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► **To cite this version:**

Maria Meletiou-Mavrotheris, Efi Paparistodemou, Loucas Tsouccas. A Case Study of Teacher Professional Development on Game-Enhanced Statistics Learning in the Early Years of Schooling. Eleventh Congress of the European Society for Research in Mathematics Education (CERME11), Utrecht University, Feb 2019, Utrecht, Netherlands. hal-02412815

HAL Id: hal-02412815

<https://hal.science/hal-02412815>

Submitted on 15 Dec 2019

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A Case Study of Teacher Professional Development on Game-Enhanced Statistics Learning in the Early Years of Schooling

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The research comes from a multifaceted program designed to provide in-service lower primary school teachers (Grades 1-3; ages 6-9) with the knowledge, skills, confidence, and practical experience required to effectively integrate digital games within the early mathematics curriculum. The article focuses on one of the teachers, employing a single case study approach to document the level of transfer and adoption of the acquired knowledge and skills into actual teaching practice. Findings provide some useful insights into the ways in which the program experiences influenced the teacher's competence in selecting, evaluating, and productively utilizing digital games to enhance learning of key statistical concepts included in the mathematics curriculum.

Keywords: Educational games, professional development, TPACK, early statistics education

Introduction

The expanding use of data for prediction and decision-making in almost all domains of life makes it a priority for mathematics instruction to help students of all ages develop their statistical reasoning. It is now widely recognized that the foundations for statistical reasoning should be laid in the earliest years of schooling rather than being reserved for secondary school or university studies. Consequently, the development of students' statistical literacy has become an important goal of mathematics education at the early school level internationally. This broadening of the mathematics curriculum to encompass statistical literacy, reasoning, and thinking has put considerable demands on teachers (Hannigan, Gill, & Leavy, 2013). In particular, it has been challenging for teachers to design lessons with engaging contexts and a focus on conceptual aspects of statistics, and to pose critical questions. As the research literature indicates, many teachers tend focus instruction on the procedural aspects of statistics rather than on conceptual understanding (Watson, 2001).

Recognizing the need for fundamental changes to the instructional practices employed in the mathematics classroom to teach statistical concepts, researchers have in recent years been experimenting with new models of teaching that are focused on inquiry-based, technology-enhanced instruction and on statistical problem-solving (e.g., Meletiou-Mavrotheris, & Paparistodemou, 2015). One promising approach lately explored is the potential for digital games to transform statistics instruction. Unlike the numerous studies investigating the instructional use of computer simulations, animations, and dynamic software, there only few published studies on the use of games for teaching statistics, the general thrust of the evidence in the existing literature is positive (Boyle, MacArthur, Connolly, Hainey, Manea, Kärki, & van Rosmalen, 2014). Findings concur with the general educational literature on game-enhanced learning which suggests that when suitably designed, digital educational games have many potential benefits for teaching and learning at all levels, including pre-school and early school years (Manassis, 2014). Most of the conducted

studies report that employing games has a positive effect on students' motivation and learning of statistical concepts (e.g. Gresalfi and Barab, 2011; Boyle et al., 2014). Digital games' greatest strength as a medium, involve their affordances for supporting higher order cognitive, intrapersonal, and interpersonal learning objectives (Clark, Tanner-Smith & Killingsworth 2014). Using games, children can individually or collaboratively engage in exploration of virtual worlds, and in authentic problem solving activities. This supports the development of important competencies essential in modern society such as logical and strategic thinking, planning, multi-tasking, self-monitoring, communication, negotiation, group decision-making, pattern recognition, accuracy, speed of calculation, and data-handling. At the same time, games can promote differentiation of instruction by matching challenges to children's skill level, and by providing immediate feedback to students about the correctness of their strategies and thought processes.

While digital educational games provide a range of potential benefits for mathematics and statistics teaching and learning, not all the games are designed to promote optimal development among children. Most of the available educational games tend to be a drill-and practice and to support mainly procedural fluency rather than high-level thinking. Some exceptional exemplars do exist that can help create constructive, and meaningful learning experiences, but their successful deployment in the early statistic classroom is highly dependent upon the knowledge, attitudes, and experiences of teachers. Implementing game-based instruction can be a challenge for teachers, requiring skills not necessarily addressed in current teacher training practices. Teachers need to be proactive, choosing high quality educational games, supporting and scaffolding pupils, and providing appropriate feedback

Acknowledging the educational potential of games for transforming statistics instruction in the early years, but also the crucial role of teachers in any effort to bring about change and innovation, the current study focused on providing in-service teacher education on the effective utilization of digital games in the lower primary classroom (ages 6-9). An exploratory case study took place within a Cypriot teacher professional development program on the integration of games within the early mathematics curriculum developed based on the notion of Technological Pedagogical Content Knowledge (TPACK) as a conceptual framework (Mishra and Koehler, 2006). It focused on one of the program participants and investigated the development of his TPACK of game-enhanced teaching and learning of statistical concepts included in the early primary mathematics curriculum

