ENHANCING FORMATIVE ASSESSMENT STRATEGIES IN MATHEMATICS THROUGH CLASSROOM CONNECTED TECHNOLOGY

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The paper analyses how connected classroom technologies can be exploited to foster formative assessment practices in the mathematics classroom. Referring to a three-dimensional framework developed within the European project FaSMEd and to Hattie and Temperley's levels of feedback (2007), an excerpts from a classroom discussion in grade V is analysed in order to show the complex dynamics between the different formative assessment strategies that can be activated.

INTRODUCTION AND THEORETICAL FRAMEWORK

Research in Mathematics education has focused on the use of digital technology to support the Mathematics teaching-learning for many years. Within the European Project FaSMEd ("Improving progress for lower achievers through Formative Assessment in Science and Mathematics Education"), we investigate the use of connected classroom technologies (CCT) as means for supporting formative assessment (FA) practices in the mathematics classroom.

Within the FaSMEd Project, FA is conceived as a method of teaching where

> "[...] evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited" (Black & Wiliam, 2009, p. 7).

Following Wiliam and Thompson (2007), we adopt a model for FA in classroom context as consisting in *five key strategies*: (A) Clarifying and sharing learning intentions and criteria for success; (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; (E) Activating students as the owners of their own learning. This model identifies the three *main agents* (the teacher, the learners and their peers) and the three crucial processes in which the agents are involved: *Establishing where learners are in their learning*; *Establishing where learners are going*; *Establishing how to get there*.

On the other hand, some studies provide evidence about how new technology can be used as an effective tool in supporting FA processes (Quellmalz et al., 2012). Specifically, CCT may: create immersive learning environments that give powerful clues to what students are doing, thinking, and understanding, make students take a more active role in the discussions, encourage students, through immediate private feedback, to reflect and monitor their own progress (Roschelle et al., 2004), and enable the teachers to monitor students' progress and provide appropriate remediation to address student needs (Irving, 2006).

Within the FaSMEd project, the Wiliam and Thompson's (2007) model has been extended in order to include the use of technology in FA processes. To this purpose, three different functionalities of technology have been identified: (1) *Sending and sharing*, when technology is used to support the communication among the agents of FA processes (for example: sending questions and answers, messages, files, displaying and sharing screens to the whole class or to specific students, sharing students' worksheets). (2) *Processing and analyzing*, when technology supports the processing and the analysis of the data collected during the lessons (such as the statistics of students' answers, the feedbacks given directly by the technology to the students, the tracking of students' learning paths). (3) *Providing an interactive environment*, when technology enables to create interactive environments in which students can work on a task and explore mathematical/scientific contents.

The result is a three-dimensional model taking into account three main dimensions (Fig.1): (1) *the five FA key-strategies* (Wiliam & Thompson, 2007); (2) *the three main agents* (the teacher, the student, the peers), and (3) *the functionalities* through which technology can support the three agents in developing the FA strategies.

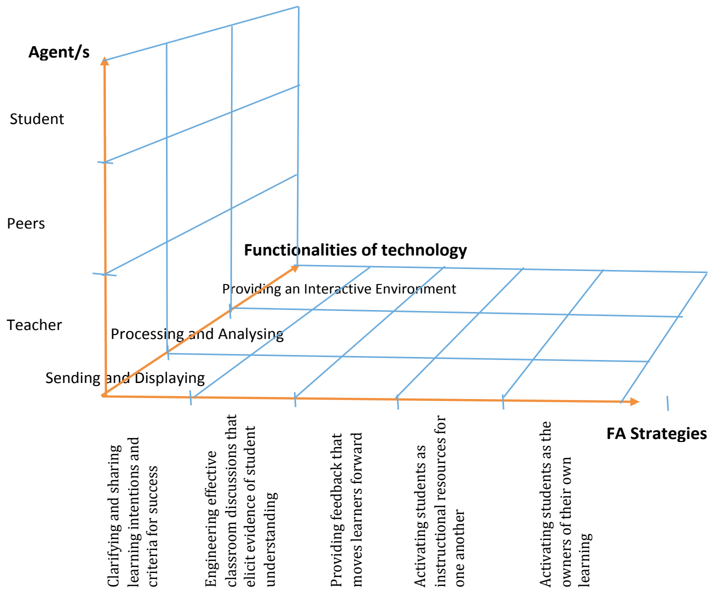

Fig. 1: Chart of the FaSMEd three-dimensional model

Feedback given by the different agents plays a crucial role for FA. Hattie and Temperley (2007) identify four *major levels of feedback*: (1) feedback *about the task*, which includes feedback about how well a task is being accomplished or performed; (2) feedback *about the processing of the task*, which concerns the processes underlying tasks or relating and extending tasks; (3) feedback *about self-regulation*, which addresses the way students monitor, direct, and regulate actions toward the learning goal; (4) feedback *about the self as a person*, which expresses positive (and sometimes negative) evaluations and affect about the student.

