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THE GESTINV DATABASE: A TOOL FOR ENHANCING TEACHERS PROFESSIONAL DEVELOPMENT WITHIN A COMMUNITY OF INQUIRY

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In this study we present a new model to design activities for mathematics teachers' professional development. The model results from the interaction of the Mathematics Teacher Specialized Knowledge (MTSK) design with a new tool (Gestinv, a structured and interactive database) within a community of inquiry. We follow a developmental approach to teachers' awareness of their beliefs, and convictions regarding mathematical knowledge and pedagogical content knowledge. We frame communities of inquiry in an Activity Theory perspective.

Rationale

Mathematics teacher training has become a research topic that entails theoretical, methodological and educational issues. Several researches (Shulman, 1986; Wenger, 1998; Ball, Thames, & Phelps, 2008, Jaworski, 2006; Da Ponte & Chapman, 2006; D'Amore & Fandiño Pinilla, 2009; Bartolini Bussi et al. 2017; Carrillo-Yañez et al. 2018) have enhanced different theoretical perspectives and methodological design that allow teachers to foster their specialised knowledge in order to implement in their school practice effective and forefront teaching methodologies and to create new cultures of mathematical activity. Our study develops within this line of research focusing both on a theoretical perspective for the design of effective methodologies and on the introduction of tools used and designed for teacher collaboration. Our methodological design results from the networking of two robust theoretical perspectives in the field of teacher training: Jaworski's notion of Community of inquiry (2006) - within a fallible stance towards knowledge it conceptualizes mathematical knowledge and knowledge in teaching as resulting from inquiry, intertwining the knower and the knowledge - and the Mathematics Teacher's Specialised Knowledge (MTSK) model (Carrillo-Yañez et al., 2018). We believe that these perspectives take into account two defining characteristics of a teacher training model. On the one hand we need to conceptualize appropriate social interaction within a community of practice between teachers and between teachers and didacticians. We consider teacher training a developmental process that entails *teacher change* (Guskey, 2002) in terms of a transformation of beliefs, convictions (D'Amore & Fandiño Pinilla, 2004), *Weltanshauungen* regarding mathematics, teaching-learning processes, the students and the political and social role of the education system. Such a change cannot be a solitary, individual and autonomous process, instead it is constitutively a sociocultural activity whose outcome is the transformation of the individual's identity as a teacher. On the other hand we need to conceptualize and outline the specific knowledge and professional skills that we would like teachers to achieve as a result of the change they undergo in their training process. We are referring to a wide range of knowledge that includes mathematics, epistemology, pedagogy, didactics, psychology etc. Sociocultural development within a community of practice requires tools that mediate the activity, contribute to the interpersonal exchange within its actors and bring to the fore cultural and conceptual objects.. As highlighted by the *ICMI 25 - Discussion Document*, within *activity theory* (Wertsch, 1981) perspective, Grossman, Smagorinsky and Valencia (1999, p. 14) make a distinction between *conceptual tools* and *practical tools*. The former are "principles, frameworks, and ideas about teaching [and] learning … that teachers use as heuristics to guide decisions about teaching and learning". The latter are classroom practices, strategies, and resources such as daily and unit plans, textbooks, and instructional materials that "do not serve as broad conceptions to guide an array of decisions but, instead, have more local and immediate utility". Our study brings into play a new tool that a group of mathematics education researchers on behalf of the Italian National Evaluation Institute for the School System (INVALSI) introduced in 2014 in order to create a friendly tool for teachers, researchers and all the stakeholders involved in the education system (Bolondi, Ferretti & Gambini, 2017). The Gestinv database collects in a structured way a broad range of information regarding the national mathematics test that INVALSI issues annually and that involves all Italian students of grades 2, 5, 8, 10, 13. This tool allows users to carry out focused and cross researches concerning the national tests, available from 2008, according to mathematical contents and their relationship with the National Guidelines, the results of the tests and the related percentages - percentage of correct, incorrect, invalid and missing answers and, for multiple choice task, the percentage of each option - school level, content keywords and statistical features (characteristic curves, distractor plots, ITN). Our experience as teacher trainers shows that Gestinv is a resource that intertwines conceptual *and* practical tools (Grossman, Smagorinsky and Valencia, 1999). On the one side, the profound theoretical framework (INVALSI, 2017) that informs both the construction and the selection of the items and the complex structure behind Gestinv triggers the use of mathematical content knowledge, mathematics education theoretical tools, ideas about teaching and learning that altogether amount for a conceptual tool. On the other side, Gestinv is a tool that can be implemented in the classroom, with a local and immediate utility, as an instructional material for mathematics teaching and learning that requires heuristics and strategic thinking on the part both of the students and the teacher. In this sense we can consider it also a practical tool. We stress the fact that in our study the use of Gestinv allows teachers to use the INVALSI standardized test not as a means of assessment but as a tool useful for them both in their pre-service and in-service training, which, within mathematics education research, can improve the teaching-learning processes of mathematics. The aim of our study is to present a new model for pre-service and in-service teacher professional development. This model is based on the affordances of Gestinv database used within a community of inquiry, which can affect mathematics teacher's specialised knowledge by critically reflecting on the complexity of standardized assessments according to the constructs of mathematics education and mathematics curriculum.

