Designing and analysing the role of digital resources in supporting formative assessment processes in the classroom: The helping worksheets

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In this paper we present the design of specific digital resources and related methodology, conceived with the aim of exploiting connected classroom technology to carry out formative assessment processes in the mathematics classroom. The digital resources have been created and experimented within the European Project FaSMEd. By using a multi-dimensional theoretical frame developed within FaSMEd, we offer elements of validation for the design, focusing in particular on the activation of formative assessment strategies through the use of "helping worksheets". The elements of validation will be illustrated through an example from a case study.

Keywords: Formative assessment, technology, digital resources, task design.

Introduction

This contribution stems from the European Project FaSMEd ("Improving progress for lower achievers through Formative Assessment in Science and Mathematics Education"), aimed at investigating the role of technologically enhanced formative assessment (FA) methods in raising students' attainment levels.

Within FaSMEd, FA is conceived as a method of teaching where evidence from learning is used to adapt both teaching and learning. Wiliam and Thompson (2007, in Black & Wiliam, 2009) focus on *three central processes* in learning and teaching, which represent the aims related to the collection, interpretation and exploitation of these learning evidence: (a) *Establishing where learners are in their learning*; (b) *Establishing where learners are going*; (c) *Establishing how to get there*.

In the model developed by Wiliam and Thompson these three *central processes* are connected to the *three main agents* that intervene (the teacher, the student, the peers) and to the *FA key-strategies* that could be activated: (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.

A theoretical model to analyse the use of technology in FA practices has been elaborated within FaSMEd (Aldon et al., in print, and Cusi, Morselli & Sabena, 2016). The model extends Wiliam and Thompson's model, taking into account three main dimensions: (1) *the five FA key-strategies* described by Wiliam and Thompson (ibid.); (2) *the three main agents* that intervene; (3) the *functionalities of technology*. The third dimension - the *functionalities* of technology – was added within FaSMEd to focus on the ways in which technology can support the three agents in developing the FA strategies: (a) *Sending and sharing*, that is the ways in which technology supports the communication among the agents of FA processes; (b) *Processing and analysing*, that is the ways in which technology supports the processing and the analysis of the data collected during the lessons; (c) *Providing an interactive environment*, that is when technology enables to create environments in which students can interact to work individually/in group on a task or to explore mathematical/scientific contents.

We argue that the FaSMEd three-dimensional framework may represent a useful tool for:

- *designing* digital materials for technology-enhanced FA practices and the corresponding methodology, and
- *analysing* how these materials are implemented in the classroom.

In this paper we will refer to the study carried out in Italy, where we added the fundamental assumption that, in order to raise students' achievement, FA has to focus not only on cognitive, but also on metacognitive factors (Schoenfeld, 1992). For this reason, our design is aimed at i) fostering students' ongoing reflections on the teaching-learning processes, and ii) focusing on making thinking visible (Collins, Brown & Newmann, 1989) through students' sharing of their reasoning with the teacher and the classmates, by means of argumentative processes.

In the following we present the design of digital materials and of the methodology for their implementation in the classroom. We will then focus on the specific case of "helping worksheets" and analyse its implementation in a case study. The analysis will be based on the FaSMEd three-dimensional framework. The analysis of FA strategy C (Providing feedback that moves learners forward) will be deepened with reference to the four major levels of feedback introduced by Hattie and Temperley (2007): (1) *feedback about the task*; (2) *feedback about the processing of the task*; (3) *feedback about self-regulation*; (4) *feedback about the self as a person*.

Design of the digital materials and of the methodology for their implementation

The research developed within FaSMEd has been built on the model of design-based research (Cobb et al, 2003), so it is based on successive cycles of design, observation, analysis and redesign of classroom sequences. The design experiments we carried out in Italy were characterised by three subsequent cycles of design. The first two cycles were carried out in March-May 2015 and in September-December 2015. The third cycle started in May 2016 and has not been completed yet. The results we present in this paper refer to the first two cycles of the design.

In tune with the theoretical assumptions presented in the previous paragraph, we chose to use a technology that supports the students in sharing, discussing and comparing both their written productions and the strategies developed to carry out the different tasks. Specifically, we explored the use of a connected classroom technology (CCT), which creates a network between the students' tablets and the teachers' laptop, allowing the students to share their productions, and the teacher to easily collect the students' opinions and reflections: IDM-TClass.

