Teachers as key players: from professional development to the design and use of digital resources and backward

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Abstract

This paper presents an ongoing research project aiming at identifying innovative methodologies and technologies to design and use digital resources supporting mathematics education. The key players in the projects are the teachers. They are involved in the collaborative design of a digital mathematical serious game with researchers and software developers. Their engagement, shaped up to be a professional development experience, will result in a crucial aspect to put into practice the exchange between the scientific and the productive world. Methodologies and technologies developed with their contribution will constitute the basis on which further professional development programs could arise. Herein we present and qualitatively discuss the early results of an initial survey aiming at investigating teachers' perceptions of their professional needs with respect to the use of digital resources in mathematics education and their role and contribution to collaboratively designing a digital mathematical serious game. The theoretical lenses that frame this investigation are the Technological Pedagogical Content Knowledge and the Meta-Didactical Transposition. The study shows how teachers recognize the role of technology in mathematics education and are willing to experiment with new digital resources to keep up with the times. The interplay between school, academia, and company is also brought to the fore as an effective strategy to cope with the educational challenges of the 21st century.

Keywords

Digital resources, Mathematics education, teacher professional development, meta-didactical transposition.

1. Introduction

With the spread of Information and Communication Technologies (ICT) and the changes they led in society and education, research on new specific forms of learning has emerged, and epistemological questions have been posed about how learning takes place and how knowledge arises beyond the boundaries of traditional education systems. This has opened up a creative space where learning, innovation, and work can be integrated [1], [2], [3]. It seemed that the society and the school world were ready for a radical technological change, rejecting the old forms of knowledge transmission and extending learning environments to virtual ones. Hence, one of the challenges for the 21st-century teachers is to educate students, for which the term "digital natives" has been coined [4], that are immersed in the culture that our virtual age imposes.

However, teachers are not "digital natives," and the speed that characterizes the evolution of technologies requires them to develop new competencies and skills. Complex questions arise and effective answers can be found only with the teachers' direct collaboration with other kinds of experts and professionals, such as researchers in the field of general and disciplinary education, experts in

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educational technology, designers, and producers of technological solutions for education. Teachers today, indeed, are asked for new skills not only related to the specific discipline they are teaching. They need to acquire interdisciplinary skills that are fundamental to solving problems and tackling new kinds of situations in the digital world. Therefore, the aims of education need to be re-thought, the design of educational solutions needs to be based on active and dynamic learning, new technology-based teaching methodologies need to be developed and experimented with, and innovative approaches to teachers' professional development need to be implemented. And on the other hand, none of these issues can be faced without the direct engagement of teachers themselves.

In the recent working paper presenting the new OECD-PISA 2021 framework, it is also emphasized how the success in the use of new technologies for educational purposes is based, above all, on the ability to select, create and manage digital resources suitable for innovative and inclusive teaching pursued by adapting the strategies for introducing technologies to the specific educational context. To overcome the effects of the crisis in the context of the pandemic and its social consequences, preparing for a digital and resilient recovery of the economy, therefore, it becomes a priority to enable educators to make the most of the potential of technological resources to promote meaningful learning.

1.1. The ongoing research project

The international research project MaTIn4MER –Methodological and Technological Innovations For Math Education Resources– arose from the context described above and is based on the collaboration between the scientific world, the productive world and the school world. In accordance with the principles of the European Pillar of Social Rights, including those relating to equal opportunities and access to the labor market, this project has the general purpose of identifying and evaluating innovative methodologies and technologies aiming at producing educational solutions that could promote the acquisition of key citizenship skills in the logical-mathematical area. It intends to foster the creation of a cooperative open net involving the Italian University of Bari Aldo Moro, the Israeli Ben Gurion University of the Negev, an Italian Company (Grifo Multimedia) that has been developing for more than twenty years digital training and educational solutions, and some secondary schools. This is in line with the recent concept of dual training, in which theory and practice, soft and hard skills, academic teaching, and apprenticeship coexist within a structured learning trajectory immersed and intertwined in the reality of the labor market. Aiming to face the needs for innovation and competitiveness required by the age of digital transformation and to investigate the changes in the relationship among teachers, students, and knowledge, with the overwhelming of digital resources, the project attempts to create a framework to develop innovative products and the related guidelines to allow teachers to exploit their affordances. In particular, we intend to focus on e-learning and gamification solutions and to design, develop and experiment with a digital mathematical serious game taking into account the direct contribution of some in-service secondary school teachers, together with that of the software developers of the company.

