

Using and designing digital mathematical resources: teachers' beliefs on their professional needs

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This study was developed within an ongoing research project aiming at identifying innovative methodologies and technologies to design and use digital resources supporting mathematics education through the engagement of teachers, researchers and software developers in the collaborative design of a mathematical digital serious game. In this paper, we present and qualitatively discuss, using the Technological Pedagogical Content Knowledge as a theoretical lens, the early results of an initial survey, involving eight teachers. It aims to investigate their beliefs on the use of digital resources in mathematics education and the professional needs for teaching mathematics in the XXI century. With respect to their involvement in the following collaborative design of a mathematical digital serious game, we also investigated their beliefs regarding their potential contribution to such an activity.

Keywords: Collaborative design of digital resources, Technological Pedagogical Content Knowledge, Teachers' beliefs on the use of technology, Mathematical digital serious games

Introduction

The teacher profile required in the Digital Age is an integrated and harmonious combination of several kinds of knowledge and competencies: cultural and disciplinary, psycho-pedagogical, didactic-methodological, and technological. Moreover, one of the key elements of effective teachers' professional development in the XXI century is to bring them out of the isolation they find themselves in by integrating them into a context of continuous training in which they are protagonists (Borko & Potari, 2020). The study that we present in this paper was developed within an international research project MaTIn4MER –Methodological and Technological Innovations For Math Education Resources– based on the collaboration between the scientific world, the productive world, and the school world, to design and experiment with a mathematical digital serious game. We refer to mathematical digital serious games as digital educational games that can foster competition and achievements thanks to the mechanism of games, such as leader boards, point systems, badges, challenges, and up-levering. They have been chosen as specific objects of research due to their potential to encourage better emotional dispositions toward mathematics and improve its teaching and learning (Capone & Faggiano, in press). Thanks to the software developers' and teachers' collaboration in the project, researchers aim to elicit guidelines to train teachers in integrating this kind of new technology in the mathematics classroom. The main hypothesis of the project is that to create a framework for developing innovative products and the related guidelines for teachers' training, it is important to directly involve teachers themselves. Moreover, being beliefs contextually significant to the implementation of any innovations, to understand how teachers might deal with digital serious games, it is important to first understand their beliefs. In this study, we refer to teachers' beliefs broadly as those tacit, often unconsciously held assumptions about students, tools

and content to be taught, their professional needs and their potential contribution to designing and experimenting with a mathematical digital serious game. A small group of teachers, called “pilot teachers”, were invited to complete an anonymous online questionnaire with the aim to investigate their beliefs on the use of digital resources in mathematics education, and their professional needs for teaching mathematics using a digital serious game. Through the lens of the Technological Pedagogical Content Knowledge (TPACK), in this paper, we present and qualitatively discuss the early results of this initial survey administered and analyzed with the aim to answer the following questions: a) What are the pilot teachers’ beliefs of their professional needs with respect to the use of digital resources in mathematics education? b) What are the pilot teachers’ beliefs of their potential role in the collaborative design of a digital mathematical serious game to experiment with in their classes?

Theoretical Framework

As far as it concerns the complexity of the integration of technologies into teaching practices, we refer to the framework of the Technological Pedagogical Content Knowledge (Mishra & Koehler, 2006) to build the survey and analyze the resulting data. With his Pedagogical Content Knowledge model, the educational psychologist Lee Shulman (1986) emphasized with his seminal work the need for teachers to combine disciplinary knowledge with appropriate pedagogical strategies to achieve quality teaching. About twenty years later, Mishra and Koehler (2006) proposed integrating a third element: technological competency. The Technological Pedagogical Content Knowledge (TPACK) model suggests that, as with content and pedagogy before, technology should not be introduced into the educational context as a stand-alone element but as a component of a broader scenario: it is the integration of these different domains that supports the teacher in teaching a subject with the support of technology (Niess, 2005). In our case, according to Mishra and Koehler, Pedagogical Content Knowledge (PCK) is concerned with the structure, organization, management, and teaching strategies for how mathematics is taught. Technological Content Knowledge (TCK) is related to how mathematics is represented in technology-rich environments. Teaching with technology requires knowing the mathematics and how mathematics 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 with the integration of technology and how a teacher should be able to choose a particular tool for a specific task considering its affordances and limitations. This framework helps us to investigate how teachers are faced with the challenge to integrate the three knowledge domains. Looking at the survey results through the lens of the TPACK, hence, can help identify teachers’ beliefs on the use of digital resources in mathematics education and their professional needs for teaching mathematics in the XXI century also using a digital serious game.

