A, B, OR C? EXPLOITING POLLS AS A FORMATIVE ASSESSMENT TOOL FOR MATHEMATICS IN A CONNECTED CLASSROOM ENVIRONMENT

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This contribution addresses the theme of technology for formative assessment in the mathematics classroom. Taking a design-based research approach within the European project FaSMEd, we focus on the ways connected classroom technology may support formative assessment strategies in whole class activities. We will refer to a theoretical framework developed within the FaSMEd project, which relates the development of different formative assessment strategies by different agents (teacher, peers, and the student) to different technology functionalities. In particular, we will focus on the functionalities that allow to submit polls to students, gather the answers from them and show the results (both individual answers and cluster ones) in real time. With reference to the theoretical framework and existing literature, we discuss, how the polls can be used, during classroom activities, to foster the activation of formative assessment strategies.

Keywords: Connected classroom technologies, formative assessment, polls, classroom discussion

INTRODUCTION AND BACKGROUND

Research has highlighted the support given to formative assessment (FA) by the so called Connected classroom technologies (CCT), i.e. networked systems of computers or handheld devices specifically designed to be used in a classroom for interactive teaching and learning (Irving 2006). CCT include: classroom response systems (Roschelle & Pea 2002), networked graphing calculators (Clark-Wilson 2010), and participatory simulations (Ares 2008). Specific features of CCT that make them effective tools for FA are related to the support they may provide in:

1. monitoring students' progress, collecting the content of students' interaction over longer timespans and over multiple sets of classroom participants (Roschelle & Pea 2002) and giving powerful clues to what they are doing, thinking, and understanding (Roschelle et al. 2004);
2. providing students with immediate private feedback, supporting them with appropriate remediation and keeping them oriented on the path to deep conceptual understanding (Irving 2006);
3. fostering positive student's thinking habits, such as arguing for their point of view, creating immersive learning environments that highlight problem-solving processes (Irving 2006);
4. enabling the students taking a more active role in the class discussions and encouraging them to reflect and monitor their own progress (Roschelle & Pea 2002, Ares 2008).

In our research we focused on the way CCT may be exploited for formative assessment during whole class activities. In particular, in this contribution we focus on a specific feature of the CCT we investigated: the possibility of activating *polls*. Polls are a typical characteristic of what research calls Classroom Response System (CRS), which consists of a set of input devices for students, communicating with the software running on the instructor's computer, and enabling the instructor to pose questions to students and take a follow-up poll (Beatty & Gerace 2009). Beatty and Gerace (ibid.) observe that one crucial feature of CRS is that they simultaneously provide anonymity and accountability, support collecting answers from all students in a class, rather than just the few who speak up or are called upon and enable recording the data of students' individual and collective responses for subsequent analysis. They also highlight the flexibility in the use of CRS technology, listing specific instructional purposes connected to its use. Among them: (a) the use of polls for status check, that is to ask students their self-reported degree of confidence in their understanding of a topic; (b) exit poll, that is to poll students to find out which concepts they want to spend more time on; (c) assess prior knowledge, that is to elicit what students know or believe about a topic; (d) provoke thinking, that is to ask a question to get students engaged within a new topic; (e) elicit a misconception; (f) exercise a cognitive skill, that is to engage students in a specific cognitive activity; (g) stimulate discussion with questions having multiple reasonable answers; (h) review, that is to pose questions aimed at remainding students a body of material already covered.

Notwithstanding the potential of these tools, many researchers have stressed that the effectiveness of these technologies depends on the skill of the instructor and on his/her ability to incorporate procedures such as tracking students' progress, keeping students motivated and enhancing reflection with technologies (Irving 2006). Different studies have highlighted that CCT have increased the complexity of the teacher's role with respect to 'orchestrating' the lesson (Clark-Wilson 2010, Roschelle & Pea 2002). Therefore, in order to bring about progress in student participation and achievement, technology must be used in conjunction with particular kinds of teaching strategies.

Beatty and Gerace (2009) developed *technology-enhanced formative assessment (TEFA)*, a pedagogical approach for teaching science and mathematics with the aid of a CRS. To help teachers implement FA, the TEFA approach introduces an iterative cycle of question posing, answering, and discussing, which forms a scaffold for structuring whole-class interaction. The essential phases of the cycle are: 1) pose a challenging question to the students; 2) have students wrestle with the question and decide upon a response; 3) use a CRS to collect responses and display a chart of the aggregated responses; 4) elicit from students different reasons and justifications for the chosen responses; 5) develop a student-dominated discussion of the assumptions, perceptions, ideas, and arguments involved; 6) provide a summary, micro-lecture, meta-level comments.