In the initial phase of the project a small group of teachers, henceforth called "pilot teachers", has been involved asking them to complete an online anonymous questionnaire. They were then asked to take part in an online focus group with the aim to share their points of view and to create the conditions for a fruitful collaboration among them. The aim of this survey is to investigate teachers' beliefs and habits concerning the use of technological resources in mathematics education, their professional needs with respect to the use of new technologies, their confidence, and awareness of the importance and effectiveness of their contribution in the design of a mathematical serious game. To build the questionnaire, conduct the focus group, and analyze the resulting data we refer: to the framework of the Technological Pedagogical Content Knowledge [5] as far as it concerns the complexity of the integration of technologies in teaching practices; and to the Meta-Didactical Transposition [6] framework to analyze teachers' praxeologies [7] and their potential evolution.

In the second phase of the project, we will start working with the pilot teachers involving them, together with the researchers and the software developers of the company, in the collaborative design of the serious game, envisioning possible implementations of mathematical classroom activities based on its use [8]. This collaborative work will constitute the core of the professional development program in which the pilot teachers voluntarily accepted to participate. According to the Meta-Didactical transposition framework, we will then attempt to highlight whether and how this collaborative work could foster the evolution of both teachers' praxeologies and software developers' praxeologies. This would allow verifying if the collaborative design can foster the pilot teachers' professional development. Moreover, it would be also useful to understand how this approach can put into practice the exchange between the scientific and the productive world, by identifying innovative methodologies and technologies aimed at designing, developing and using digital resources to support mathematics education.

In the final phase of the project, the designed serious game will be experimented with by the pilot teachers in their classes, and results will be collaboratively analyzed and discussed to implement coherent changes, both in the product and in its didactical use. The developed methodologies and technologies will be finally validated both qualitatively and quantitatively involving the larger net of teachers and schools (approximately 150, distributed in the whole Italian territory) sharing the program of the Liceo Matematico [9]. This will contribute to the international debate on digital resources' task design for mathematics education and on the related issues concerning teachers' professional development. Moreover, results will create the conditions for the development of a line of innovative products aimed at the industrial market. 4.0 and at the Digital Transformation.

1.2. Overview of the paper and research questions

In this paper, we present, analyze and discuss the results of the survey (based on a questionnaire and the following focus group), developed with the participation of pilot teachers. Results are analyzed in order to answer the following research questions:

a) What are the "experienced" teachers' perceptions of their professional needs with respect to the use of digital resources in mathematics education?

b) How do they imagine their role and their contribution in collaboratively designing a digital mathematical serious game to experiment with in their classes?

In particular, in section 2 we refer to some related literature that is relevant to the rationale of our research project; in section 3 we describe the theory which framed the building and the result analysis of the survey, namely the Technological Pedagogical Content Knowledge and the Meta-Didactical Transposition; methods, participants and aims of the survey are described in section 4; in section 5 results are finally presented and discussed.

2. Literature review

There are several interdisciplinary studies on the use of technologies in teaching and learning mathematics. They concern the pedagogical field, educational psychology, computer science, educational technology, mathematics, mathematics education, etc. Many of them report on teacher educators' successes and dilemmas of integrating technology into their courses. For example, with the aim to determine how teacher educators can design courses and activities to better prepare pre-service teachers to effectively integrate technology in their teaching, Wetzel and colleagues [10] describe an integrative approach to guide teachers in developing and implementing content-based lessons in which students employed technology to meet content and standards.

The complexity of the integration of technology into mathematics education has been widely highlighted. Many studies have shown that the use of technology can improve the teaching-learning processes in mathematics [11] but also helps teachers rethink their beliefs and practices.

For example, Laborde [12] underlines that introducing technology produces a perturbation. Researchers also agree on the point that integrating technology into teaching takes time for teachers because to ensure a new equilibrium they need to understand that learning might occur in technology-rich situations and then create appropriate learning situations. Moreover, Laborde [12] claimed, "…whereas the expression integration of technology is used extensively in recommendations, curricula, and reports of experimental teaching, the characterization of this integration is left unelaborated." Trouche [13] underlines that pre-service and in-service teacher training should take into account the complexity of this integration at three levels: a mathematical one (new environments require a new set of mathematical problems); a technological one (to understand the constraints and the potential of artefacts); a psychological one (to understand and manage the instrumentation process and its variability). This point of view is based on the idea that a technology-rich learning environment could promote the learners' construction of situated abstractions [14, 15] and on the "instrumental approach" as developed by Vérillon and Rabardel [16]. The idea that the integration of technology into teaching practices requires further skills, in addition to the technical ones, has been described by Shulman [17], Mishra & Koehler [5] and other researchers, in the so-called TPACK framework that is described below.