A model for mathematics teachers' professional development

The model we propose stands on three legs, the Community of inquiry, the MTSK model and the use of standardized assessment in the mathematics education field. As we mentioned in the introduction, we believe that teacher training has to take into account three dimensions that contribute to the formation of a mathematics teacher identity: social activity, tools that allow individuals to enact and materialize social practices, mathematical knowledge and teaching knowledge that constitute the teacher's specialized knowledge.

Community of inquiry

Social interaction within a community of practice accounts for the construction of subjectivity as a teacher. Sociocultural perspectives in mathematics education (Radford, 2008; Sfard, 2008) have shown the role of social-communicative practices in a cultural-historical context both on the learning processes and the construction of identity, two sides of the same coin. We believe that we can extend and adapt these research findings to mathematics teacher's professional development, since their training can be envisaged as an objectification-subjectification within the learning of mathematical knowledge and pedagogical content knowledge. Furthermore, within the sociocultural perspective we are advocating here, mathematical knowledge and knowledge for teaching are not fixed a priori entities that must be taken for granted. They are continuously reflected and refracted in social and communicative activity that allow us to make sense of cultural-historical constructs and we call this sense making process learning. Teacher's professional development cannot disregard this feature of thinking and knowing. Jaworski (2006, 2014) adds an important feature that characterizes a community of practice (Wenger, 1998) that is, *inquiry*, which unfolds in terms of critical thinking, questioning, doubting, bringing new points of view ecc.

> "The transformation of a community of practice to a community of inquiry requires participants to look critically at their practices as they engage with them, to question what they do as they do it, and to explore new elements of practice. Such inquiry-based forms of engagement have been called "critical alignment" (Jaworski 2006). Critical alignment is a necessity for developing an inquiry way of being within a community of inquiry. " (Jaworski, 2014, p.77).

Therefore, within this conception of a community of practice, we can think of "inquiry as a way of being" in which teachers take on the mantle of inquiry as central to how they think, act, and develop in practice and encourage their students to do so as well." (Jaworski, 2014, p.77). We see how belonging to a community of inquiry results in a special attitude, a mode of being and becoming that defines the way teachers act, feel, think, learn and teach. This new attitude has important implications on the way teachers are going to handle the complexity of Chevallard's triangle whose vertices, knowledge, pupil and teacher (Chevallard & Joshua 1984), are inseparably intertwined. An attitude of inquiry allows the teacher to be tuned with an intrinsically unpredictable, uncontrollable, fluid and flexible situation, i.e. the mathematics classroom, which requires constant interpretation and reinterpretation in order to design and carry out activities, make decisions and handle social interaction. The subjectivity that the teacher realizes in his professional development in a community of inquiry cannot be separated from his mathematical knowledge and his knowledge for teaching. In the following section, we will look at the other leg of our model, that is the knowledge for teaching that a teacher acquires in a community of inquiry. We will turn to the construct of Mathematics Teacher Specialized Knowledge (MTSK) introduced by Carrillo-Yañez and colleagues (2018).