The design experiments involved 25 classes (from grade 4 to grade 7) from three different clusters of schools located in the North-West of Italy. Each school was provided with tablets for the students and computers for the teachers, linked to IWB or data projector. In order to foster collaboration and sharing of ideas, students were asked to work in pairs or in small groups on the same tablet.

During the first two cycles of design, we carried out about 450 hours of lessons. The researcher was in the class as both an observer and a participant (to support the teacher in the use of the technology and in the implementation of the digital resources). In some cases, also Master students were present as observers. The corpus of data is constituted by video-recordings of the lessons, written transcripts, field notes taken by the observers, teachers' interviews after sequences of lessons, students' written questionnaires and groups of students' interviews during a Q-sorting activity (questionnaires and Q-sorting data were collected at the end of the design experiments).

The use of IDM-TClass was integrated within a set of activities on relations and functions, and their different representations (symbolic representations, tables, graphs). These activities, in line with the aims of the FaSMEd Project, where adapted starting from existing research-informed materials.

For each activity, we have prepared a sequence of different 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*, aimed at supporting students, who meet difficulties with the problem worksheets, through specific suggestions (e.g. guiding questions); (3) worksheets prompting a poll between proposed options (*poll worksheets*); (4) worksheets prompting a focused discussion (*discussion worksheets*).

Usually the activity starts with a problem worksheet, sent from the teacher's laptop to the students' tablets. Students work in pairs or small groups of three. 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 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 by the teacher and by classmates. 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. During the part of the discussion focused on these aspects, therefore, the criteria for success could be clarified through the analysis and comparison of the different written productions.

The teacher can also display the discussion worksheets or poll worksheets, if she realises that some specific aspects were neglected, to support the class discussion during different parts of the lessons. It is also possible to create polls on the spot to check students' understanding, or their awareness about what has been developed during the activity, or their attitudes toward the activity.

In the next paragraph we illustrate the design of the helping worksheets and the corresponding implementation, and present the analysis of an example from a case study. The example has been chosen because it is a paradigmatic one, which enables to highlight how the implementation of helping worksheets, through the support of CCT, fosters the activation of FA strategies and the dynamics between them.

The design and implementation of the *helping worksheets*: Analysis of an episode

Helping worksheets are conceived to support students in facing the tasks posed through the problem worksheets and are sent to selected students during the problem-solving phase, when: (a) they ask to receive a help; (b) the teacher realises that they are stuck; (b) the answers they send to the teacher highlight mistakes or difficulties. Moreover, helping worksheets may be sent to all groups, after they sent their answers to the teacher, as a checking tool for their work.

Usually we design sets of differentiated worksheets, according to the possible difficulties students could meet when facing a problem worksheet. Since our activities are adaptations of existing research-informed materials, the hypothesis about students' difficulties and the corresponding feedback that could be provided are drawn also from these materials.

We focus on helping worksheet 1A (see figure 1), which is matched to problem worksheet 1 within an articulated activity on time-distance graphs. The activity, which is our adaptation of some materials from the Mathematics Assessment Program, developed at the University of Nottingham (http://map.mathshell.org/materials/lessons.php), starts with the interpretation of a given time-distance graph and develops through the matching between graphs and stories and the construction of graphs associated to specific stories. We adapted the tasks in order to propose them to students from grade 5 to 7. To ground the time-distance graph on a meaningful activity, we designed an introductory activity on the use of a motion sensor (a device connected to a graphic calculator, showing, in real time, the Cartesian representation of a produced motion).

Worksheet 1 introduces a task on the interpretation of a time-distance graph representing the journey of a student, Tommaso, from home to the bus-stop. The worksheets' sequence connected to this task was conceived to gradually lead students in the interpretation of the graph, focusing their attention on the meaning of ascending, descending and horizontal traits of the graphs. Students are also asked to focus on the reasons supporting the correct interpretation of a time-distance graph, with the aim of making them, on one side, reflect on their thinking processes and share these processes with their classmates and, on the other side, consolidate their competencies in justifying and analysing their answers. The question on worksheet 1 (within the white box, see fig.1) requires students to interpret the meaning of a descending line within the graph. Students have to highlight that in the period of time from 50s to 70s the distance from home decreases, so Tommaso is going back for a while. Helping worksheet 1A (fig. 1) first of all makes students focus on the word "straight" to help them to abandon the idea that the graph could represent the drawing of the road. Moreover, it aims at fostering a correct interpretation of the descending line in the graph, making students look at two specific points within the graphs, that is (50, 100) and (70,40), to highlight that the distance from home is decreasing.