This complexity also affects the interactions between technology and research in mathematics education. In this sense, Kaput and Thompson [18] used the very suitable metaphor of deep-water ocean waves. At the surface level are the waves themselves-short term events very much affected by local conditions such as winds and eddies. Then there are swells, of longer duration, of more distant origin, and affected larger-scale local conditions such as temperature and currents. Distinguishing waves from swells requires us to analyze wave behavior over more extended periods and situate that behavior within a larger context of interacting forces. Finally, there are tides whose origins are found in the frames of reference for swells and waves and whose behavior is measured in time units order of magnitude greater than the others. One can focus on any level of wave activity in isolation from the others, describing its behavior and effects on crafts or beaches. But the different levels of activity interact in subtle yet significant.

In the past two years, educational technology for learning has become imperative due to the pandemic that has forced the world's population into periods of isolation. Teachers needed to adapt traditional face-to-face teaching by using applications and software to allow distance learning. Bakker and colleagues [19] wondered if the pandemic changed the point of view on the themes of mathematics education research. According to the authors, the pandemic worked as a lens on the already important issues of social and educational problems. Some authors [20] evaluated the online learning of mathematics, highlighting the changes in learning methods. For example, they designed new teaching approaches and orienting mathematics learning toward solving social problems such as species extinction, climate change, and building a sustainable future. Still, others have studied how to use resources and laboratory activities with distance learning. A special issue [21] by Educational Studies in Mathematics gathers voices from researchers internationally in mathematics education about teaching mathematics during this pandemic. Leveraging data from a mathematics learning software as a substitute assessment, Rutherford and colleagues [22] found that students had a lower engagement with the software during the pandemic. Still, students who did engage had increased performance. The authors have highlighted the importance of using technology and a situation-aware platform to keep high engagement, motivation, and participation levels and the importance of using technology to prevent drop-out by improving engagement, motivation, and participation through Situation Awareness [23, 24, 25].

In recent years, technological innovations in education include gamification, serious games, and many apps to motivate and support students with special educational needs. In particular, these technological tools seem to have improved science and mathematics teaching [26].

Gamification use in education is well documented from its appearance in 2008. It differs from educational and serious games as the latter are not based on entertainment. Still, it was properly implemented only in 2010, and it was defined as "the use of game elements in non-game contexts" [27]. Serious games can be considered games to all effects, as they are based on a typical game structure but bear an educational objective. Their first goal is to educate and not to entertain. A serious game has a different approach than gamification and it takes the mechanics of games, such as leader boards, point systems, badges, challenges, and up-levelling, to encourage competition and achievements [28]. However, serious games could be designed as part of a more complex learning strategy, not only in stand-alone training mode.

Psychologists have adopted some gamified tests, utilizing game features in the real assessment situation. The common phrase '*Imagine of*' is easy to find in some tests, and participants, unconsciously, accept to play imaging themselves in a fictional dimension to perform the task. Also, in education, some learning tools are structured about gamification strategies. A large contribution has come from serious games applied to assessment [29]: the assessing situation is completely translated into a game. serious games can be easily carried out on laptops or other electronic devices, substituting traditional tests assessing cognitive abilities, personality traits, etc.

In previews works, the authors focused on two main questions [30, 31]. Firstly, they wonder whether the use of serious games encourages better emotional dispositions towards mathematics and improves the teaching-learning process of the discipline. Secondly, whether serious games allow the teacher to reflect on his teaching methodologies to encourage effective mathematics teaching.

The results were remarkable: from the tests carried out on the students and the analysis of the obtained data, a strong emotional involvement seems to emerge, overcoming epistemological obstacles in mathematics learning [32]. The quantitative results showed that teachers like to integrate traditional teaching with a more engaging and captivating education. The formative assessment test results reveal the didactic action's effectiveness in their classrooms. They look at a serious game as an instrument that mediates a collective activity in Rabardel's cognitive ergonomics approach [15]. Furthermore, they perceive the serious games for learning mathematics as an essential part of educational activities, including pedagogical, methodological, and technological aspects.

This work will refer to serious games as educational games and to gamification as a teaching methodology that uses games to introduce students to a mathematical topic. Specifically, we refer to video games made for educational purposes.

3. Theoretical framework

The Technological Pedagogical Content Knowledge and the Meta-Didactical Transposition are the theoretical lenses that we used to frame the survey and read its results.

3.1. Technological Pedagogical Content Knowledge

This paper referred to the Technological Pedagogical Content Knowledge (TPACK) framework conceived by Shulman in 1986 to define the elements that can characterize teaching when supported by technologies without neglecting the pedagogical aspects and the specific teaching contents of the discipline. The acronym TPACK arises from the intersection of three knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Pierson [33] illustrated the TPACK model as the intersection of three sets representing the three knowledge domains. The transformative model can be seen as a compound. In the integrative model, the didactic contents of the discipline, the pedagogical aspects, and the technology constitute three separate domains merged into a single element during the classroom lesson. In the transformative model, the disciplinary contents are combined with pedagogical elements and technology in a holistic way providing greater teaching support than the simple combination of the parts. Mishra and Koehler [5] make further clarifications by describing the meaning of the intersections between TK and CK and between PK and CK. Between TK and PK and subsequently, from their intersection, they explain the purpose of the intersection of the Technology, Pedagogy, Content, and Knowledge elements, such as schematically shown in Figure 1.