The MTSK model

The importance of knowledge for teaching, concerning a specific school subject, is internationally acknowledged; already in the mid-80s, Shulman (1986; 1987) focused on the concept of Subject Knowledge for Teaching and proposed a model aimed at outlining the areas of knowledge that teachers should possess, in terms of Pedagogical Content Knowledge (PCK). His innovation was the outlining of a "new knowledge of the content", specific to teaching. Within this line of research, over the last few years several works have tackled different aspects concerning both mathematical knowledge, and the specific knowledge for teaching (PCK) (i.e. Depaepe et al., 2013). To investigate teachers' knowledge, these studies did not set off from the contents listed in school curricula, but focused on empirical approaches in order to understand the mathematical content needed for teaching by investigating its basis, role and relevance. These studies - one of the most relevant is Ball, Thames, & Phelps (2008) - not only contributed to the improvement of the PCK by identifying its related subdomains of skills necessary for teaching, but also provided a framework for the conceptualization of the mathematical content knowledge, thereby harmonizing PCK and the mathematical content into the so called Specialized Content Knowledge (SCK). The results obtained by Ball and colleagues (2008) have been developed into a broader model to frame teachers' professional development. Carrillo-Yañez and colleagues (2018), introduce the Mathematics Teacher Specialized Knowledge (MTSK). MTSK coordinates two extensive areas of knowledge, the Mathematical Knowledge (MK) and the Pedagogical Content Knowledge (PCK) that meet and intersect in the teacher's system of beliefs. MK is the knowledge possessed by a mathematics teacher in terms of a scientific discipline within an educational context and PCK is the knowledge relating to mathematical content in terms of teaching-learning. Beliefs about mathematics and its teaching and learning lie at the "center" of the model (fig. 1) to "underline the reciprocity between beliefs and knowledge domains" (Carrillo-Yañez et al., 2018, p. 240). In the model, MK and PCK are divided into three sub-domains. The MK is composed of Knowledge of Topics (KoT), Knowledge of the Structure of Mathematics (KSM), Knowledge of Practices in Mathematics (KPM). In the MTSK model, the PCK "is a specific type of knowledge of pedagogy which derives chiefly from mathematics." (Carrillo-Yañez et al., 2018, p.

246). The three subdomains of PCK are the Knowledge of Mathematics Teaching (KMT), the Knowledge of Features of Learning Mathematics (KFLM) and the Knowledge of Mathematics Learning Standards (KMLS).

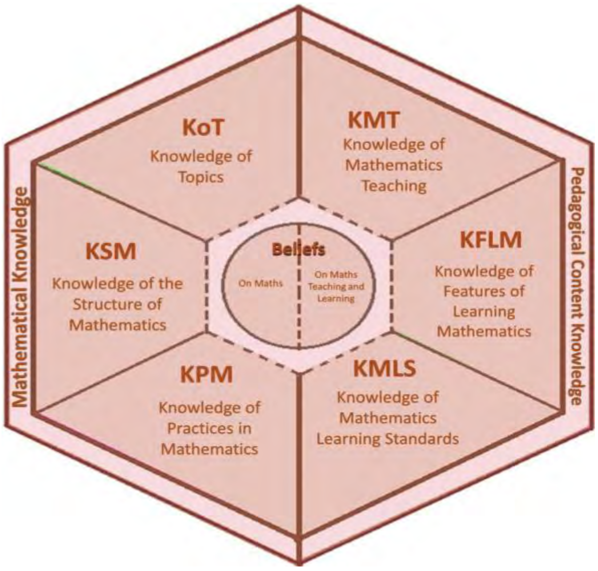

Figure 1: The MTSK model (Carrillo-Yañez et al., 2018, p. 241)

We would like to draw the attention of the reader on the fact that in our model the features of the inquiring practice, in which the teachers engage and align, are entangled with the change and construction of the system of beliefs that is at the core of the MTSK model. In our understanding, the core of the MTSK model is triggered by questioning, doubting, discussing, exploring, investigating etc. both MK and PCK within the community of inquiry. So far, our model provides a framework for activity and its outcome in terms of MTSK. We need a tool that bridges the gap between the community of inquiry and the MTSK and, furthermore, mediates and materializes/condenses the practice of inquiry. We are ready to introduce the third leg of our model: the database Gestinv.

The database Gestinv

In recent years more and more studies in mathematics education pinpoint the relevance of standardized evaluations and their impact on school systems (De Lange, 2007). As pointed out by Looney (2011), one of the main objectives of research regarding the role of standardized assessment is to find an effective way to merge its results, methods, theoretical frameworks and tools – that are designed in order to impact at a systemic level – into the local actions of teachers and schools. Therefore, teachers play a crucial role in this process that involves their professional development and system of beliefs. In order to meet this pedagogical demand, a group of mathematics education researchers (ForMATH Project), in collaboration with computer scientists, on behalf of the National Evaluation Institute for the School System (INVALSI) introduced in 2014 a new tool that teachers could use in order to bring the standardized assessment into their school practice and professional development. We are referring to Gestinv, a database with structured information regarding Italian standardized assessment that contains 1718 test items, spanning 10 years of INVALSI activity. The impact of the Gestinv database has been assessed both quantitatively and qualitatively, through standard indicators such as the number of registered users (more than 16.643), the number of accesses (on average, 200 every day), the time spent on the website and other parameters. These data, along with its structured information, promote Gestinv as a tool to implement in the design of teacher training models. Given the teachers' acquaintance with such a tool, it could be easily used both in the training sessions and their everyday practice, thereby bridging the gap between teachers' educational and school practices. There are many ways you can use the database; inside you can in fact carry out different forms of searches. The database has been devised both for Italian and Mathematics. Entering the Mathematics section you can search according to:

