A Collaborative Model for Training Teachers to Use Graphing Calculators

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Introduction

It is a well-known criticality of contemporary educational systems the fact of not being able to keep up with the dramatic changes occurring in our highly technologized society, in particular in digital technologies. (Collins & Halverson, 2009)

In Italy this criticality was particularly severe because of years of chronic underfunding for the renewal of school instrumentation. The result is that Italian teachers are not used to take advantage of digital technologies in their teaching and appear even more distant from the contemporary world than many of their European colleagues.

In recent years, in order to reduce this gap, a lot of efforts and much money have been put in the realization of the "National Digital School Plan" (PNSD) both for acquiring new instrumentation and providing teachers with suitable training for bridging the digital skills gap that had been accumulated over the years. (Avvisati & al., 2013). Therefore, many laboratory activity courses have been set up to update individual knowledge on technology issues in different areas. This means that thousands of teachers participated to these activities on IT skills organized by the Ministry of Education. In addition, many institutions and private companies offer professional training aimed at developing skills in digital technologies. We believe that the effectiveness of these courses is unsatisfactory.

In our experiences both as trainees and as trainers we got confirmation of the idea that a different model of training is necessary. It usually happens that teachers attend trainings that deal with topics completely unrelated to what they are teaching in their classrooms. For teachers unfamiliar with the contents of the training courses, this means that too much information is usually packed in too short time. Moreover, these courses are not connected with classroom activities. Therefore, the time elapsed between training and experimenting in class is too long and trainees usually forget everything they learned before making use of it in their classes.

In Service Teacher Training for Digital Technologies in Italy

In service teacher training has a short and weak tradition in Italy. Even if the situation

is decisively improving, the legacy of the past is reflected in a conservative attitude towards teaching. This manifests itself in a widespread inertia toward changes. To overcome this inertia it is necessary to involve teachers to play a more active role.

Resistance to changes becomes particularly evident in the implementation of teaching practices with new technologies.

The Italian Ministry of Education is implementing a series of interventions to promote the use of educational technologies. Among these, the choice to allow the use of graphing calculators in the State exam is particularly relevant. As we have already said, it is difficult to train Italian teachers at using new technologies. Convincing them to use graphing calculators is, if possible, even more difficult. There are many preconceptions and alibi such as: they are not very intuitive; they causes arithmetic and graphic illiteracy; computers are more powerful; they are obsolete; I have already got a good scientific calculator hence I don't need a graphing one...

On the other hand, many students show a strong interest to experiment with graphing calculators because their use is now permitted in State exam and because they appear very user friendly when they begin to use them. Therefore, there is a lot of demand for training courses. Very often however these courses leave teachers dissatisfied for many reasons which we will briefly sketch in the next section.

The stimulus to develop a more effective training model is therefore particularly urgent for graphing calculators and we concentrate upon this particular technology. However, the same model can have, in our opinion, the same positive effects also for training in all other digital technologies.

Training Teachers to Use Graphing Calculators

We started from analyzing the various teachers' attitudes towards graphing calculators in order to devise a more effective training model. We have classified these attitudes in 5 categories.

Teachers Refractory to Digital Technologies (type A)

They are old-fashioned teachers, which are very tied to frontal teaching and are not favorable to introduce digital technologies in teaching. It is not a problem linked to a particular type of instrument but a negative approach to technological tools in teaching.

Teachers Favorable to Use Technology but Against Graphing Calculators because "They Make Students Lazy" (type B)

They are favorable to the use of technology, they use digital presentation and educational

software, online resources and frequently interface with the computer world but oppose to the introduction of graphing calculators in teaching. Their most typical objection is that «nowadays no one is able to perform elementary arithmetic calculations by mind anymore because of the widespread use of scientific calculators. If we allow graphing calculators, no one will be able to study the graph of a function, to compute the value of a derivative, the value of a statistical index anymore». They believe that calculators are subsidies that allow students to do without studying. They fear that calculators could cancel the need of studying and the fatigue of computing by providing immediate answers. Moreover, they object that the faith in graphing calculators makes students believe that they are exempted from providing justifications.

Teachers Favorable to Use Technology but Opposed to Graphing Calculators because "They are Ineffective" (type C)

They consider graphing calculators as simple games that do not add any useful competence. They believe that graphing calculators may be helpful only for solving exercises of mere computational content but they are useless in solving problems that require any form of reasoning. Their views on the potentiality of graphing calculators is severely biased and they do not believe that many intriguing activities can be arranged with this instrument. Their underestimation of the educational value of calculators let them consider that the required investment of time and energies is disproportionate compared to the results.