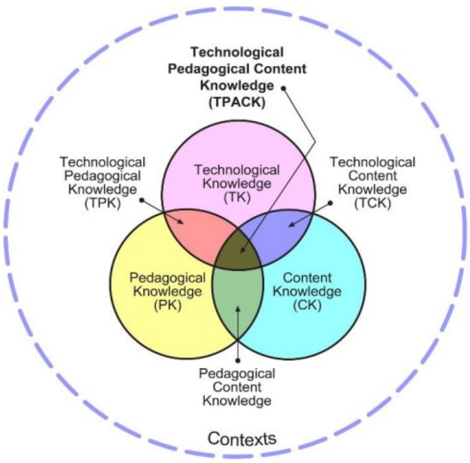

Figure 1: TPACK Venn diagram in Mishra and Koehler [5]

They specify the following. Pedagogical Content Knowledge (PCK) is concerned with the structure, organization, management, and teaching strategies for how the particular subject matter is taught. Technological Content Knowledge (TCK) is related to how one specific subject matter is represented in technology-rich environments. Teaching with technology requires knowing the subject and how subject matter can be changed with the application of technology, and this knowledge is called TCK. Technological Pedagogical Knowledge (TPK) is concerned with how teaching and learning change due to integrating technology into instruction and how a teacher should be able to choose a particular tool for a specific task considering its affordances and limitations. Technological Pedagogical Content Knowledge (TPACK) "is an emergent form of knowledge that goes beyond all three components" [5] According to the transformative model, TPACK is different from "knowledge of a disciplinary or technology expert and from the general pedagogical knowledge shared by teachers across disciplines" [5].

This framework helps to structure some of the results of this research. In particular, it helps to investigate and interpret the attitude of teachers in the face of innovation in their didactic. Teachers are faced with a difficult challenge: they must integrate the knowledge of pedagogical content or the knowledge of the content that deals with the teaching process, the knowledge of the technological content that refers to how technology can create new representations for the specific content, technological pedagogical knowledge which refers to the knowledge of how various technologies can be used in teaching.

3.2. Meta-Didactic Transposition

The lens of observation of the didactic phenomena experimented with has been that of the Meta-Didactic Transposition (MDT) [6]. The model of Meta-Didactic Transposition is based on the Anthropological Theory of Didactics of Mathematics [34]. It focuses mainly on the "meta" aspects. Still, it refers to the specific context of teacher training. The entire training process is the subject of reflection, and the didactic actions are seen in the light of the research results in mathematics teaching.

The Meta-Didactic Transposition considers the mechanism by which the praxis of the research community is transposed to the communities of teachers and how this transposition transforms the professionalism of teachers. The model refers to two types of communities involved in the teacher training process: the researcher community, which organizes and manages the training activities, and the teacher's community, which participates in the project. Each of the two communities has its praxis. When we talk about praxeology, we refer to what Garcia et al. [35] decline in two fundamental aspects: praxis on the one hand and logos on the other. That is, "know-how" (praxis), which includes classes of similar problems and their solving methodologies, and "knowledge" (logos), that is, the "discourse" that describes, explains, and justifies the methods used and produces new ones [35]. Our attention is focused on meta-didactic praxis that includes all forms of interaction with teachers in training, including practices and reflections. Therefore, there is a shift from "wise knowledge" to the mathematical and pedagogical knowledge necessary for teaching [36, 37].

This work also makes collaboration with an information technology company. Therefore, the practices of the research community, before being transposed to the community of teachers, intersect with the practices of the business community, identifying, in synergy, innovative methodologies and technologies to develop and use digital resources to support mathematics education and the formation of key competencies of active citizenship.

The praxeologies of researchers and teachers can be, from the outset, at a nonempty intersection. Still, the purpose of teachers' training activities is to transform the praxeologies of teachers into new praxeologies, which are a fusion of the praxeologies of the two involved communities (multiple communities, if we consider all the teachers), thus becoming shared praxeologies. For the creation of shared praxologies, the figure of the "broker" (mediator) is fundamental, who is the subject who belongs to more than one community and can create new connections between them and open new possibilities for the creation of meanings and learning. The transposition is then centered on specific actions of "brokering" between the various communities.

