation.

402. R: Do you agree that these two [*R points to the fourth and fifth argumentations*] are equivalent?
(…)
410. Lucio: In my opinion, the fifth one refers more to the graph, because the previous one (*the fourth*) only refers to when it stops, so the line is horizontal, whereas the other one always refers to the graph.
411. R: And what words do they use to make it clear that the speed changes?
412. Vincenzo: They don't say that. They say that "the line goes up a lot". They don't say that the speed increases, they just say that the line swoops or rises a lot.

At the beginning of this excerpt (line 402), R plays the role of *activator of reflective attitudes and metacognitive*

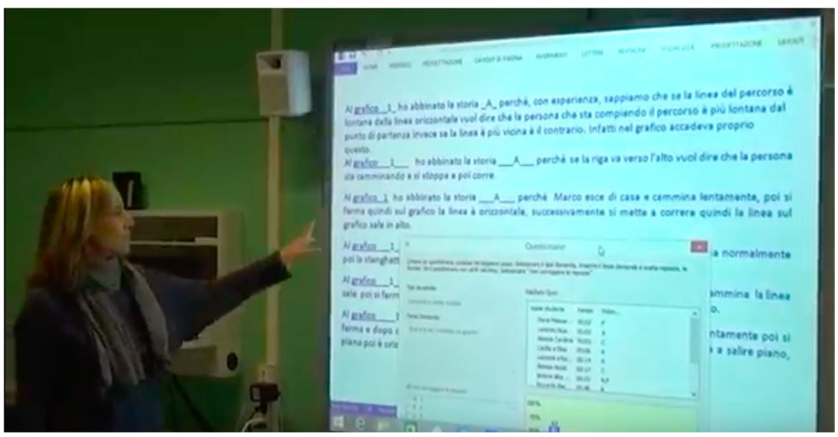


Fig. 7 R leading the discussion with the support of the DT

acts, since she draws the students' attention to Michele's comments on the equivalence between the content of argumentations 4 and 5 in order to make them reflect on the different levels of completeness of these two argumentations.

With her intervention in line 411, R also plays the role of *reflective guide*, since her aim is to draw the students' attention to certain parts of the text that is being analysed. In this way, she makes the class focus on a 'written intervention' of a group of students, trying to make their analysis and interpretation of the graph more explicit.

The discussion continues with a comparison between the completeness of argumentations 3 and 5: some students observe that the fifth argumentation at least tries to point out the fact that the speed changes, while others state that the third argumentation specifies more than the fifth.

At this point, Filippo asks to intervene and proposes to shift the focus to a comparison between argumentations 1 and 3.

> 428. Filippo: I would compare the first one and the third one because… I like the first one as an explanation because it tells you what they based on to decide that graph 1 matches story A. And they based it on experience, but it doesn't say anything mathematical. Whereas the third one explains that it goes fast and is based on the graph, so it is more complete than the first one.
> 429. R: Which one did you choose? (*addressed to Leonardo and to his group*)
> 430. Filippo: The third one.
> 431. Teacher: They told me earlier they were torn over two. The third and ...
> 432. Filippo: The first one.
> 433. R: He (*Leonardo*) says: "The first one, in my opinion, doesn't refer so much to the graph, but only to experience". He says: "I prefer the third one because it refers more to the graph".

By opening up the fact that the most complete answer is not the one chosen by the majority, Filippo's intervention allows the discussion to move to a level of assessment on the effectiveness of the choice made during the poll. In this excerpt (lines 429, 433), R plays the role of *reflective guide* at a meta-level, as she supports Filippo in making his reflections on the reasons for choosing the best option more explicit.