In this paper, we use the FaSMEd framework and the four levels of feedback in order to investigate the FA processes that take place in the mathematics classroom context, thanks to the support provided by CCT and to the teacher's choices. We also highlight the complex dynamical development between the different FA strategies activated by the agents involved.

METHODOLOGY

In Italy the FaSMEd project involves 18 teachers, from three different clusters of schools located in the North-West of Italy (from grade 4 to grade 7). Our hypothesis is that, in order to raise students' achievement, FA has to focus not only on basic competences, but also on metacognitive factors (Schoenfeld, 1992). Accordingly, we planned and developed class activities with the aim of: (a) fostering students' development of ongoing reflections on the teaching-learning processes; (b) focusing on making thinking visible (Collins, Brown & Newmann, 1989) and on students' sharing of the thinking processes with the teacher and the classmates. For these reasons, we explored the use of a CCT, which connects the students' tablets with the teachers' laptop and allows the students to share their productions, and the teacher to easily collect the students' opinions and reflections during or at the end of an activity. Each school was provided with tablets for the students and computers for the teachers, linked to IWB. In order to foster collaboration and sharing of ideas, students were asked to work in pairs or in small groups on the same tablet.

The use of the CCT was integrated within a set of activities on relationships and functions, and their different representations (symbolic, tabular, graphic), adapting activities from the ArAl project (Cusi, Malara & Navarra, 2011) and the Mathematics Assessment Program (http://map.mathshell.org). In line with our hypothesis and aims, our adaptation consisted in the creation of different worksheets belonging to three main categories: (1) *Worksheets focused on one or more questions* involving the interpretation or the construction of different representations of mathematical relationships between two variables (e.g. interpreting a time-distance graph); (2) *Helping worksheets*, aimed at supporting students, who meet difficulties with the type 1-worksheets, through specific suggestions (e.g. guiding questions); (3) *Worksheets prompting a poll* between proposed options.

Usually the activity starts with a worksheet focused on one or more questions (type 1), sent from the teacher's laptop to the students' tablet. After facing the task and answering the questions, the pairs/groups send back to the teacher their written productions. The teacher can decide to send helping worksheets (type 2) to some groups, or the groups can ask for them. After all groups have sent back their answers, the teacher sets up a classroom discussion in which the students' written productions are shown and feedbacks are given. The discussion is engineered starting from the teacher's selection of some of the received written answers, to be shown on the IWB, and aims at highlighting: (a) typical mistakes; (b) effective ways of processing the tasks; (c) the comparison between the different ways of justifying claims. Polls are also used to prompt the discussion, in different parts of the lessons.

During the teaching experiments, one of the authors was always in the classes with the teachers, acting as a participant observer, namely taking notes, video-recording the lessons, and helping the teacher carry out the activities, for instance proposing interventions to foster fruitful discussions.

In this paper we will focus on a classroom discussion in grade 5. Specifically, in the next section we will analyse an episode that was selected because of the different FA strategies that are activated and the plurality of feedback that is provided. A variety of data were collected. We rely, in particular, on the qualitative analysis of the video-recordings, with the help of the written transcription of dialogues.

ANALYSIS OF AN EXCERPT FROM A CLASS DISCUSSION

The lesson is focused on time-distance graphs, introduced in the previous lesson through an experience with a motion sensor. The excerpt refers to the discussion of the first worksheet, reported in Table 1. As said, a researcher (first author of this paper) was present as a participant observer, and helped the teacher in managing the discussion.