In our specific case, the training researchers had previous teaching experiences in high schools and, therefore, played the role of brokers.

An important feature of MDT is that some of the praxeologies of the two communities change over time. In teacher training, the aim is that some of the external components of a community become internal due to transcoding. For example, thanks to the praxeologies sharing, a Mathematics teacher who has to introduce a geometric topic - traditionally taught in a transmissive way as a theorem with its proof - may introduce it through a game. A change in teaching methodology can impact students in terms of increasing engagement in the study of mathematics and less disaffection. Moreover, the community of researchers can also introduce the use of some educational technologies and tools such as dynamic geometry software for the study of Geometry itself or serious games. In this way, the process of meta-didactic transposition could produce a dynamic change in teacher praxeologies, as some components of researchers' praxeologies and of software developers could become internal components of teachers. Our Meta-Didactical Transposition is therefore intended as an intersection of praxeologies of teachers, researchers and software developers.

4. Methods, participants and data collection

The study uses the survey technique and the questionnaire as a tool, consistent with the aims of the investigation. In addition, a focus group was carried out with the pilot teachers that were invited to answer the questionnaire.

The questionnaire was structured in three sections:

- Section A contains questions concerning teachers' personal data (in order to gain characterization of their profiles).
- Section B contains questions concerning teachers' technological, didactical and methodological competencies.
- Section C contains questions concerning teachers' beliefs about their potential contribution to a project involving schools, universities, and companies.

A small group of mathematics secondary teachers was chosen for the starting phase of the project for their known bent on didactical innovations and their willingness to experiment with new educational solutions. Eight of them voluntarily decided to join the project as pilot teachers, answered the questionnaire and participated in the focus group. The eight teachers have varying years of service experience from 12 to 35 years and their geographical origin is distributed across the country. They teach in scientific high schools (4), classical high schools (1) technical high schools (2), and vocational high schools (1). The linear interaction with the teachers through the anonymous questionnaire was considered first, followed by a focus group [38] with the same questions but with a network interaction [39].

The focus group was used as a non-standardized method of gathering information based on a discussion, which was only apparently informal. It was carried out online on a gmeet platform, with a researcher who acted as moderator and involved the eight teachers who had previously answered the semi-structured questionnaire. The focus was on the same topics of the questionnaire, and it aims to discuss the use of serious games in the teaching of mathematics and gamification as an educational methodology to support mathematics teaching and learning. The questionnaire was administered in Italian and, together with the answers given by teachers, was translated by the authors, The focus group was also carried out in Italian, and the discussion was then transcribed and translated into English by the authors, as well.

The focus group was exploratory, i. e. characterized by a low level of directionality and a low level of structuring because it is more suitable for our research in the exploratory phase. In this way, we intended to acquire information on a little-known phenomenon. Indeed, at this phase of research, we are interested in knowing the teachers' perspectives (the aspects they consider most relevant, priorities, conceptual and linguistic categories, the way they articulate their reasoning, etc.) on their professional needs with respect to the use of digital resources in mathematics education and their role and contribution to collaboratively designing a digital mathematical serious game. The researcher who acted as moderator limited himself to posing issues and providing some rules of interaction, then letting the debate unfold freely and intervening only in case of problems in the group dynamics or excessive deviations from the main topic.

Considering the heuristic potential of this technique, we chose to use the focus group, as a secondary technique, especially in an exploratory function, to get indications on how to proceed in the subsequent phases of the research, to generate hypotheses, to build and then pre-test a serious game as an educational tool and, more generally, gamification as an educational methodology to support teaching and learning mathematics.

5. Results and discussion

In what follows, we describe and discuss the results of the survey. In particular, a descriptive analysis is performed based on the teachers' answers to the questionnaire, while the following qualitative analysis is grounded on the transcripts of the focus group.

5.1. Descriptive analysis

Answers to the questionnaire first reveal that not all teachers have used Information Technologies in their practice and, in particular, only two teachers have already had experience with gamification. However, all agree that technologies support the teaching-learning of mathematics. Indeed, when asked about it, they gave, for example, the following answers:

T1: I think that, if properly integrated, ICT can be an effective tool to facilitate teaching, motivate students, to design innovative lessons.

T2: Technologies, if properly used, can greatly enhance teaching in all its aspects.

T3: Information technologies are important, but it would be necessary to have adequate tools (both theoretical and practical) to use them correctly.

In these answers, the teachers' interest in educational technologies is evident. However, two important elements can also be highlighted: T2 says "if properly employed," and T3 underlines that teachers should have the theoretical and practical tools to use them correctly.

Teachers are also asked: "What difficulties do you think one might encounter when designing and developing a mathematics lesson using ICT somehow?"