The main effect of using the DT to empower the roles of R as a reflective guide and activator of reflective attitudes and metacognitive acts through this specific on-the-spot poll is that peer assessment is realised at two levels (*FA strategy D*):

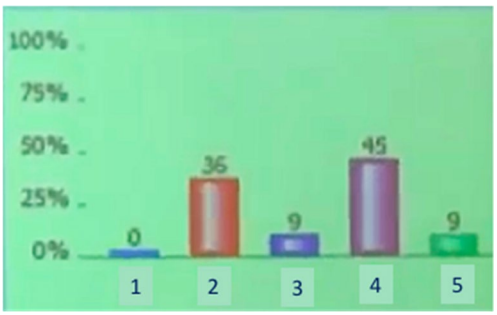


Fig. 8 Results of the third on the-spot poll

- students are encouraged to reflect on the characteristics of the list of argumentations on the IWB, i.e. they assess the completeness of these argumentations;
- the reflection on the correctness of the choice of one or another answer is a moment of peer assessment on the poll itself, as the students have the opportunity to reflect both on the answers and on the choices and motivations of the "assessors".

9.3 Third and fourth on-the-spot polls launched during the activity

Then, another meta-level on-the-spot poll is launched. The question asked is: "*Which graph was the most difficult to match with the story?*".

Again, DT is used in its *analysing* functionality, together with the *communicating functionality*, as the results of the analysis (namely, the results of the poll) are shared and discussed on the IWB. In terms of FA, the poll encourages self-assessment by the students and provides feedback to the teacher on the effectiveness of the previous discussion. *FA strategies E* and *B* are therefore activated.

By launching this poll, R plays the role of activator of reflective attitudes and metacognitive acts, empowered by the poll function of DT. Figure 8 shows the results of the poll: graphs 2 and 4 are indicated as the ones that were the most difficult to match with the stories.

As soon as the results of the poll are presented on the IWB, R starts the discussion on the graphs (3 and 5) that received fewer mentions, then she encourages a focus on graphs 2 and 4, as the two graphs with more mentions.

If we compare these results with the results of the first poll ("*Which graph required the most attention and reflection?*"), we can see that graph 3 received fewer mentions (9% vs 50%), while graphs 2 and 4 received more mentions (36% vs 16%, 45% vs 33%). In fact, the previous discussion highlighted that the difficulty with graph 3 was related to

the fact that there was no corresponding story among the options, so the difficulty was in the openness of the task rather than in the graph itself. Conversely, graphs 2 and 4 had an element of difficulty in themselves (the change of slope and the presence of a vertical segment respectively).

Students' recognition of the intrinsic difficulty of graphs 2 ("*Simone and I kept on discussing because […] For me, he walked slower, then faster, then he ran, but Simone said something else, but in the end we more or less understood it.*") and 4 ("*We tried to match the vertical segment with each story, but we couldn't understand how this graph worked and we tried all the stories, but we couldn't understand…*") is, in our opinion, an effect of the first part of the discussion, during which the students had the opportunity to reflect on the reasons behind the matching between the graphs and the corresponding stories.

As we have already noticed, in the first discussion the students focus on the sources of difficulty that are linked to specific parts of the graph to be interpreted. Therefore, a final on-the-spot poll is proposed: "*When interpreting a graph, what is the first thing you look at? (A) If the graph starts from the origin; (B) If the graph goes up or down; (C) If the graph has horizontal traits; (D) How many traits compose the graph; (E) How steep is the graph; (F) What is written on the axes.*" (for further details, see Cusi et al., 2019 and Cusi, 2022).

This on-the-spot poll was designed to encourage a metacognitive reflection on effective ways of approaching graph interpretation tasks, so there is no one right answer. Most students (72%) choose option F, 18% choose A and 9% choose C. The discussion starts with R displaying the results of the poll on the IWB, then drawing the attention of the class to the fact that some students have changed their minds and asking these students to share their reflections; then, R shifts the focus of the discussion to the most chosen answer and to the reasons subtended to its choice.

At the macro level, the *analysing and communicating functionalities* are again used. This episode has already been analysed by Cusi (2022), according to the same theoretical lenses adopted in this paper. The analysis has shown how displaying the results of the poll on the IWB could empower the role of the expert as an activator of reflective attitudes and metacognitive acts and as a reflective guide, by promoting the students' interpretation of poll's results and the explanation of their choices. Moreover, the analysis has highlighted the links between these roles played by the expert and the consequent activation of FA strategies B, D and E.