- the National Guidelines, that is, the Learning Objectives at the end of the third grade of Primary School; the Learning Objectives at the end of the fifth grade of Primary School; the Goals for the competences development at the end of Primary School; the Learning Objectives at the end of the Lower Secondary School; the Goals for the competencies development at the end of the Lower Secondary School; the National Guidelines for Liceo; the Guidelines for Technical and Professional High Secondary School; the transversal High Secondary School Cultural Axis);
- Keywords (there are about 200 keywords that identify the main topic for each item);
- "Full Text": the database allows you to find the full text of an item by typing in the search record one or more of its words;
- the vertical cognitive processes outlined by the INVALSI theoretical framework - six both for Primary Level and Secondary Level;
- national rates of correct/incorrect/invalid answers
- types of test questions (multiple choice, open questions, ecc..)
- guided search - it is possible to carry out a cross search (with and/or logical connectors) involving all the parameters mentioned above.

We believe that, in our model, Gestinv plays an important role in providing teachers and didacticians with an *interactive* tool to access a broad range of information and feedback regarding both the learning and teaching processes. Information are available not only in terms of global rates (measured by statistical models) but also to precise occurrences that we can observe in the answers to the items. In particular, the results of the INVALSI tests highlight and quantify relevant macro-phenomena, which can be interpreted according to methods and results of mathematics education research. On the one hand, the articulated structure and richness of information provided by Gestinv bridges the practice carried out in the community of inquiry with the subdomains of the MTSK model, acknowledging both the mathematical knowledge and pedagogical content knowledge. On the other hand, Gestinv serves as a mediator of and materializes the activities of the community of inquiry. In fact, an inquiring activity carried out in the *interaction* with Gestinv could trigger a change in the teachers' beliefs about mathematics and mathematics teaching and learning, by questioning, doubting, focusing, discussing etc. on mathematical contents and their development throughout the school levels, modes and results of assessment, teaching strategies and methodologies, cognitive processes and vertical difficulties. We can conclude that, in our model, Gestinv plays the role of both a conceptual and practical tool. Below a diagram that synthesizes our model for mathematics teachers professional development that pivots around Gestinv.

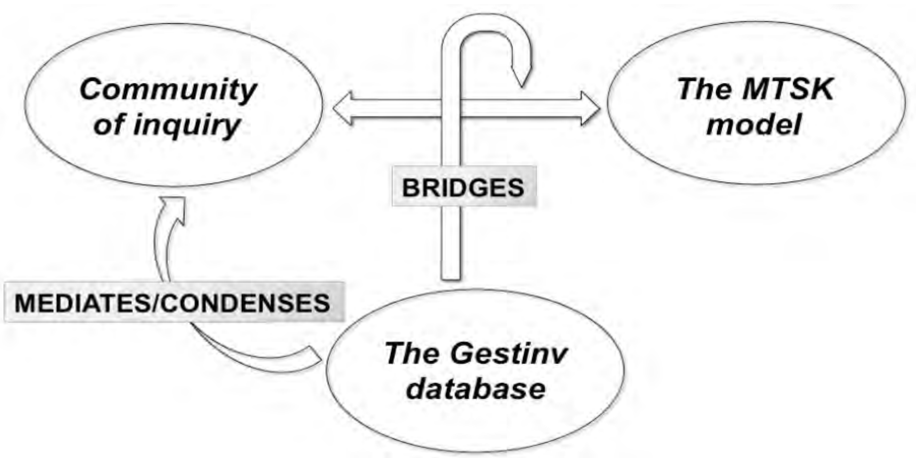

Figure 2: The model of mathematics teachers' professional development using Gestinv

The model used with teachers' professional development courses

We implemented the model we described above in several courses that involved both in-service teachers (almost 1300 in the last 4 years), at Italian national level, and pre-service teachers (almost 800 in the last 3 years) that attended the laboratory of mathematics education at the Free University of Bolzano-Bozen (the activity are conducted inside the *Multilab Project* of the Faculty of Education). The courses were designed according to the rules and expectations of a community of inquiry, that is, questioning - asking and seeking to answer questions (Jaworski, 1994; Mason, 2001) - doubting, problem solving, discussion, exploring and investigating, thus accomplishing learning on mathematical knowledge and pedagogical content knowledge. We embrace a developmental approach that pushes teachers and didacticians "into a deeper awareness of their own actions, motives and goals" (Jaworski & Goodchild, 2006, p. 353) The teacher professional development courses are conceived with the aim of constructing professional communities of learning in which groups of teachers engage in inquiring about the teaching and learning of mathematics (DuFour, 2004). According to our model for teachers' professional development, teachers engaged in activities that required an interactive use of Gestinv and exploited its richness of information and the structure of the search tools that we described in the previous section. The practices were designed in order to enhance and accomplish teachers' awareness on both subdomains of MTSK model. Special attention was devoted to the changing of beliefs pursued through the inquiry attitude, which underpins the community of practice. The community of practice worked according to the principles of group learning, thus teachers were divided in sub-groups of maximum 5 persons. The activity plan followed the following schema:

- Introduction of the activity. The didacticians discuss with the teachers the mathematics education constructs, also looking at learning difficulties, that will be useful for the activity. Moreover, the didacticians present some of the functions of Gestinv that the teachers will use in their inquiry. Last but not least the didacticians address the mathematical content selected for the activity (for example, algebra) from a conceptual and epistemological point of view. The mathematical content is discussed with the teachers according to some of the principles of Bartolini Bussi (1996) *mathematical discussion*.
- Analysis of an example. The didacticians discuss with the whole group of teachers, according to the rules of a community of inquiry, a didactical macro-phenomenon (as a paradigmatic example) using Gestinv within the MTSK model stressing the mathematical knowledge and/or the pedagogical content knowledge.
- Group activity. The group divides into sub-groups of maximum 4/5 members. The didacticians in charge of the course assign a task covering a mathematical content, a learning difficulty, a cognitive process related to one or more sub-domains of the MK and the PCK that are developed according to objectives and goals of the National Guidelines. The small group activity is carried out according to the rules of a community of inquiry, and the members of the group strongly interact with Gestinv. In-service teachers usually work on the same topic, whereas pre-service teachers sub-groups usually work on different ones. The group activity aims at the construction of a multimedia product, an artifact, the design of an activity for students etc., which should highlight teachers' reflections, convictions and beliefs. For example, as regards algebra, teachers are invited to inquire Gestinv, according to the preparatory activies mentioned above. It results that some of the lowest percentages of correct answers concerns items that require symbolic manipulations of powers. The activity on Gestinv prompts an attitude of inquiry - based on a working-sheet and the study of specific research materials regarding the historical-epistemological and didactical aspects of algebra and powers - that brings to the fore beliefs, convictions, reflections, emotions, agentivity etc., which will inform their multimedia product.
- General discussion. The sub-groups present their materials in a written or oral form to the big group. Each presentation is discussed within the community of inquiry in order to highlight beliefs and convictions, tackle doubts, difficulties and unclear contents regarding both the MK and the PCK and outline the subdomains of the MTSK that emerged from the activity. Another setting for this final phase requires each sub-group to prepare a written presentation that is exchanged so that each sub-group presents orally to the big group the material of another sub-group. The final discussion, based

on the oral presentations is performed with the same characteristics of a community of inquiry described above.

We conclude this paragraph presenting some extracts, which show significative changes in beliefs regarding the subdomains of the PCK, taken from a focus group carried out at the end of a teacher course.

Knowledge of Mathematics Teaching - KMT

T_05: In this period I saw a new possibility in getting inspiration from the database in order to prepare tests for my students.

T_06: I did the same especially for tests involving argumentation and reasoning.

Knowledge of Features of Learning Mathematics - KFLM

T_05: I never thought I could get so much information about the INVALSI tests. Under this perspective they can be really useful. D: What do you mean? T_05: we can really access information regarding the learning of our students and single out didactical paths for our activities.

T_06: Exactly, I found extremely useful to look for the items with the lowest percentage of correct answers. I was amazed and I proposed some of the questions we analyzed together to my students because I did not believe it could be so. Instead they gave the same incorrect answers like the other students!

D: Can you give some examples?

T_06: For example, fractions. I could not believe in the results after all the hours devoted to this topic. Instead I was not surprised with the results regarding area and perimeter.

Knowledge of Mathematics Learning Standards - KMLS

D: As regards the link to the National Guidelines do you think that the INVALSI tests can be useful to exemplify them?

T_01: Yes, there is an objective that I searched in the database, and it gave me hints to design an activity with my students.

These data result from a first explorative implementation of the model and are insufficient to verify the effectiveness of our model in teachers' professional development. Further empirical investigation is necessary to bring evidence regarding the efficacy of our model both for in-service teacher training and undergraduate university pre-service teachers. This process is started and we have already collected new experimental data that have to be analyzed and show that the model can be effective in teachers' professional development.

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