Here are two answers that we find significant:

T2: It requires time and attention beyond the classroom. It requires constant training because technologies are always evolving. It is not easy to stay one step ahead of your students who are digital natives while we are digital migrants.

T5: The use of technology must not equate to the uncritical choice of pre-packaged answers. Preparing a good lesson or test using digital technologies also takes longer. The ICT-based lesson could generate distraction and superficial learning; therefore, it must be carefully designed to engage and arouse curiosity. Students can then develop themselves through peer education.

Here, too, the need arises for a conscious use of technology for teaching to be effective. The need for training to keep up with the times again emerges.

The following questions go more into the specifics of the competencies required of the teacher in the 21st-century school. The first concerns technological skills: "What technological competencies do you think the teacher should have?"

Below are some answers:

T6: The teacher should be in continuous training in technology. They should know how to use the PC, the Interactive Whiteboard (IWB), and the tablet. They should be familiar with teaching and assessment applications in a more evolved way. Then there are more advanced skills such as using video games for teaching purposes, as a tool for assessment, knowing how to create video lessons, and interacting with students with online sharing resources (padlet, google classroom, etc.).

T1: I think that technological competencies can act as a framework for other competencies that the teacher must have, such as knowledge of subject content and the methodologies for teaching this content. Technological competencies alone are of little use.

Some teachers, like T6, referred exclusively to the technological competencies that, in general, every teacher should have but without focusing on technologies for the teaching of mathematics. Others, like T1, highlighted the relationship between technological, disciplinary, and methodological competencies.

The second question concerns pedagogical competencies: “What pedagogical competencies do you think the teacher should have?”

Some answers are the following:

T1: To know how to relate to pupils; to understand how to manage the dynamics, the conflicts that arise within the class or even between pupil and teacher; to know how to achieve positive educational communication. In addition: knowledge of the cognitive and psychophysical processes of mental, affective, and relational development in childhood; basic knowledge of developmental and learning psychology.

T3: The teacher should know the cognitive processes underlying student learning. Knowledge of the psychology of learning.

It is interesting to observe that the same T1 teacher who stressed the need to intersect technological competencies with disciplinary and methodological ones does not recognize the need for such an intersection in the case of pedagogical competencies.

The third question concerns methodological aspects: “What methodological competencies?”

Some answers are given here:

T1: Mastering different teaching styles from the knowledge of several teaching methodologies so that teaching can be diversified, stimulating, and inclusive.

T2: The teacher must master several methodologies, which can confer the capacity to carry out the tasks according to a plan and strategy developed previously and applied successfully.

T8: Knowing the theoretical frameworks, know how to create interesting and engaging learning units or individual lessons, including through technology.

And here, again, T1 does not mention the specific methodological competencies that might be needed to teach mathematics through the use of technology, but rather they stay on the general side.

Once again, the teachers’ need for continuous training emerges from these answers. However, it seems to emerge that it is not considered indispensable for the teacher to have absolute mastery of the technologies but rather to learn how to use the resources. In other words, it is not necessary to make the teacher a "technologist", and the fundamental thing is to know the relationship between the technological component and teaching action. The teacher’s ability is measured in the ability to design teaching experiences. These technological, methodological, and pedagogical competencies are effectively integrated and adapted for their work context.

The following questions deal more specifically with the area of games with technology. The first one is: “What do you think about using a serious game for your mathematics lessons?”

Some teachers answer as follows:

T6: *It could be a stimulating methodology, especially at certain stages of the teaching-learning process.*

T7: *The student who finds the importance of what they have learned in the game is encouraged to go deeper into the topics to improve*.

T8: *I'm willing to learn it!*

T5: *I never tried it because I don't know. Another thing to learn!*

Interesting answers to the question “What impact do you think it will have on students?” are given below:

T2: *I think it can be motivating. It can intrigue even the most reticent students; it can be inclusive. But it can also be a stimulus for teachers.*

T3: *It would arouse interest and involvement.*

Then we have the answers to: “What essential features should a serious game have for you to use in the classroom?”

T2: *It must meet the discipline's teaching objectives and learning aims.*

T3: *It must be rigorous and captivating.*

T4: *It must make people understand that the discipline can also be approached in a non-classical way, even if the traditional study cannot be replaced.*

From these answers, it seems to arise once again the teachers’ willingness to be trained with regard to the use of serious games in teaching. The idea is that using a serious game must be instrumental to the teaching objectives; it can be a support tool for more traditional education and a stimulus for students and teachers.

When asked: “Have you ever thought of collaborating on designing a serious game for mathematics with an IT company and a team of researchers?”, only one teacher replied that he had already collaborated on designing a serious game in the past. Still, they all agreed that it could be stimulating.