Sending a helping worksheet to a specific group of students is a way to activate FA strategy C, because students are provided with feedback about the task (if they receive this kind of worksheets, they realise that their answers should be completed and/or corrected) and feedback about the processing of the task (the suggestions and the guiding questions on the helping worksheets are aimed at supporting the students in facing the problem). Moreover, giving feedback represents a way of making students activate themselves as owners of their learning (FA strategy E).

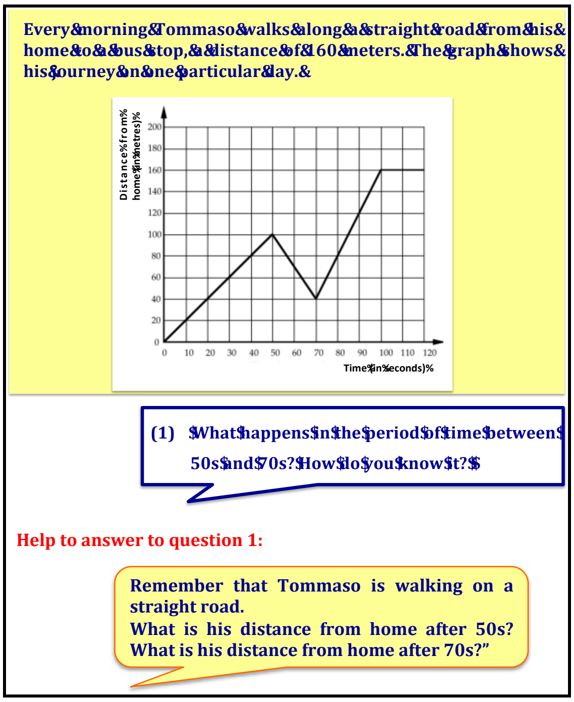

Fig. 1: The helping worksheet

During our design experiments, some students (in particular, low-achieving students) face difficulties also in interpreting the *purpose* of the provided helping worksheets, as supports to face the tasks. This is a manifestation of their lack of metacognitive control. For this reason, after the first cycle of design experiments, we introduced the displaying and collective meta-level analysis of helping worksheets as a fundamental characteristic of the methodology for their implementation.

As an example of this specific implementation of helping worksheets, we present and analyse an excerpt from a discussion on helping worksheet 1A, which was carried out in a 5th grade class. The discussion was aimed at making students aware of the goal of the helping worksheet and at pointing out specific mathematical aspects related to the task, namely to make them: (1) look at points within time-distance graphs as bearers of two linked information (the distance from home and the time spent); (2) interpret the variation of the distance in terms of moving away/approaching home; (3) avoid the typical mistake of interpreting the graph as a drawing. We remind that the researcher takes part in the discussion as both an observer and a participant.

220 Researcher: The first ones who are going to speak are those who did *not* receive this helping worksheet. Let's read the help that is given and try to say why, in your opinion, it is an help…what it helps you to do… The main question to be answered is still this one (*she indicates question 1, presented in Worksheet 1*). The help says (*reading*) "Remember that Tommaso is walking on a straight road. What is his distance from home after 50s? What is his distance from home after 70s?"

221 Teacher: Why do the suggestions focus on this?

222 Researcher: What do these questions help to do?

Several students raise their hands.

223 Carlo: Because they help you to understand the distance in the period between 50s and 70s. Because, at 70s, he is nearer…

224 Researcher: So you are saying that it enables to look at the distance, aren't you?

This discussion was planned with the objective, on one side, of eliciting evidence of students' understanding at a metacognitive level (strategy B), and, on the other side, of activating some students as resources for their classmates (strategy D). In fact, the researcher (lines 220, 222) and the teacher (line 221) are fostering a meta-reflection, involving the students that did not receive the help in clarifying the reasons why the questions posed on helping worksheet 1A could provide help in answering questions 1. Their aim is, therefore, to activate FA strategy C at the peer's level. Specifically, Carlo's intervention (line 223) represents a feedback about self-regulation because he highlights that the questions in worksheet 1A enable to focus on the change in Tommaso's distance from home, during that period of time. Through this comparison with their classmates, students can therefore become aware of the kind of support that helping worksheets could give and can also develop new tools to face similar activities in an effective way.