The analysis of the main characteristics of the different phases of the discussion carried out in this paradigmatic example highlights the role of the sequence and relationship between the four polls in empowering the roles played by R throughout the discussion. For example, we notice that poll 1 and poll 3 address the difficulty of the process of matching the graphs before and after the discussion on the correctness of the matching. Poll 2 brings to the fore the important criterion of completeness of the answers, emphasising that performing the correct matching is not sufficient. Finally, poll 4 deals with a crucial step in the process of matching, namely the interpretation of the different parts of the graph.

10 Synthesis of results

The double-level (macro and micro) analysis of the two paradigmatic examples we have selected allows us to approach the two research questions mentioned above:

1) How does the expert use the functionalities of DT to empower specific roles?
2) What are the effects of empowering these roles in terms of activating specific FA strategies?

With regard to question 1, the first paradigmatic example shows how the *communicating functionality of DT* could empower the $M_{AE}AB$ roles. More specifically, we highlighted some categories of use of specific DT affordances during the discussion and the corresponding roles that are empowered:

- *zooming-out and/or scrolling from top to bottom* to empower the role of *activator of reflective attitudes and metacognitive acts*, by providing the class with an overall view of the groups' answers;
- *zooming-in to focus on specific answers* to empower the role of *reflective guide*, by enabling students to better focus on specific written answers under discussion.

In addition, we have identified other specific actions that the expert can take, even without DT, to empower the role of *reflective guide* and *activator of interpretative processes*:

- *inviting a student to come to the IWB* to comment on his/her answer, focusing on both the answer and the text of the task;
- *standing in front of the IWB,* reformulating a student's discourse and repeating his/her gestures.

The relevant presence of the role of *reflective guide* during the discussion in the first example is in line with the general aim of making thinking visible in order to promote FA strategies.

The analysis of the second paradigmatic example complements the first by showing a systematic use of on-the spot polls throughout the lesson, where the *communicating and analysing functionalities of DT* empower the roles

Table 3 Interrelations between the expert's use of specific functionalities of DT, the empowerment of specific roles and the activation of FA strategies

Actions of the expert	Functionality of technology that is used	$M_{AE}AB$ role empowered through the use of DT	FA strategy supported by the role's empowerment
R zooms-out and scrolls answers from top to bottom	Communicating	Activator of reflective attitudes and metacognitive acts	E: activating students as the owners of their own learning
R invites a student to come to the IWB, where a task is displayed, and asks him/her to comment on both the representations and the answers under discussion	Communicating	Activator of interpretative processes Reflective guide	D: activating the student as instructional resource for his peers
R scrolls through the file and zooms-in on a particular answer written by a group of students	Communicating	Reflective guide	D: activating all the students as instructional resources for the authors of the answer under discussion
R launches an on-the-spot poll focused on metacognitive aspects	Analysing	Activator of reflective attitudes and metacognitive acts	E: activating all the students as the owners of their own learning
R displays a group of students' answers and launches a poll to make the students assess these answers according to a specific criterion	Communicating and analysing	Guide in fostering a harmonized balance between the syntactical and the semantic level Reflective guide Activator of reflective attitudes and metacognitive acts	D: activating students as instructional resources for the authors of the answers under discussion A: clarifying and sharing assessment criteria
R shows the results of a poll on the IWB and asks the students to interpret them	Communicating and analysing	Activator of interpretative processes Activator of reflective attitudes and metacognitive acts	C: making students provide feedback to each other D: activating students as instructional resources for one another
R shows the results of a poll on the IWB and asks the students to justify the answers they have chosen	Communicating and analysing	Reflective guide	E: activating all the students as the owners of their own learning

of *reflective guide*, *activator of interpretative processes*, *guide in fostering a harmonized balance between the syntactical and the semantic level* and *activator of reflective attitudes and metacognitive acts*. We point out that the analysing functionality is combined with the communicating functionality (*communication of technology*) since the results of the polls are displayed at the IWB and become an object of discussion. Furthermore, the combined analysis of on-the-spot polls within the second example highlights the effectiveness of R's choices in sequencing interrelated polls in such a way as to use the affordance provided by DT to empower her roles.