Teachers Afraid of Using Digital Technologies, in Particular Graphing Calculators (type D)

They are simply afraid of their lack of knowledge of the instrument. Sometimes they are frightened because they doubt or are worried about not having an adequate preparation and therefore they are fearful of not being up to answer to students' questions. Therefore they do not intend to show their lack of competence and they prefer not to get involved for fear of losing their professional respectability. Often their refusal to use a new tool derives from the lack of knowledge and from the little time available to learn its functioning.

Teachers Favorable to Use Technology and Eager to Learn to Use Graphing Calculators (type E)

They are the more technological ones. They frequently introduce new tools in their teaching and have a positive attitude towards technological innovations. They are curious about the possibilities offered by new technologies and are not afraid to try them. So, they are usually quite willing to tinker with graphing calculators.

The Graphing Calculator is a Useful Tool for Teachers

Regardless of teachers' attitudes towards calculators and computers, wide availability of powerful numerical processing tools dramatically changed the priorities in mathematics curriculum. Graphing calculators may be precious allies in shifting the focus of teaching/learning from "computing" to "controlling computations". Thanks to computers rapidity of calculation, one can quickly analyze data variation with respect to parameters. Therefore, computers favor, through heuristic investigation, the development of intuition behind data modelling and free data modelling from the heavy computation burdens that previously hindered their development.

Calculators and computers, as is well known, may offer effective ways to experiment and discover many aspects of mathematics, by enhancing intuitions that derive from calculators' graphical and numerical processing capabilities and provide proper context and motivations for subsequent formal analysis. Moreover, calculators and computers favor teaching/learning activities through the mediation of modern and captivating languages, able to propose contents in an interactive and innovative way, close to students' attitudes and habits, and to encourage cooperative learning.

Using graphing calculators in a class is less expensive and cumbersome than using computer laboratories, but, eventually combined with the use of simple and cheap controllers, not less powerful.

Calculators pose various educational challenges. Italian teachers are particular concerned with evaluation, which they consider a very crucial one, especially after recent changes in the structure of the final exams, as briefly recalled in the introduction.

If we want to evaluate learning processes about "controlling computations" we need to specify better what we mean by that.

We limit ourselves to recall three aspects of it:

1. Get a qualitative/heuristic idea of what we compute and what we expect to get by computation
2. Link computing procedures in order to build algorithms
3. Link different views (numerical, graphical) on a given set of data.

The Steps of Our Research

The reason behind our involvement in teachers' training on the use of graphing calculators comes from the request of devising a new model for a more effective training. We devised this model proceeding along the following steps:

1. Analysis of the characteristics of training as offered by various graphing calculators' companies;
2. Analysis of teachers' opinions about criticalities;
3. Design and analysis of specifically devised experimentations conducted in collaboration with the group of trainers;
4. Elaboration of the new "collaborative training model";
5. Experimentation of the model in some pilot experiences;
6. Trainers training;
7. Nationwide delivering of 50 collaborative trainings in the 2018-2019 school year.

The Standard Training Model and Its Ineffectiveness

The standard training model, adopted by all calculator companies in its essential features, is based on a single meeting between a group of teachers and a trainer. The meeting lasts two or three hours, during which the main commands and the possible use of the calculator in the various areas of mathematics are presented.

The strength of this presentation-based method is that of packing a lot of information with extreme synthesis, that is to say that many features of the graphing calculator are briefly illustrated. The standard training is based on a model of vertical interaction, from trainer to teachers, which leaves little space to individual work, which teachers are assumed to do later. With this model the risk of being puzzled and forgetting everything is very high. The typical reaction of teachers is epitomized by the following phrase, which we have collected in our interviews:

"When the trainer showed us the potentialities of graphing calculators, I thought: amazing, but I will never be able to do it!"

The weakness of this training is also due to its duration, which is too short and needs to be split in more meetings. It is highly probable that all the information acquired during the meeting cannot be easily connected with daily teaching practice.

After a standard training, most teachers are amazed by calculators but scared to be left alone with them. Moreover, many teachers said that they could not understand how the activities shown by the trainers could have been used in their daily teaching.

Designing a New Training Model

The purpose of this research has been to develop collaborative trainings on the use of

the graphic calculator, based on a model of global interaction. In the intent of making teaching more effective we promote cooperation between trainer and teachers and between teachers and students, both in training meetings and during the classroom activities designed by teachers with the help of the trainer.

The trainings made use of Casio FX-cg50 graphing calculator and have been delivered in 50 upper secondary school classes in Italy.

The collaborative training model is intended, in particular, to meet the demands of teachers who are skeptical (Type B) or doubtful about the usefulness of graphing calculators in everyday teaching (Type C) or afraid to learn how to use this new tool (Type D).

