Formative assessment in Mathematics in the digital age: teacher's practices and roles

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My contribution concerns the ways in which teachers' practices in supporting formative assessment (FA) *processes through digital technologies* (DT) *can be interpreted and analysed. After a reflection on the results of research studies on this issue, I present a model recently refined to characterize, at a macro level, the teachers' FA practices through DT and then the analysis of an example, developed at a micro level to highlight the roles that the teacher plays when interacting with students. I conclude with some reflections on the impact that the experience of distance teaching during the Covid-19 emergency could have on the future evolution of teachers' assessment practices through DT.*

Keywords: formative assessment, digital technologies, teachers' practices, teachers' roles.

Investigating teachers' formative assessment practices and roles in the digital age

Teaching practices in the digital age have been a fundamental focus of Mathematics Education research for decades, leading to the development of frameworks recently discussed by Haspekian (2020) in her MEDA2 plenary. Some of these frameworks explicitly focus on teachers' practices, characterizing teachers' expertise in supporting a fruitful integration of DT in teaching, such as the *structuring features of classroom practice* framework (Ruthven, 2009), and identifying categories of teachers' *instrumental orchestration* of classroom activities in technology-rich environments (Drijvers et al., 2010). Others explicitly refer to the roles played by teachers in the integration of DT in mathematics classrooms and to the levels at which teachers have to act to effectively integrate DT in their teaching (Trigueros et al., 2014).

The integration of DT in teaching affects also teachers' assessment practices. Focusing on the ways in which digital summative assessment is developed at university level, Iannone (2020) stresses on the need of re-thinking the ways in which assessment in the digital age is designed and implemented, observing that it is "far failing to realise its full potential and that usually it is designed in a conservative way" (p. 15). These reflections could be certainly referred also to the case of FA practices, which, according to Black and Wiliam (2009), could be conceived as practices through which evidence about student achievement is elicited, interpreted, and used by three main agents (teachers, learners and their peers) to make decisions about the next steps in instruction. The question of the integration of DT in Mathematics teaching for assessment purposes has been addressed in many research studies in the last decade (see, for instance, Stacey & Wiliam 2013, Cusi et al. 2017A, Dalby & Swan 2019, Olsher 2019).

In a review chapter aimed at reflecting on the changes in the ways in which mathematics is assessed due to the increasing availability of powerful technology, Stacey and Wiliam (2013) distinguish between *assessment with DT*, where the mathematical capabilities of technology are used by students in the mathematical performance that is being assessed, from *assessment through DT*, where technology is used to deliver and administer the assessment processes. According to them, "the real

power of computerized assessment is likely, in the future, to be in the creation of learning environments in which students use a range of information resources, engage with powerful software for problem solving, and collaborate with other students." (p. 748). The role played by DT within these kinds of environments have been the object of various research studies in the last years. Jankvist et al. (2021), for example, investigated the ways in which CAS augment and change assessment situations (both summative and formative). They stress that the new kinds of orchestration that the use of CAS introduces change FA "from being an individual dialogue between teacher and student, which due to resources will need to happen relatively seldom, to a collective – although but perhaps anonymous – class discussion of the different problems and understandings present in the class." (p. 114). The role played by the teacher seems to be crucial to avoid the risk of shifting to this kind of anonymous discussions. These reflections are also shared by Rezat et al. (2021), who, as a result of their investigation on the use of tasks with automated feedback within digital textbooks, stress on the need of a careful teacher's handling of classroom discussions aimed at questioning and evaluating the arguments that students develop to make sense of the received feedback.