To the question “What contribution do you think you can make?” some teachers answer as follow:

T2: *Teaching experience, knowledge of the discipline for correct implementation of the game, imagination that should characterize a good mathematician.*

T3: *I could help in identifying objectives and criticalities and experiment on groups of students. In this way, I would also contribute to validating the serious game model for Mathematics.*

T5: *Having some (small) knowledge of computer science and theoretical frameworks in Didactics of Mathematics, I can contribute positively to both areas.*

To the question “What benefits do you expect to achieve?” they answer:

T2: *It could be a stimulus to broaden teaching methodologies and experiment with new ways to involve even the most reluctant students.*

T3: *Professional growth, contribution to the advancement of teaching technologies, possible economic gratification.*

T6: *Expanding my knowledge with something that has direct and positive educational spin-offs.*

An important element arises from these answers in that the teachers, on the one hand, expect to acquire new methodological competencies and the growth of their professionalism. On the other hand, they think they can actively contribute to designing a serious game by bringing their teaching experience and disciplinary knowledge. They would have a fundamental role in conveying the experience of designing the game with the game’s educational aims.

When asked, “Do you think it is relevant for a teacher to collaborate on research in mathematics education?”, T8 and T6 answered as follows:

T8: *I think it's very important. Having had a small chance during some didactics lessons at university, it was nice to observe what was being studied and to be able to devise activities that could have positive educational effects. So, by collaborating, the teacher would have the opportunity to correct himself (and his not always correct methods) and improve, involving students positively in the subject considered the "ugliest" by the learners.*

T6: *It depends: a teacher's experiences should not constitute a simple "protocol" to be analyzed by a researcher, if both (teacher and researcher) have the common objective of improving the effectiveness of teaching, then I believe that a teacher's experience can make a great contribution to research.*

All the others believe in bringing together teaching experience and research in mathematics education.

Through research, the teaching profession becomes a profession.

Finally, we asked: “What do you think you can contribute?” and received the following answers:

T2: *I think those good theories are born from good practices. Research is often far removed from the real problems in schools. Many educational researchers have never been in a classroom except as observers (in the best cases). Often teachers are used only as guinea pigs without deriving any real benefit from the experiments in schools. Good research also relies on the experience of teachers*.

T8: *A collaboration has several stages, so it could also be a stimulus and development for researchers.*

T3: *Ideas, experimentation in groups of students with data production, and analysis of these data.*

T4: *It depends on the research objectives; very often, the realization of an activity, even an innovative one (with the use of creative methodologies and tools such as ICT), is not important for research in mathematics didactics, where more emphasis is given, for example, to the analysis of emotions, verbal and non-verbal communication... I do not know whether my simple role as a teacher can play a significant role in research in mathematics education or whether it simply constitutes 'experimental data'.*

All teachers believe in sharing teaching experience and research in mathematics education. Indeed, the following are their answers to the final question: “What do you expect from a collaboration with a research team in mathematics education for your professional training?”

T1: *Educational growth*

T2: *I expect to improve my professional training*

T3: *I believe that my professional training, albeit with considerable commitment, would have an irreplaceable contribution from research activity on topics that are currently among the most advanced on the teaching horizon, the best I could wish for.*

T4: *Professional growth*

T5: *New stimuli for teaching*

T6: *I always hope to learn something new*

T7: *I expect cooperation, with the opportunity to conceive, experiment, make mistakes, improve/yes... and succeed in creating meaningful activities!*

T8: *It makes me grow in quality and gives me new tools to involve the class group.*

The important thing is the common goal of improving the effectiveness of mathematics teaching and learning.

5.2. Qualitative analysis: open questions

The focus group, conducted online, was attended by the eight pilot teachers, a researcher in the role of moderator and an observer.

The teachers were asked the same questions of the questionnaire they had previously answered to favor the exchange of ideas the possible rethinking of some positions and so that there could be a network-type interaction among them. The focus group lasted 75 minutes.

The teachers first introduced themselves because they came from heterogeneous realities. Each of them briefly presented their experiences using innovative teaching methodologies (reference is made to educational vanguards, experience in the "Liceo Matematico"[9], [40] project, PLS, European PON, eduopen, MOOCs). Some experiences were lived as teachers in continuous training, others as trainers. It was immediately noticed that all the teachers often live the double role of trainers and "training users", so their nature to get involved and experiment with new educational paths emerge. All the teachers agree that it is useful in achieving educational and training objectives about the use of technology. It contributes to the emotional well-being of the pupils and truly inclusive education. They "*contribute to improving learning and teaching processes".* They *"allow for greater flexibility and personalization of content according to the needs of each student*".

The discussion emerges that the use of ICT can somehow change the learning environment, the way of teaching, and the dynamics between actors in teaching/learning situations.