We place teachers' needs at the heart of the activities by involving them in deciding the contents of the training according to the following scheme:

1. At the beginning of each training, teachers propose a list of topics that they intend to teach in their classes in the next weeks;

2. Trainer makes teachers practice the fundamental functions of the calculator related to the chosen topics;

3. Teachers design possible educational activities with calculator that, according to what they practice, they think they could develop in class;

4. Trainer and teachers discuss and redesign the proposed activities in order to transpose them in their classrooms in the most effective way.

A peculiarity of our collaborative model is the idea that a successful training should properly acknowledge the teaching and methodological competencies of teachers and should be based on their needs. The goal is to make teachers aware of the potentiality of graphing calculators in everyday classroom activities and to let them experiment some ways in which they can enhance their teaching during the period of the training.

The methodology envisaged is that of Cooperative Learning, in which trainees work together in small groups to reach common goals, mutually improving their learning, and Peer-to-Peer education, in fact they cooperate for acquiring knowledge. The model of Peer-to-Peer education has proved to be particularly fruitful when, as planned in the first meeting of our training, teachers work also with some of their students. The purpose is to modify the relationship of educational dialogue between teachers and students, who become themselves trainers of their classmates and work alongside the teachers in the activities. Students become reference figures in the classroom and help teachers in administering the activities by cooperating in guiding and supporting their

companions. This will be further explained in the next section.

The Implementation of the Collaborative Training

According to the principles outlined in the previous sections we devised a format for collaborative training delivered to 50 Italian upper secondary schools. At each school one trainer trains the teachers of mathematics of 3/5 classes. At least two students of each class, chosen by their teacher, were asked to participate to the first meeting.

The format envisages three meetings, separated by two weeks breaks. Between the first and the second meeting teachers are required to design classroom activities based on calculators, to be carried out in their classes between the second and third meeting.

In more details, the contents of the meetings are the following.

First Meeting

The first meeting is divided in two parts: one hour and half with trainer, students and teachers followed by one hour and half with trainer and teachers only.

During the first part the trainer introduces the use of graphing calculators through the exploration of the most important menus and functions and the step by step solution of simple exercises, like: finding the approximate root of an equation with given approximation; displaying the graph of a function in a certain window; representing the graph of the derivative of a given function; studying the modification of graphs of a one parameter family of functions,… The trainer develops the activities in cooperative learning between teachers and students. Teachers observe their own students and verify how easily they begin to use a graphic calculator, without detailed explanations, and how effectively they help each other in the discovery of how it works. Contrary to their worries, they realize that there is no need to become experts in the usage of the instrument in order to make students use it effectively. Students do not need to be trained if they are allowed to work together. Rather, they are quick to find how to perform specific tasks with calculator and are very supportive among themselves and with their teacher, which may concentrate more on making sense of what students get rather than explaining how to use the calculator. This helps teachers to overcome the fear of not remembering the sequence of instructions which are necessary to perform a task, relying on the help of their students.

The exercises solved by the trainer to illustrate the use of the calculator in the first part of the meeting are chosen among those which are commonly considered by teachers in their classes in order to highlight the continuity of calculator-based activities with daily teaching and the added value of its graphical and numerical processing capabilities.

In the second part of the first meeting trainer discusses with teachers the program they are going to carry out in their classes in the next two weeks and the possible activities which can be done with graphic calculators to support it. Trainer illustrates the possible use of graphic calculator in some of the activities suggested by teachers (Rogora, 2019) and shows how to prepare activity sheets for supporting the use of calculators in class (Bologna, Rogora & Veronesi, 2019). According to our interviews, teachers greatly appreciated the idea of explaining the use of graphical calculators starting from activities proposed by themselves.

At the end of the meeting, it is decided the activities that teachers are requested to prepare for the next meeting, following the lines already illustrated.

In the days immediately following the first meeting, teachers bring calculators to their classrooms and replicate the activities they have done in the first part of the first meeting, supported by the students who participated.

Before the second meeting, teachers design the calculator-based activity decided at the end of the first meeting, trying to prepare suitable activity sheets. In this phase trainer does not indicate how to set up the activities, but only support teachers on technicalities concerning the use of calculators through a WhatsApp group.

Second Meeting

Two weeks after the first meeting, a second meeting is scheduled, only for teachers, without the participation of students. The first part of the meeting is devoted to a discussion about impressions and feedbacks on the first introductory classroom activity, especially about difficulties and criticalities. Many teachers are surprised by the ease with which the students are able to immediately use the graphing calculator and realize that they are not required to be “omniscient” about the features. In the interview a teacher says:

“Before the training I was very doubtful by the possibility of using it, but I found it a very easy tool when I used it in class, repeating what we experimented and discussed during the first meeting of the training”

In the second part of the second meeting, trainer and teachers discuss and refine the work sheets to be used during curricular activities in the classroom. Calculator based activities encourage cooperative and collaborative learning and many teachers recognized the importance of an articulated discussion during the second meeting among them and with trainer about the possible outcomes of the transposition in class

of the designed activities.