Connected classroom technologies (CCT) certainly represent powerful DT to support FA practices. By providing teachers with more insight into their students' sense-making processes, they lead to more thoughtful teacher interventions to promote meaningful mathematical classroom discourse, prompted by shared responses and screens (Clark-Wilson, 2010). Clark-Wilson (2010) highlights the complexity of the roles played by the teacher in the context of FA, since managing the use of CCT in the mathematics classroom requires teachers to develop specific competences, such as, for example, being able to quickly make sense to the diversity of students' screens that are visible. The ways in which these roles are shaped when sophisticated interactive systems are used has been investigated by Dalby and Swan (2019), who observe the emergence of differing views of the role of the teacher when using DT in the classroom, shifting from a central role to a role of "guide on the side". Similar results stressing on the complexity of teachers' roles have been highlighted by recent studies that investigated the use of dashboards as digital curricular resources and, in particular, the teachers' role in planning, implementing, gathering information, and making real-time decisions starting from the "in-the-moment" pedagogical perspective provided by the teacher dashboards (Edson & Difanis Phillips, 2021). Amarasinghe et al. (2021) model teachers' orchestration actions during their interaction with learning analytics dashboards to deconstruct the notion of orchestration load. Their study enabled them to highlight that the use of guiding tools, which visualize learners' interactions with the learning systems and guide teachers to take remedial actions to enhance the learning situation, requires teachers to distribute their attention to evaluate both epistemic (the content of students' responses) and social (the actions to be taken to foster collaboration) aspects, contributing in creating a cognitively demanding situation for them.

The teachers' expertise in the use of various combinations of DT does not necessarily implies a corresponding expertise in the use of DT to develop FA processes, since making FA through DT an integral part of teachers' practice requires changes in their beliefs about teaching and learning and in the classroom culture itself (Feldman & Capobianco, 2008). A three-level developmental progression for teachers' full transition to the highest level of expertise in carrying out FA processes through DT is described by Bellman et al. (2014), who distinguish between: *immediate level*, when teachers

examine students' feedback and take decisions about "what to do next" after class; *expert level*, when teachers are able to use students' data to make "real time" decisions; and *master level*, when teachers are able to command the full range of advanced interactive capabilities that DT offer.

Macro level of analysis: a model to interpret teachers' FA practices through DT

In a recent work developed with Gilles Aldon, Barbel Barzel and Shai Olsher (Aldon et al., submitted for publication), we introduced a model aimed at supporting the interpretation of teachers' FA practices carried out through DT. The model, which was conceived by combining a survey of general literature on the issue of FA with a survey of studies on the use of DT for FA purposes, represents a refinement of the one introduced within the European Project FaSMEd (Aldon et al., 2017). It is constituted by three main elements: (a) the *key areas* in which FA practices can be taken forward; (b) the *moments* in which teachers' FA practices are carried out; (c) the *functionalities* provided by DT to support FA processes.

The *key areas* for FA (first element) have been identified by referring to the studies developed with the aim of investigating what happens inside the "black box" (Black & Wiliam, 1998), where FA theoretical principles become a reference for framing the design and implementation of FA in practice. The survey of these studies (due to space limitation, I just mention Black & Wiliam 1998, Black et al. 2003, Lee 2006, Bartlett 2015) enabled us to identify four main areas in which FA practices can be taken forward: (1) sharing goals and criteria with learners; (2) designing and implementing classroom discussions and other learning activities (which includes three fundamental processes: monitoring students' understanding, scaffolding their learning and fostering their reflections); (3) fostering the quality of feedback; (4) involving students in peer- and self-assessment.

The second element of the model - the *moments* in which teachers' FA practices are carried out - has been identified with the aim of better characterizing the complex work that teachers have to develop, in time, to carry out effective processes within the four areas. This element of the model was inspired by Mason's (2009) characterization of the processes developed by teachers to prepare themselves to teach a topic during four phases: *pre-paration, paration, meta-paration* and *post-paration*. In our model we combine paration and meta-paration in a unique moment, due to their strict interconnection, focusing on three moments that constitute a cycle of teacher's FA practices.

The starting point for the identification of the main *functionalities* that constitute the third element of our model is the framework introduced within FaSMEd, in which three functionalities of technology to support FA processes are considered: sending and displaying; processing and analyzing; and providing an interactive environment. The rapid evolution of digital tools, the new available formats of online interaction and the possibilities offered by artificial intelligence suggested as to extend these three functionalities to best capture the current realities. 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 and of technology (Ball & Barzel, 2018); (2) *analyzing*, which involves different levels, from providing just an overview of the work progress, to providing information on the learning status, to realizing an advanced analysis which allows 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, by simply offering tasks to be chosen by the

teacher, or suggesting the learning paths for students, or providing teachers with learning materials designed on the basis of a comprehensive learner's profile.