The use of technology is fine, but it should not invade spaces and should remain "human". It is essential to integrate technologies with teaching, but not all teachers are willing to change or have the required competencies yet; moreover, any didactic action involving the use of ICT needs to be supported by a project structure that establishes well-defined objectives, timeframes, and methods that respect the natural evolution of pupils' growth process and learning rhythms.

It was concluded that it is important to choose the most appropriate technologies for learning certain contents, with certain didactic approaches and considering the context.

Teachers report their personal experiences also of collaboration with some researchers in mathematics education, saying that it was something very constructive. However, for the teachers, the cooperation with a company developing multimedia games is new. They are very curious about this. Some answer by saying that a greater presence of the research world alongside the teachers could mean continuous training, which would be beneficial to the learning-teaching of mathematics.

The teachers are also very keen to cooperate and create a network between the various schools to compare notes in the subsequent phases of the project.

Teacher training can become a social activity in this way, as situations of collaborative interaction are created, both in virtual and face-to-face environments.

6. Conclusions

This paper describes the preliminary study of a wider international project, Methodological and Technological Innovations For Math Education Resources (MaTIn4MER).

The project aims to implement the interchange between the world of research and the productive world through the convergence of some specific purposes: to involve people, to create positive problem-solving attitudes; to develop the Digital Mindset; to acquire competencies in Digital Transformation models and tools; to recognize the advantages of digital ecosystems based on the integration of people, processes and technological platforms. It stems from the intersection of technological expertise from the productive world, the academic world, and the world of education through the initial involvement of teachers from different secondary schools.

The preliminary phase of the project aimed to involve a small group of teachers (pilot teachers) in designing and implementing a serious game. To better understand the teachers' training needs, we asked them to fill out a questionnaire and to participate in a focus group. Specifically, we asked which technological, methodological, and pedagogical competencies the teachers think they need. We also asked whether teachers would be willing to make their classroom experience available to collaborate with researchers in mathematics education and with a company that develops serious digital games for teaching.

Here we summarize the main findings of this preliminary study by answering the two research questions:

a) What are the "experienced" teachers' perceptions of their professional needs with respect to the use of digital resources in mathematics education?

b) How do they imagine their role and their contribution in collaboratively designing a digital mathematical serious game to experiment with in their classes?

Analyzing the answers of our eight pilot teachers, we can say that it seems they are aware that their knowledge, systematic and organic, is changeable, and structured according to an intrinsic complexity. This knowledge is content-related but above all pedagogical and technological, which implies that the teacher is facing new educational challenges in which the conscious use of technology becomes an essential element. Answers reveal their awareness to be asked to make a different educational effort than in the past; they are not only asked to transmit culture but also the continuous and autonomous process of its elaboration, in close relationship with society. According to their answer, they are aware of the need to put knowledge into concrete cases and different, new, unpredictable contexts, shifting the educational focus from knowing to knowing how to do. They feel themselves no longer the repository of consolidated concepts that the students must assimilate, but rather mediators, not solvers of given problems, but problem posers, tutors, or coaches. The focus group also shows that the teachers want to break out of the isolation of their classroom in which they often take refuge. They need to compare themselves with other teachers, they feel the need to be guided, through reflexivity, toward new teaching models. This allows us to give an answer to question a). In particular, it emerged that the intersection of the technological and pedagogical competencies responds to their training needs consistently with the TPACK theoretical framework.

The pilot mathematics teachers, moreover, feel ready to try out new paths, even to experiment with serious games, if this can serve to motivate their students and guide them out of crystallized knowledge. In this phase of the project, we cannot yet specify what the intersecting praxologies might be. It emerged that our pilot teachers, however, are willing to implement methodologies that have never been tried before; they are welcome to receive the suggestions coming from the researchers and are also interested in bringing the experience that comes from the corporate world into the classroom. On the bases of the information gathered in this preliminary survey, in the next phases of the project, it will be possible, thanks to the Meta-Didactic Transposition, to bring out that the intersection of praxeologies derived from multiple actors can give rise to shared praxeologies that give rise to effective teaching practices. According to the Meta-Didactic Transposition, indeed, when two communities meet, the community of teachers and researchers, each brings its know-how (logos) and experience (praxis). Hence, our research hypothesis is that new knowledge and new scenarios for applying this knowledge arise from the encounter and become shared, enriching these communities [6]. The preliminary study allows us to answer question b). Indeed, it already shows that teachers themselves believe they can benefit greatly from research as it can help teachers reflect and rethink the way they teach. On the other hand, they think that they can contribute by assisting the researcher and the software developers in focusing on some unthought scenarios. There was no shortage of critical voices from those who see research in education as being far removed from the school world and who would like analysis to make more use of teachers' experience.

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