With regard to question 2, both examples show the link between specific roles empowered through the use of DT affordances and the corresponding activation of FA strategies.

Table 3 summarises the main results of our analysis of the ways in which the expert uses DT to empower her/his roles during classroom discussions in order to foster fruitful FA processes. FA strategy B (engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding) is constantly activated in the two paradigmatic examples, so it does not appear in the fourth column of Table 3.

11 Discussion and conclusions

The study presented in this paper aimed to provide insights into how the expert can promote FA during classroom discussions through the use of specific functionalities of DT. Our analysis showed that the use of specific functionalities can support the expert in empowering his/her roles, thus promoting FA strategies (see Table 3).

These results contribute to research on both a theoretical and a pragmatic plan.

Regarding the theoretical plan, the study introduces a three-dimensional framework that combines three different constructs: two theoretical tools coming from previous studies (the DT functionalities for FA and the FA key-strategies) and a specific construct concerning the roles that the expert teacher plays during classroom discussions (the $M_{AE}AB$ construct).

Considering the use of DT, our study can be related to Trouche's (2004) and Drijvers et al.'s (2010) characterisation of orchestration types. However, whereas Trouche's (2004) and Drijvers et al.'s (2010) orchestration types refer to the use of DT to perform mathematical activities, in our case DT is used to realise FA. In the first paradigmatic example, students' written answers, previously collected via CCT, are shared and discussed on the IWB. In the second paradigmatic example, what is shared and discussed are the results of on-the-spot polls. In both cases, our contribution provides a specific characterisation of the discuss-the-screen type during FA processes and provides a micro-analysis of the teacher's interventions using the coordinated theoretical tools.

Moreover, the double-level analysis that we carry out aims to complement a macro-level characterisation of the ways in which the expert uses specific functionalities of DT to activate FA strategies (which can be interpreted as types of orchestrations in relation to the development of FA processes), with a micro-level analysis developed by zooming-in into specific excerpts of the classroom discussions to highlight, through the study of the expert's actions and interventions, the roles that are empowered by the use of specific DT functionalities.

We acknowledge that our results are strictly linked to the specific teaching approach developed within the FaSMEd project. Despite this fact, we believe that the analytical methodology developed is also promising for other contexts.

A possible limitation relates to the fact that the researcher orchestrated the discussion in place of the teacher. As already explained, this is in line with our aim to explore how DT can be used by an expert to empower specific roles to promote FA, rather than to provide a description of teacher' actual practices in using DT to promote FA. Moreover, by allowing us to show how many decisions and choices are made in-the-moment by the expert in relation to the use of DT to support specific roles and activate corresponding FA strategies, our analysis of the two paradigmatic examples highlights the complexity of managing this kind of discussions mediated by DT, realising a synergic interplay between the combination of different functionalities of DT and the roles that the expert can play to foster FA strategies. Although in this study we have focused on the researcher, we believe that the role of expert could be played by the teacher in the classroom and that this complexity can be managed by him/her, provided that he/she has developed the necessary level of awareness.

This reflection allows us to move on to the question of teachers' professional development. First of all, the researcher in the classroom can act as a model for the teacher, who can thus interiorise ways of using DT to empower the roles that could promote FA. Moreover, the methodology adopted and the choice of having an expert in the classroom allow us to identify paradigmatic examples of the use of DT to promote FA. This can be turned into guidelines on how to use DT to empower specific roles that an expert should play during classroom discussions in order to promote FA processes. This result at a pragmatic level is promising because there is a need for teacher education on how DT can support FA, as shown by the recent experience of teaching in times of pandemic (Cusi et al., 2023).

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