Micro level of analysis: the teacher's roles in fostering FA processes through DT

In this section I will focus on an example from a teaching experiment, carried out within the FaSMEd project in Italy (firstly presented in Cusi et al., 2019), to discuss the roles that the teacher could play during the phase of *paration/meta-paration* of a FA lesson developed with the support of DT. During the teaching experiment, activities were carried out through the use of a CCT. The example refers to the ways in which the teacher exploits the *communicating and analyzing* functionalities of this CCT by administering an instant poll to her students and by carrying out a classroom discussion starting from the results of the poll. The use of a CCT to develop FA processes involves the monitoring of students' work by sharing the students' screens with the teacher and the collecting and displaying of students' answers to design and implement fruitful discussions with students (*communicating* functionality). When instant polls are activated, the DT provides teachers with synthetic information on the class-wide distribution of answers to a focused question (*analyzing* functionality). Then, the teacher's task is to use this information to react in a supportive way, e.g. by designing and initiating in-the-moment classroom discussions to make students reflect on the processes developed when they answered to the polls (Cusi et al., 2019). In this example I focus on this last aspect, by sharing some reflections on the teacher's roles that proved to be effective in fostering the realization of a learning dialogue with students aimed at supporting their reflective processes.

The aim of my analysis of the example is to move: (a) from a *macro level of analysis* of a FA assessment practice realized through DT, which locates the teachers' actions within specific FA key areas (*the where of FA*), in a specific moment (*the when of FA*), and characterizes teachers' practices by highlighting the functionalities that are used (*the how of FA*), (b) to a *micro level of analysis*, which deepens the investigation of the *how of FA* by zooming into a scene of classroom interaction focusing on the teacher's interventions and on their effects in terms of the activated FA key-strategies.

To develop this micro analysis, I will interpret and analyze the teacher's interventions by referring to the MAEAB (acronym for "Model of Aware and Effective Attitudes and Behaviours") construct (Cusi & Malara, 2016). The key-roles characterizing the construct are subdivided into two groups. Here I focus on the roles that the teacher plays when she guides students to reflect on the approaches adopted during classroom activities and to become aware of the relationships between the activities in which they are involved and the knowledge they previously developed. The three key-roles belonging to this group are presented in Table 1, together with indicators to support the coding process.

I will highlight the strategies activated through teachers' interventions by referring to Black and Wiliam's (2009) five FA key-strategies: (1) clarifying and sharing learning intentions and criteria for success; (2) engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding; (3) providing feedback that moves learners forward; (4) activating students as instructional resources for one another; (5) activating students as the owners of their own learning.

Roles of a M-$_{AE}$AB	Characterization of each role	Indicators to code each role
Guide in fostering a harmonized balance between the syntactical and the semantic level	She/he helps her/his students control the meaning and the syntactical correctness of the mathematical expressions they construct and, at the same time, the reasons underlying the correctness of the transformations they perform.	She/he poses questions/ makes interventions aimed at making students reflect on the correctness of specific transformations that are performed and highlight connections between the processes that characterize the resolution of a problem and the corresponding meanings. For example: "Is this transformation correct?", "Why did you make this transformation?", "How have we obtained this result?".
Reflective guide	She/he stimulates reflections on the effective approaches carried out during class activities in order to make students identify effective practical/strategic models from which they can draw their inspiration in facing problems.	She/he poses questions / makes interventions aimed at supporting students in making the meaning of effective strategies/approaches explicit. For example: "Could you explain your reasoning to your classmates?", "Is there someone that could explain his/her reasoning?", "She/he reasoned in this way: "since I want to obtain this kind of result, I could…".
"Activator" of reflective attitudes and metacognitive acts	She/he stimulates and provokes meta-level attitudes, with a focus on the control of the global sense of processes.	She/he poses questions / makes interventions aimed at supporting students in highlighting strengths/weaknesses of specific arguments/strategies and in fostering the sharing and comparison of different arguments/strategies. For example: "Do you agree with what she/he said?", "Do you think it is an effective choice/strategy? Why?", "What differences are there between theses answers?".