In our research we focus on the use of polls to enhance *effective classroom discussions with FA purposes*. In this contribution we will analyse, in particular, how the processing of students' answers by technology can be exploited to activate different FA strategies. This study is part of a wider design-based research, characterized by cycles of design, enactment, analysis and redesign, where the goal of designing learning environments is intertwined with that of developing new theories (DBRC 2003). The research is carried out in authentic settings (classroom environments), focusing on "interactions that refine our understanding of the learning issues involved" (ibid. p. 5).

FORMATIVE ASSESSMENT WITH TECHNOLOGY: A THEORETICAL FRAMEWORK

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).

Taking this perspective, in the FaSMEd project we developed a three-dimensional framework for the design and implementation of technologically-enhanced formative assessment activities (Aldon et al. 2017, Cusi, Morselli and Sabena 2017). The starting point is the work by Wiliam and Thompson (2007), who identified five key strategies for FA: (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.* These FA strategies may be activated by three agents: the teacher, the peers and the student himself. The FaSMEd framework extends this model of FA, taking into account the two dimensions already included (FA strategies and the agents activating such strategies), and adding a further dimension: the functionalities of technology. Technology, indeed, may support the three agents in developing the FA strategies in different ways, which we categorized in three *functionalities*:

(1) *Sending and displaying*, that is the ways in which technology support the communication among the agents of FA processes (e.g. sending and receiving messages and files, displaying and sharing screens or documents to the whole class...).

(2) *Processing and analysing*, that is the ways in which technology supports the processing and the analysis of the data collected during the lessons (e.g. through the sharing of the statistics of students' answers to polls or questionnaires, the feedbacks given directly by the technology to the students when they are performing a test…).

(3) *Providing an interactive environment*, that is when technology enables to create environments in which students can interact to work individually or in group on a task or to explore mathematical/scientific contents (e.g. through the creation of interactive boards to be shared by teacher and students or the use of specific software that provide an environment where it is possible to dynamically explore specific mathematical problems…).

The following chart[1] (fig.1) schematizes the FaSMEd three-dimensional model.

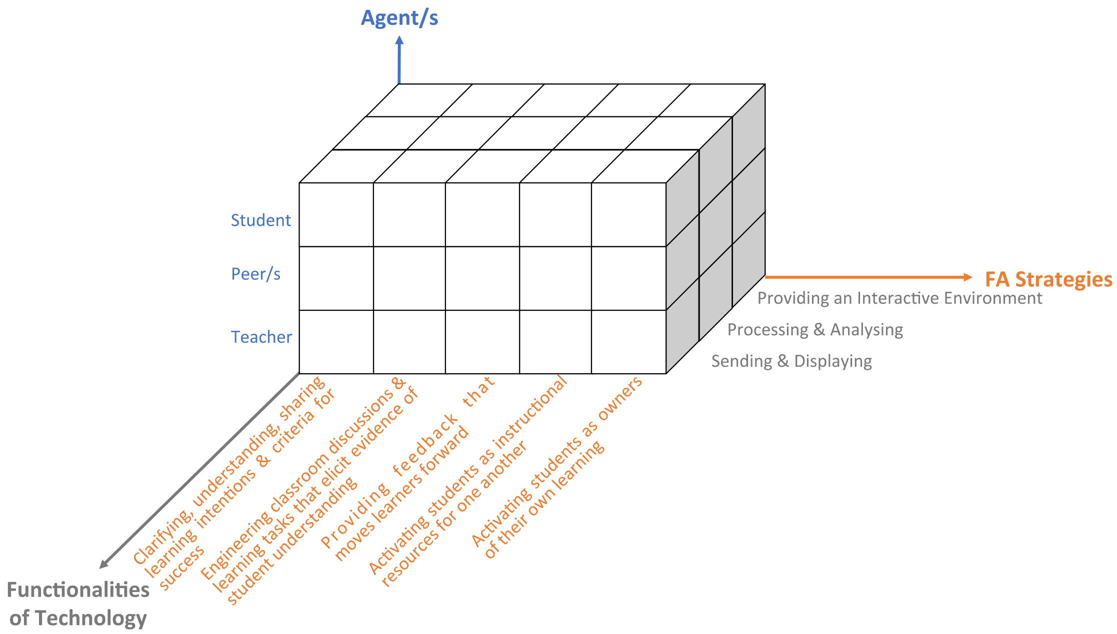

Fig. 1: Chart of the FaSMEd three-dimensional model

[1] We thank D. Wright (Newcastle University) for the digital version of the chart and Hana Ruchniewicz (University Of Duisburg-Essen) for its adaptation.