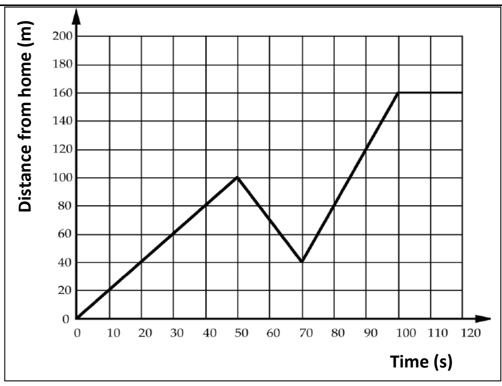	**Worksheet 1** *Every morning Tom walks along a straight road from his home to a bus stop, a distance of 160 meters. The graph shows his journey on one particular day.* *What happens in the period of time between 50s and 70s? How did you establish it?*

Table 1: The worksheet sent to the students' tablet

From the mathematical point of view, the task and the discussion are aimed at: (1) Guiding the students in the interpretation of a time-distance graph; (2) Making the students focus on the processes underlying the correct interpretation of a time-distance graph, in particular with reference to the ascending/descending lines and to the information contained in the coordinates.

Four different answers are selected and projected on the IWB. The teacher asks the students to comment on them. One student, Livio, starts the discussion and proposes to focus on the following answer, which he declares (erroneously) *not* to be correct:

"*Tommaso, in 20 seconds, was able to walk for 60 metres. We know that in 20 seconds he walked for 60 metres because we took 50s away from 70s, obtaining 20s, then we subtracted 60m from 100m and we obtained 40 metres*".

Livio and his groupmate Giacomo declare that, in the period from 50s and 70s, Tommaso walked for 40m, not for 60m. Another student, Stefano, agrees with them, saying that the point (70,40) in the graph guarantees that Tommaso walked back for 40m. Almost all the students (even Vincenzo and Mirco, the authors of the answer) think that Livio and Stefano's arguments are correct. Only Arturo says that, in his opinion, the written answer is correct. In managing this part of the discussion, the teacher chooses to first invite those students who think that the answer is not correct express their point of view; then she asks Arturo to explain why, on the contrary, he thinks that the answer is correct.

145. Arturo: … if we look at the graph, he (*Tommaso*) arrives at 100m, then he goes back.

146. Teacher: Do we all agree that he goes back? (*A chorus of students answer "yes")*

147. Teacher: Who doesn't agree on the fact that he goes back? (*None of the pupils raises his/her hand*)

148. Arturo: However, he goes back to 40m, not for 40m (*stressing on the words 'in' and 'for'*). So we have to do the subtraction 100 minus 40. And the result is 60, not 40. So it (*the answer*) is correct.

149. Teacher: So is it (*the answer*) correct? Do you agree with Arturo? (*to the class*)

Silence.

150. Researcher: Please repeat the words you used (*speaking with Arturo*), since they are very precise. Listen to them (*speaking with the other students*).

Arturo repeats his reasoning, stating it slower and stressing the most important words, as asked. In particular, he explains that 60m is the result of the difference between 100m and 40m. At this point the projected answer is read again, and Vincenzo and Mirco (the authors of the answer) are addressed.

166. Researcher: You (*speaking to Vincenzo and Mirco*) said that you wanted to change your answer. Would you still change it or would you keep it as it is?

167. Mirco: We would keep our first answer.

168. Researcher: Ok. I have one question for all of you (*speaking to the whole class*): what is missing in this answer?

169. Mirco: That Tommaso went back! We did not write it.

170. Researcher: You did not say that Tommaso went back.

This part of the lesson exploits the *Sending and displaying* functionality of the technology: *sending* in a double direction, because the worksheets are sent to the students, who, in turn, send back their answers to the teacher's computer when they finish; *displaying* because the answers of the students are projected on the IWB and form the base for the class discussion. Projecting the collection of students' answers on the IWB enables the teacher, the researcher and the students to focus on different aspects, through the comparison of answers and justifications proposed by the students: the *Sending and displaying* functionality appears to support the teacher (and the researcher) in activating the *FA strategy B* (*Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding*).

One student (Livio) erroneously identifies one correct answer as wrong, and explains what he identifies as a mistake. When many students (even Vincenzo and Mirco, who indeed gave the correct projected answer) agree with him, the teacher asks them to express their point of view: in this way, mistakes and misinterpretations come to the fore, and so she can gain information about *where the learners are in their learning*. Only afterwards, she exploits Arturo's disagreement to activate the *FA strategy D*: Arturo, in fact, is *activated as an instructional resource for his classmates* (lines 145, 148). His explanation (line 148), which highlights how to determine for how many meters Tommaso walked back, represents both a *feedback about the task* and a *feedback about the processing of the task*: *Strategy C* (*Providing feedback that moves learners forward*) is activated at the peers' level.