Table 1: The second group of roles within the M-$_{AE}$AB construct (Cusi & Malara, 2016)

The analysis of a wide set of data collected during the FaSMEd Project enabled us to classify polls according to their different focus and aims in relation to the aspects to be highlighted during classroom discussions that could be structured starting from polls' results (Cusi et al., 2019). We identified four categories of polls: (a) polls on specific mathematical content; (b) polls on argumentation; (c) polls on metacognitive aspects; (d) polls on affective aspects. The instant poll discussed within this example belongs to category (c). It was administered to a grade 5 class at the end of a sequence of tasks on time-distance graphs and created on the spot by the teacher (T) and by a researcher (R), who participated to the lesson and guided the discussion with T.

This is the wording of the poll, aimed at boosting a metacognitive reflection on effective ways to tackle graph interpretation tasks: "*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.* This poll does not encompass only one correct answer. The subsequent discussion was aimed at making visible students' strategies when approaching a graph and compare the efficiency of such strategies. In Cusi et al. (2019), a long excerpt from this classroom discussion was analysed to highlight the FA strategies activated by T and R during the discussion and the characteristics of the ways in which FA discussions developed thanks to the activation of polls are initiated and evolve.

At the beginning of the classroom discussion, to which the following excerpt refers, R displays on the interactive whiteboard the results of the instant poll: most students (72%) chose option F, 18% chose A and 9% chose C.

1. R: Here we have 72% that answered F. Someone chose A: "If the graph starts from the origin". Someone chose C: "If there are horizontal traits". The other options were not chosen. Some of you said to have changed her mind. Would you like to tell it now? (*speaking to Sabrina, who, before the beginning of the discussion, asked R to change her mind*)
2. Sabrina: We chose A, but later we changed our mind. We want to choose F.
3. R: So, actually for you it is F? We could start from F. Why do you think the first thing to look at is what is written on the axes? (*some students raise their hands. Among them, Elsa and Carlo, who worked in pairs*)
4. Elsa: Because, if you look at what is written on the axes, you can already understand the graph… and you can get some information.
5. R: Let's listen to somebody else. Carlo.
6. Carlo: I wanted to say that on the axes it is written what they are, what you have to measure, look at, observe…
7. R: Ok.
8. Luca: Also on the axes… if, for instance, it had been the contrary, here (*with gestures, he draws a vertical line*) the time and here (*with gestures, he draws a horizontal line*) the distance, the graph would have changed… (*he draws with gestures a possible new graph*).
9. R: Did you listen to what Luca said? (*speaking with the other students*)
10. Voices: Yes!
11. R: I guess that somebody did not listen.
12. T: He said a very interesting thing.
13. R: Would you like to repeat what Luca said? (*to a student who raised her hand*).

This short excerpt shows how the teacher (in this case R) could initiate a classroom discussion aimed at exploiting the results of a poll on metacognitive aspects to activate the *FA strategy 2*. The excerpt starts with R highlighting one typical effect of the displaying of polls' results, that is student's revision of their answer (*FA strategy 5*). R, in fact, poses herself as an *activator of reflective attitudes and metacognitive acts* (line 1), making the class notice that Sabrina and her mate have changed their mind and asking to the two students to share their reflections and to make their thinking explicit.

The role of *activator of reflective attitudes and metacognitive acts* is again played by R in line 3, when she focuses on the most chosen answer (F) and stimulates a discussion on the reasons subtended to the choice of looking at what is written on the axes. This makes Elsa and Carlo intervene (lines 4 and 6) to justify their choice, activating themselves as *resources for their classmates* (*FA strategy 4*) by explaining that knowing the variables represented on the axes make it easier to interpret the graph and to grasp the information it brings.

When Luca expresses his idea (*FA strategy 5*) proposing an interesting observation about the effects of inverting the two variables represented on the axes of the graph (line 8), R, to highlight Luca's intervention and to turn him into a real *resource for his classmates* (*FA strategy 4*), poses herself as a *reflective guide*, relaunching Luca's intervention and asking to other pupils to repeat Luca's idea (lines 9, 11, 13). This strategy makes Luca's thinking visible to his classmates.