Then, the teacher focuses students' attention on a part of the helping worksheet that was *not* mentioned by Carlo:

225 Teacher: And why does it [the help] suggest that Tommaso is moving on a straight road?

226 Carlo: Because it wants to make us reason on the fact that he is going back.

227 Researcher: What mistake couldn't be done if I remember that the road is straight? … (*Silence*) If I don't know that the road is straight, what could I think?

Anna mimes a curvy road with her hands.

228 Arturo: I could think that the sensor initially indicates a direction, then he goes on the right… (*Arturo is referring to the introductory activity with the motion sensor*)

229 Teacher: So a change in the direction.

230 Researcher: That we are zigzagging, in a strange way.

231 Teacher: It is the reason why it remembers us that the road is straight. You recalled, with your memory, what we experimented last time. If we hadn't worked with the sensor, you, maybe, would have proposed different answers.

Again the teacher and the researcher focus students' attention on the suggestions contained in helping worksheet 1A to make them become aware of its role in supporting the resolution of the task (strategy C). The teacher (line 225) focuses on the first suggestion given in worksheet 1A (*Remember that Tommaso is walking on a straight road*) and the researcher (lines 227) aims at making students reflect on the possible misinterpretations that this suggestion wants to prevent. Students are, in this way, provided with both feedback about the processing of the task and feedback about self-regulation, because they can become aware of the possible mistakes that could be done in the interpretation of this kind of graphs, learning how to monitor their work. Also the teacher (line 231) provides a feedback about self-regulation because she is making the students notice how the previous experience has influenced their answer to the current question. Carlo (line 226) and Arturo (line 228) are activated as instructional resources for their classmates (strategy D).

Discussion

In this paper we referred to the theoretical lenses provided by the FaSMEd framework to present and discuss the design of digital resources and the corresponding method of implementation, with a special focus on the helping worksheets. The analysis we developed, on one side, shows that the

FaSMEd three-dimensional framework represents a useful tool for both designing digital materials for technology-enhanced FA practices and the corresponding methodology, and analysing how these materials are implemented in the classroom. On the other side, this analysis provides a validation of the design and implementation because the FaSMEd framework offers some important criteria according to which the digital worksheets and the methodology for their implementation can be evaluated as effective tools to foster FA processes: (1) the activation of different FA strategies; (2) the involvement of all the agents; (3) the evolution of the FA strategies (in particular toward strategy E, which should constitute a constant objective of the activities); (4) the different levels of feedback provided; (5) the support provided to the three fundamental FA processes.

At the same time, the analysis of the design and implementation of the helping worksheets in the chosen episode enabled us to highlight a pattern that characterises the evolution of FA strategies when helping worksheets are implemented. In fact, the use of the helping worksheet, combined with the sending and displaying functionality of technology, turned into the activation of several FA processes, with the involvement of all the agents. During the group-work phase, by sending the helping worksheet to the students, the teacher is activating FA strategy C with the aim of activating also strategy E. After the group-work phase, a meta-level discussion devoted to the sharing and analysis of helping worksheet is planned by the teacher (strategy B). As a result of the design based process, two different ways of fostering students' meta-level reflections have been identified: initially, the students who did *not* receive the worksheets are asked to reflect on the possible role played by the provided help (becoming instructional resources for their classmates, strategy D); then, the students who *did* receive the help (mostly low achieving students) are asked to discuss on the ways in which they used it, making their reasoning explicit and being activated as the owners of their own learning (strategy E). During the discussion, all the students receive feedback from the teacher and their classmates (strategy C) and are provided with the opportunity to clarify the learning intentions associated to the worksheet (strategy A).

We think that this pattern, since it is recurring throughout our corpus of data, represents an important validation of the design of helping worksheets, because it highlights the effectiveness of these resources and their implementation in fostering the development of FA strategies and the fruitful involvement of all the agents.

Other elements of validation can be highlighted if we interpret the results of the activities carried out through the helping worksheets in terms of the three fundamental FA processes that are supported: (a) the students are supported in establishing *where they are in their learning* when they use the help as a feedback to assess their own answer; (b) the teacher is supported in helping students clarify *where they are asked to go* when, during the class discussion, the characteristics of given answers are analysed and discussed; and (c) the teacher and the students are supported in establishing *what needs to be done to get there* when, during the class discussion, the helping worksheets are analysed to highlight in what ways they could help and what kind of suggestions they give.

We are now developing a similar analysis to highlight, referring to these criteria, how the other categories of worksheets are used to foster the activation of FA strategies through the support provided by technology. This will enable us to identify the connections and mutual support between the different worksheets and the methodologies through which they are implemented during the lessons.

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