DESIGNING FA ACTIVITIES WITHIN A CCT ENVIRONMENT

In our design study we adopted a Vygotskyan perspective on the crucial role of the interaction with peers and with an expert in students' learning (Vygotsky 1978). Moreover, we believe that FA has to focus also on metacognitive factors (Schoenfeld 1992). Accordingly, we designed activities aimed at supporting students in (a) making their thinking visible (Collins, Brown & Newmann 1989), through the sharing of their thinking processes with the teacher and the classmates, by means of argumentative processes, (b) developing their ongoing reflections on the learning processes. Effective mathematical discussions (Bartolini Bussi 1998) are considered a key activity, where the teacher plays a key role in planning and promoting fruitful occasions for FA and learning.

Concerning technology, we explored the use of a CCT (provided by a software called IDM-TClass), which connects the students' tablets with the teachers' laptop, 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, by means of the creation of instant polls.

The use of IDM-TClass was integrated within a set of activities on relations and functions, and their representations (symbolic representations, tables, graphs), adapted from different sources. For each activity, we designed a sequence of worksheets, to be sent to the students' tablets or to be displayed on the IWB (or through the data projector). The worksheets were designed according to *four main categories*: (1) Worksheets introducing a problem and asking one or more questions *(problem worksheets)*; (2) *Helping worksheets*; (3) Worksheets prompting a poll between proposed options (*poll worksheets*); (4) *Worksheets prompting a focused discussion*.

As said before, in this contribution we focus on the creation and use of instant polls, combined with the possibility, offered by the CCT, of showing the results of the polls to all the students. The IDM-TClass software collects all the students' choices and processes them, displaying an analytical record (collection of each answer) as well as a synthetic overview (bar chart). In reference to the analytical framework, we may say that instant polls are used through the support of the "*Processing and Analysing*" functionality of the technology. The possibility of showing the results in real time brings to the fore also the "*Sending and Displaying*" functionality of technology.

In principle, the software enables also to set the time given to students before completing the poll, and offers the opportunity to provide an immediate automatic correction to the student. However, our choice was *not* to provide the immediate automatic correction to student, so that they could be engaged in a subsequent classroom discussion. In tune with Beatty and Gerace's framework (2009), we, in fact, conceived the use of polls as a way of scaffolding whole-class interaction with the aim of fostering the sharing of results and the comparison between students (*FA strategy B*). This is also coherent with our belief on the key role of the teacher and the importance of peer interaction.

During our design experiments, we both implemented *planned polls* that were a priori created to be inserted within each teaching sequence (through *poll worksheets*, which can be used in alternative to *problem worksheets*, where the students are expected to write down a written solution and justification) and *instant polls*, created and implemented on the spot. In the perspective of design-based research, polls created on the spot that revealed fruitful in terms of FA strategies may be inserted in the repertoire of planned polls for the subsequent cycles of experimentation.

Concerning polls, our investigation is guided by the following research question: *What kind of FA strategies can be activated thanks to the use of technology enhanced (planned or instant) polls?*

Due to limits of space, in this paper we focus on planned polls.

DATA ANALYSIS

All the lessons were video-recorded, fields notes were taken, and students' productions (doc files) were collected, building a large amount of data (about 450 hours of class sessions, carried out in collaboration with 20 teachers). Furthermore, teachers were interviewed every two-three lessons and, after each lesson, they were asked to write a report on the effectiveness of the lesson in terms of the activated FA processes and of the support provided by technology. In line with design-based research, the study is carried out through a close collaboration between researchers and teachers, who share the aim of improving practice, taking into account both contextual constraints and research aims.

In the following, we present an excerpt from a class discussion developed starting from the results of a *planned poll.* The example relates to an activity on time-distance graphs adapted from the task sequence "Interpreting time-distance graphs", from the Mathematics Assessment Program (http://map.mathshell.org/materials/lessons.php). From the original source based on paper-and-pencil materials for grade 8, we adapted the activities and created a set of 19 digital worksheets to be used with students from grade 5 to 7. Here we refer to a discussion carried out in grade 7.