The discussion goes on with a collective reflection on the effects, on the graph, of inverting the variables on the two axes. During this phase of reflection (not reported within the excerpt), R poses herself also as a *guide in fostering a harmonized balance between the syntactical and the semantic level*, with the effect of giving feedback that moves students' learning forward (FA strategy 3).

The analysis of the whole set of data collected within the FaSMed project enabled us to identify other ways of initiating and developing discussions on metacognitive aspects, such as focusing on the options that were not chosen and asking students the reasons for not having chosen them. The analysis of these data confirmed the results on the interrelation between the key roles played by the teacher and the corresponding FA strategies highlighted in the example reported in this section.

Concluding remarks

In this contribution I shared reflections on the ways in which teachers' practices in developing and supporting FA processes through DT could be interpreted and analysed. In the path toward the development of these reflections, I gradually zoomed into the investigation of teachers' practices by shifting the focus: (1) from the results of research studies that investigated the teachers' practices in exploiting the support provided by DT to develop FA processes; (2) to a model recently refined to characterize the teachers' FA practices with DT at a *macro level* by describing *the where, the when* and *the how* of these practices; (3) to the presentation of an example aimed at deepening the investigation of the how of teachers' FA practices through DT by developing an analysis at a *micro level* to highlight the roles that the teacher plays when interacting with his/her students.

The analysis shared in the last section was focused on the teachers' roles associated to specific interventions during episodes of classroom interaction located within the *paration/meta-paration moment* and supported by the *analyzing* and *communicating functionalities* of DT. This analysis highlighted the connection between specific roles that are played and the corresponding FA strategies that could be activated, which locate the example within the *second* and *fourth key areas* of FA. In particular, it showed that a combination of the roles of *activator of reflective attitudes and metacognitive acts* and of *reflective guide* contributes to the implementation of classroom discussions aimed at fostering students' meta-level reflections (*second area*) and at involving them in peer- and self-assessment (*fourth area*).

The micro level analysis of several classroom interactions performed during teaching experiments developed within FaSMEd and other projects led us to reflect on other aspects that characterize the teachers' FA practices through DT, such as the typical strategies employed by the teacher to provide feedback (Cusi et al., 2017B) or the roles that teachers can activate to guide classroom discussions aimed at supporting students' argumentative processes and at scaffolding their awareness about the effectiveness of the written productions they share by means of digital environments (Cusi & Olsher, 2021). The crucial role played by the teacher was also highlighted in the context of a digital

environment aimed at supporting students in individually revising mathematical topics through individualized digital paths at university level, since the tutor's interventions proved to be fundamental in supporting students' interpretation of the meta-scaffolding and feedback provided by the digital environment (Cusi & Telloni, 2020).

In this contribution I focused on what the teachers do to develop FA processes through the support of DT. As a contribution to the issue of delineating a model to characterize teachers' FA practices in the digital age, it is important to intertwine the analysis of what teachers do with the analysis of how they interpret what they do, that is how they describe and justify their FA practices through DT. We started this kind of investigation within two studies carried out at the beginning of the Covid-19 emergency and after one year from the first lockdowns (Aldon et al., 2021; Cusi et al., 2022). These studies have shown that the experience of distance teaching triggered teachers' reflections on the future of assessment in Mathematics and enabled them to highlight the value of FA. Moreover, the distance teaching experience enabled some teachers to discover other 'possibilities', that is, other possible ways of developing assessment processes, potentially enlarging their repertoire of assessment techniques by exploiting the potentialities offered by DT. The results of these studies also showed that not all of the new techniques discovered by teachers continued to be part of their praxeologies after the distance teaching experience. This enabled us to develop reflections on the 'stability' of the changes and transformations of assessment practices declared by teachers and on the need of promoting and supporting the stabilization of these changes by focusing on educational programmes aimed at deepening teachers' professional development to foster the teachers' autonomous use of DT to carry out effective FA practices.

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