In the weeks following the second meeting, the planned activities are taken in the classroom, either as individual activities where each student has his calculator or as group activities in groups of up to three students.

Third Meeting

During the third meeting, ample space is given to the discussion between trainer and teachers about the results of the activities in class. The strengths are highlighted, and the weaknesses are analyzed. Feedbacks on the outcomes of the activities developed in the classroom are exchanged. Trainer, starting from the highlights of this discussion, shows other possible uses of graphing calculators in activities suggested by teachers.

The observations and reflections of teachers and their suggestions for the organization of future activities have been collected in the form of individual written interviews. Teacher's satisfaction was generally high because they were able to use with small effort an instrument which was very well integrated in their teaching. The use of graphing calculators was perceived more as an amplification of the possibilities of their teaching than as a revolution in it. Actually, we believe that graphing calculators have potentialities which go much further than a simple aid for traditional teaching (Perrotta & Rogora, Submitted), but we also think that the majority of Italian teachers need to be gently introduced to their use by focusing on continuity with their traditional didactics.

Effectiveness of Collaborative Training

Teachers' feedbacks

Various interesting aspects emerged from discussions and feedbacks with teachers. In the feedback forms we asked teachers to complete, among other things:

1. If the teachers' attitude towards graphing calculator had changed during the training and, if so, how;
2. If the topics chosen for the first meeting met their expectations;
3. If the trainer support for preparing activities for their classrooms was well calibrated and non-invasive;
4. Strengths and weaknesses of this training.

About question 1. Some teachers, almost half of them, were quite skeptical about graphing calculators. All of skeptical got a better opinion because they got effective support to smoothly integrate it in their teaching. Some teachers were worried of not

being able to handle in their classes the use of a complicated instrument without a long training. They realized that for students it is not complicated and that students do not need to be helped in its usage but only in making sense of the results they got. They also felt more inclined to continue explore more advanced features with a more relaxed attitude borrowed from their students.

About question 2. Teachers appreciated the simplicity with which is it possible to show with graphic calculators the interconnection between algebraic, geometric and graphic aspect of some mathematical topics: equations, inequalities, differential and integral calculus, regression, … Using a teacher's phrase,

"This training was not aimed at astonishing but at reassuring".

They also appreciated the decision to involve young students coming from second high school classes which resulted very supportive during their classroom activities.

About question 3. Teachers appreciated that the chosen activities were well integrated with their everyday lectures and with their way of teaching thanks to a non-invasive support offered by the trainer.

About question 4. Some teachers found a decisive strength of this training in being "forced" to organize complete activities that gave them the opportunity to learn the potential of the calculator and implement their abilities with guided materials. Other teachers appreciated the wide freedom of choice that has been granted, the discussion, during the second meeting, of their proposals and trainer support for the modification of the activity in order to make possible and immediate transposition in their classrooms. Teachers are often critical about the need to attend refresher courses, about the quality of the content and, especially, the weak connection with their everyday teaching. They appreciated the efforts to overcome these weaknesses, characteristic of classical trainings, with this new model of collaborative training.

Trainers' feedbacks

A monitoring action has been also carried out also on trainers. Trainers acknowledged a high degree of satisfaction with this new training model. They think that collaborative training meets teachers' and students' needs better than standard training, which had a modest impact on teachers' propensity to use graphing calculators.

More than being informed on the possibilities of the instrument (focus of standard training) teachers need to be helped in preparing simple activities for their classes and experience that using the calculator in class is much easier than expected because students do not need much help in being instructed in basic calculator usage.

From the questionnaires it clearly emerged that collaborative training is more demanding and more difficult to organize than the standard one. Teachers involved have difficulty finding time to plan the activities and tend to rely heavily on the trainer, sometimes asking him to carry out the training with students or to foresee an activity in the classroom. This action, even if it has in some cases favored the inclusion of graphic calculators in class, is not in the spirit of the training since the point is precisely to make teachers able to manage the use of calculators in their classes by themselves.

An interesting aspect that emerges is that almost all the trainers have maintained contact with trained teachers. This has facilitated the creation of an active user network for sharing support and materials, open to inclusion of new interested colleagues.

Conclusions

Collaborative training seems a promising new way for training teachers to the use of graphing calculators, more effective than standard training for fostering a daily usage of this instrument in class. To monitor the impact of this training and the effectiveness of graphing calculator usage in the longer run, the research group in didactics of mathematics of the Department of Mathematics University of Salerno in collaboration with expert trainers of CASIO Italia is carrying out an educational research project which has been named “LabClass”.

The results of this project will be illustrated in a future paper.

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