Seizing the effective and precise distinction made by Arturo in order to highlight that 40m, which is the distance from home, should not be confused with the walked distance, the Researcher (line 149) recognizes that the student has provided a correct argument, by asking him to repeat his words, and positively assessing them ("they are very precise"). In this way, she is activating *Strategy C*, giving students a *feedback about the processing of the task*, because she wants to make them focus on Arturo's way of interpreting the graph in order to understand what 40m represents. Afterwards, in order to activate *Strategy E* (*Activating students as the owners of their own learning*), the Researcher (line 166) asks Vincenzo and Mirco if they changed again their mind. By accepting Mirco's answer (line 167) without further questioning it or asking for additional justification (line 168), she is communicating, in an implicit way, that the answer is correct (*feedback on the task*). At the same time, she is prompting students to further focus on the same answer and look for something that is missing (again, *feedback on the task*). Mirco (line 169) shows that he really has *activated himself as the owner of his own learning* (*strategy E*) because he correctly identifies how his own answer can be completed.

In summary, the *Sending and Displaying* functionality of the technology supported the teacher in activating different FA strategies (in this case *strategies B, C, D* and *E*). We point out that the teacher is not the only agent involved and active during these processes. The students themselves, in fact, activate some strategies, because they give feedback to each other (*strategy C*, activated by peers), becoming instructional resources for one another (*strategy D*, again at the peers' level) and owners of their own learning (*strategy E*, activated by the students themselves). The following diagram (Fig. 2) illustrates the variety of these strategies, together with the agents and the functionality of the technology that is used.

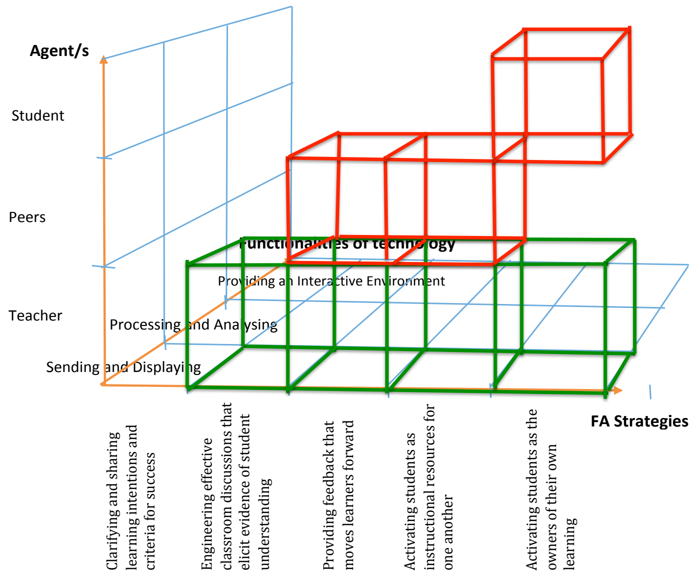

Figure 2: The FaSMEd three-dimensional model applied to the excerpt

CONCLUSIONS

The diagram (Fig.2) shows a global *static* picture of the episode, according to the FaSMEd framework. In our analysis we integrated this framework with the analysis of the levels of feedback, highlighting, in particular, feedback about the task and about the processing of the task. In other episodes from our teaching experiments we also gained evidence of feedback about self-regulation and about self as a person. As concerns the role of technology, the CCT we chose enables also to use the *processing and analysing* functionality through instant polls, which can be exploited by the teacher in engineering discussions rich in FA strategies (Aldon et al., in press).

The excerpt can also be analysed from a *dynamic* point of view. The following diagram illustrates the dynamic structure through which the class discussion has been engineered (*strategy B*) to activate other FA strategies:

The teacher asks to students to comment on a list of selected written productions, with the aim of activating the students as instructional resources for one another (*strategy D*).	→	The students provides feedback to each others and the teacher, too, comments, providing further feedback (*strategy C*).	→	The students, thanks also to the support provided by the teacher, exploit the provided feedback, activating themselves as owners of their learning (*strategy E*).

Table 2: The dynamic evolution of FA strategies in the analysed excerpt

In our view it is very important that strategy E is activated by the students themselves. From our results, it appears that working on strategies B, C and D (possibly A) is a promising road towards this goal. Further research is needed to confirm this hypothesis on firmer base.

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