The sequence starts with a short text about the walk of a student, Tommaso, from home to the bus stop. This text is accompanied by a time-distance graph, as illustrated in Figure 2:

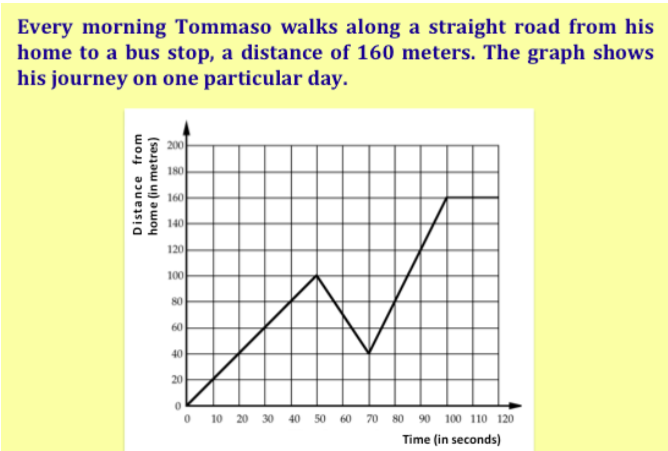

Fig.2: The time-distance graph of Tommaso's walk

Students' interpretation of this graph is guided through questions, posed to them within *problem*, *helping*, and *poll worksheets*. Since the students meet time-distance graphs for the first time through this activity, we designed an introductory activity based on the use of a motion sensor, in which students could explore in a laboratorial way the construction of the graph after a motion experience along a straight line.

Here we focus on an episode concerning the interpretation of the final part of the graph. At first, students were asked via a *problem worksheet* to establish what happens during the last 20 seconds, motivating their answers. During the classroom discussion, a *poll worksheet* was used to focus on the *completeness* of answers (FA strategy A). Specifically, the poll required students to identify which is the most complete among three given answers:

"Some students of another class wrote these answers. Which of them is the most complete?
A) During the last 20s, Tommaso is not walking because we have already said that he has reached the bus stop
B) I think that, during the last 20s, Tommaso is not walking because, from the graph, it is possible to understand that, in the period between 100s and 120s, he is always at the same distance from home, that is 160m
C) I understood that, during the last 20s, Tommaso is not walking because the line of the graph is horizontal."

Students discussed in pairs to answer to the poll. Afterwards, the teacher displayed the distribution of their answers on the IWB: 10% of students chose option A, 50% chose option B and 40% chose option C. Starting from the display of the results, the discussion took place. The teacher exploited the poll worksheet as a way to engineer *effective classroom discussions that elicit evidence of student understanding* (FA strategy B). The following table (table 1) presents selected excerpts from the discussion, analysed according to the FaSMEd framework in the right column.

Excerpts from the class discussion	***Analysis according to the FaSMEd three-dimensional framework***
After a brief analysis of A, justifications B and C are compared. 353) Teacher: let's look at B and C. Let's hear some explanations of those who chose C, why did they chose C, and some motivation of those who chose B. 354) Brown: we chose B because B specifies also that he (*Tommaso*) stayed still from 100 to 120 seconds, while C doesn't say this, saying that they were only 20 seconds they could have been 150, 170, 180 and so on… 355) Silvia: B is the most complete. 356) Teacher: B is the most complete. 357) Mario: for me the B is not right because, we understood that, when we used the motion sensor, let's say, you understand that a person stops when the line is horizontal, and there (justification B) it doesn't say this, then it is not the most complete.	The teacher encourages the students to discuss the reasons behind the choices of the poll. Her aim is to promote a discussion on the completeness of the two options. This is an instance of *FA Strategy* A, since the focus is on the requirements that a complete answer must satisfy. Suggesting that answer B gives more information on the last trait, Brown activates herself as responsible of her learning (*FA strategy E*) and at the same time as instructional resource for her mates (*FA strategy D*). Silvia, echoing Brown, affirms that B is the most complete, thus giving a implicit feedback to Brown (*FA strategy C*). In line 357 the student Mario challenges the former evaluation, activating himself as owner of his own learning (*FA strategy E*) : in his opinion, answer B is not complete because it does not refer to the experience with sensor detectors. This intervention provides a good occasion to discuss again the role and value of the empirical experience with sensors
… 390) Lollo: but if we had not done that	Lollo suggests that one cannot refer to the experience with sensors, since the answer should be intelligible also by a reader who did not do