Methods

The study uses the survey technique and the questionnaire as an explorative tool, consistent with the aims of the investigation. The questionnaire, anonymous and semi-structured, was composed of three sections: Section A contains questions concerning teachers’ data (to gain characterization of their profiles); Section B contains open questions concerning teachers’ technological, pedagogical and content knowledge; Section C contains open questions concerning teachers’ beliefs about digital

serious games and teachers' potential contribution to the collaborative project involving schools, universities, and companies. A small group of mathematics secondary teachers, with a known bent on didactical innovations and a willingness to experiment with new educational solutions, were invited to join the project. Eight of them, to whom we refer as "pilot teachers", voluntarily decided to answer the questionnaire. The questionnaire was administered in Italian and, together with the answers given by teachers, was translated by the authors. Results analysis is performed based on the teachers' answers to the questionnaire, taking into account the TPACK model. In what follows we will mainly focus on the descriptive analysis of some of the answers given to Sections B and C.

Results

One of the first questions asked to teachers in Section B, was the following: "What difficulties do you think one might encounter when designing and developing a mathematics lesson using ICT somehow?" The answers reveal the need for designing and implementing effective teaching experiences integrating technology and, therefore, the need for pre-service and continuous training. For instance, T2 and T3 respectively answered: "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"; "it would be necessary to have adequate tools (both theoretical and practical) to use them correctly". Some open questions were more specific about the knowledge required to be a teacher in the XXI century school. Here we focus on the following: 1) "What technological knowledge do you think the teacher should have?"; 2) "What pedagogical knowledge do you think the teacher should have?". Some teachers referred exclusively to technological knowledge without focusing on technologies for teaching mathematics. T6, for example, answered: "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." Others highlighted the relationship between different kinds of knowledge: "I think that technological competencies can act as a framework for other knowledge 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". From the questions in Section C, that dealt with digital serious games, emerges the teachers' interest to learn how to integrate them into their teaching. They thought that a serious game can be a supporting tool for more traditional teaching and a stimulus for students and teachers, but it must be instrumental to the teaching goals. To the question "what contribution do you think you can bring to the design of a serious game?" T2, for example, answered: "Teaching experience, knowledge of the discipline for correct implementation of the game". Finally, according to their answers, teachers believed that they could benefit greatly from both the research and the productive world that can help them reflect and rethink how they teach.

Discussion

According to the answers to the questionnaire, all teachers agreed that technologies support the teaching and learning of mathematics, but also that it would be necessary to have adequate knowledge. They referred to the need to have what, in agreement with the TPACK model we have called Technological Pedagogical Knowledge (TPK). Although they did not mention the specific technological and pedagogical knowledge that might be needed to teach mathematics using

technology, they also highlighted the need for more comprehensive knowledge, integrating technological, content, and pedagogical aspects, to improve the effectiveness of mathematics teaching and learning when using digital resources. Moreover, if, on the one hand, teachers felt the need to acquire new technological and pedagogical knowledge, on the other, they thought they can actively contribute to the design of a mathematical digital serious game by bringing their experience in terms of pedagogical content knowledge and assisting the researcher and the software developers in focusing on some unthought scenarios. Finally, teachers' beliefs about their potential role in the collaborative design of a digital mathematical serious game to experiment with in their classes confirm our hypothesis concerning the importance of the direct involvement of teachers in the project.

Conclusions and further developments

This paper describes the preliminary study of a wider international project, that stems from the intersection of expertise from the technological, productive world, the academic world, and the world of education to identify innovative methodologies and technologies to design and use digital resources, such as serious games, supporting mathematics education. The project's initial phase aimed to involve a small group of pilot teachers in sharing a common base to collaboratively design and implement a digital mathematical serious game. This required conducting a survey to investigate teachers' beliefs concerning the use of technological resources in mathematics education, their professional needs with respect to this use, and their awareness of the importance and effectiveness of their contribution in the design and experimentation of a digital mathematical serious game. It emerged that the intersection of technological, methodological, and pedagogical competencies consistently responds to their professional needs with the TPACK theoretical framework. In the next phase of the project, we will further study how the intersection of knowledge and experience derived from multiple actors could give rise to the identification of shared innovative methodologies and technologies to design and use mathematical digital serious games.

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