activity before… 391) Teacher: the activity with the motion sensor. 392) Lollo: we could not have known that if you are still the line is horizontal …	such an experience. Lollo turs himself as instructional resource for his mates (*FA strategy D*). In particular, he gives feedback to Mario (*FA strategy C*). The teacher reformulates Lollo's intervention so as to involve the other students, turning Lollo as a resource for his mates (*FA strategy D*). In this way she also activates *FA Strategy C*.
399) Rob: And anyway from the graph you can understand why the distance is always the same but the seconds, let's say, go on… 400) Teacher: ok… then, even if we had not had the experience with the motion sensor, that made you understand in an experimental way that if I stay still the line is horizontal, your classmate [*Rob*] says: "from the graph I can understand it anyway". Why? Rob, could you please repeat it? 401) Rob: because from the graph you can understand that when you don't move, that is to say when there is the horizontal line… 402) Teacher: what does it mean? 403) Rob: the meters remain the same but the seconds go on, let's say.	Rob intervenes, stating that in the horizontal trait the distance from home is always the same. This is a shift from an explanation based on the experience with sensors to a theoretical explanation, based on the meaning of the graph. Rob provides to other students a feedback to move forward (*FA strategy C*), turning himself as an *instructional resource for his classmates* (*FA strategy D*). The teacher reformulates Rob's intervention, giving to all the students a *feedback that moves them forward (FA strategy C)*. Reformulation is also a means to activate Rob as a *resource for his classmates* (*FA strategy D*).
… 413) Teacher: B explains why the line is horizontal, while C just says "the line is horizontal"; B instead explains why the line is horizontal, because the meters remain the same, even if time goes on, isn't it?	As a final intervention, the teacher rephrases the result of the discussion, pointing out what makes answer B more complete. In this way she activates *FA strategy A*.

Table 1: Excerpts from the class discussion and corresponding analysis

The analysis showed a wide range of FA strategies activated by different agents: not only by the teacher, but also by the students themselves. More specifically, since options B and C were both chosen by many students (50% and 40%), the teacher decided to ask students to express the motivation subtended to their choice. In this way, on one side, it was possible to focus on the mistakes subtended to the choice of incorrect answers, making students activate themselves as owners of their own learning (*strategy E*) because they could recognize their own mistakes and reflect on the reasons subtended to them. On the other side, students who chose the correct answer provided their justification, becoming more aware of the reasons why they chose a specific option (again activation of *strategy E*). The students were therefore activated as instructional resources for their mates (*strategy D*) because they gave feedback to each other (*strategy C*) on the reasons why a chosen option is better than the other.

CONCLUSIONS

In this contribution we studied the use of polls for promoting formative assessment in the classroom. The analysis, carried out by means of the FaSMEd analytical framework, showed the emergence of a variety of FA strategies and involved agents, suggesting that planned polls, exploiting the "*Processing and Analysing*" and "*Sending and Displaying*" functionalities of the technology, may turn into a fruitful formative assessment activity.

The outlined pattern may be related to Beatty and Gerace's (2009) TEFA cycle of question posing, answering and discussing. Also in our case, the use of polls may be conceived within a cycle of activities that encompass: solving a problem (and justifying the answer), taking a position in relation to a question in form of poll, commenting the poll results, justifying choices. Our analysis brings even more to the fore the variety of FA strategies that are promoted by the use of the polls, thus giving more insight into each phase of the TEFA cycle.

Although in this paper we confined ourselves to an example of discussion carried out starting from a *planned poll*, we are currently analysing a variety of examples concerning poll use. After three cycles of design, implementation and analysis, we propose a first tentative classification of the polls used during our design experiments, according to their different focus and (consequent) aims: (1) polls that ask to choose the correct answer to a problem, with the aim of promoting a discussion on solving strategies; (2) polls that ask to compare different answers to a problem, with the aim of promoting a meta-discussion on the features of the answers (such as in the example discussed in this paper); (3) polls focused on the difficulties students meet when facing specific kind of tasks or the best strategies to be used to face specific tasks, with the aim of promoting metacognitive reflections; (4) poll focused on students' feelings when facing a specific kind of task or when a particular methodology were adopted during the lessons, with the aim of bringing to the fore also the affective dimension. Referring to the instructional purposes of polls described by Beatty and Gerace's framework (2009), type-1 may be related to "provoke thinking" and "exercise a cognitive skill", whereas type-2 may be linked to "elicit a misconception" and "stimulate discussion with questions having multiple reasonable answers". Types 3 and 4 are of different nature: even if they could be somehow related to "status check", they bring to the fore metacognitive and affective issues that are not so evident in Beatty and Gerace's list. We remark that, in our design, polls are always intended as a starting point for a class discussion and not for individual "revising" or "check status".

Further research will be done on the analysis of the effects of the use of the four types of polls in terms of patterns of FA strategies activated during the class discussion that takes place after each poll. Moreover, we are going to study how the structure of the class discussion is influenced by the results of the processing of data.

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