Methodology

Program Structure, Context and Participants

The professional development program was attended by six lower primary school level educators (Grades 1-3; ages 6-9), and it was designed to provide them with the knowledge, skills, confidence, and practical experience required to effectively exploit digital games as a tool for fostering young children's motivation and learning of mathematics. Following the TPACK model and action research procedures, the program was designed and carried out in three phases:

- *Phase I – Familiarization with Game-Based Learning:* In Phase I (6 hours duration), teachers were offered a critical introduction into the potential and challenges of using serious games in early mathematics and statistics instruction. They experienced some of the ways in which

purposefully selected games, blended with carefully constructed learning experiences, could help improve children's attitudes towards the subjects, while at the same time advancing their mathematical and statistical thinking and problem solving skills. The unit also familiarized participants with the design principles for constructivist gaming environments (Munoz-Rosario & Widmeyer, 2009), and promoted the development of their skills in properly evaluating and selecting games with pedagogically sound design features.

- *Phase II – Lesson Planning:* In Phase II, teachers' TPACK was enhanced through their engagement in lesson planning. They selected a topic from the national mathematics curriculum for Grades 1-3, and developed a lesson plan and accompanying teaching material aligned with the learning objectives specified in the curriculum, which incorporated the use of digital games. They were instructed to integrate into their lessons educational games that adhered to important principles associated with well-designed educational games (Gee, 2007) such as facilitation of an authentic learning experience, active participation, collaboration, and promotion of higher order thinking skills. The lesson plans were shared with the researchers for comments and suggestions, and were revised based upon received feedback.
- *Phase III – Lesson Implementation and Reflection:* Next, the participants implemented the lesson plans in their classroom, with the support of the research team. Once the classroom research was completed, teachers prepared and submitted a reflection paper, where they shared their observations on students' reactions during the lesson, noting what went well and what difficulties they faced and making suggestions for improvement.

Detailed information regarding the implementation of the different Phases of the program and their impact on the whole group of participating teachers can be found in Meletiou-Mavrotheris, Paparistodemou, & Tsouccas (2018). In this article, we focus on Phase III of the program. We draw upon the data collected from the case study teacher and his students to investigate the level of transfer and adoption of TPACK competencies acquired through the training to actual teaching practice. This teacher, who was an expert educator (9 years of teaching experience), was the sole program participant whose teaching intervention focused on concepts related to statistical data analysis. The rest prepared and implemented lesson plans focusing on other areas of the mathematics curriculum.

Research Design: Scope and Context of Study

The teaching intervention took place in a Grade 2 classroom with 18 students, and lasted for 80 minutes (two teaching periods). The class teacher selected a topic from the national mathematics curriculum for Grades 1-3, and developed a lesson plan and accompanying teaching material aligned with the learning objectives specified in the curriculum, which incorporated the use of mobile game apps. The lesson plan targeted the following indicators of achievement included in the curriculum for Grade 2: (i) Collect information and data in the environment and present them in an organized way; (ii) Record, organize and present data in tables and graphical representations (pictogram, bar graph, pie chart); (iii) Represent the same data in multiple ways.

The lesson plan was shared with the researchers for comments and suggestions, and was revised based upon received feedback. Next, the teacher implemented the lesson plan in his classroom, with

the support of the research team, and afterwards prepared a reflection paper where he shared his observations on students' reactions during the teaching intervention, noting what went well and what difficulties he faced and making suggestions for improvement.

Central to the teaching intervention was the game app The Electric Company Prankster Planet, available on Android and iOS platforms as well as online. Prankster Planet is based on the Emmy Award-winning PBS KIDS TV series The Electric Company, and it targets children aged 6-10. It features eight unique quests with math curriculum woven throughout that children have to complete to save Earth from the Reverse-a-ball machines of Prankster character Francine, that are scrambling up all the words on Earth and are causing a lot of confusion. Children complete a series of data collection, representation and analysis challenges in order to shut down all eight machines hidden in the jungles, cities, junkyards, and underground world of Prankster Planet. The app features side-scrolling play and exploration in a 2D platformer world, an avatar creator with many customization options, a rewards system to encourage repeat play, and the option of collaborative play through group activities. The online gaming platform Kahoot! was also used during the lesson.

Data collection and analysis procedures

Although multiple forms of data were collected to document changes in teachers' perceptions and attitudes, and in their TPACK of game-enhanced learning as a result of participating in the teacher professional program, only data collected during Phase III in the case study teacher's class was utilized in this study. Researchers were present in the class, observing closely and videotaping the lesson, keeping field notes, and collecting student work samples. Qualitative data were also obtained from the reflection papers written by the teacher at the end of the lesson.

For the purpose of analysis, we did not use an analytical framework with predetermined categories to assess how the teacher's acquired TPACK impacted his teaching practice, due to the lack of well-established frameworks and methodological insights for studying game-enhanced statistics education in the context of in-service teacher training. What we did instead was to identify, through careful reviewing of the transcripts, reflection paper, and other data collected during the study, recurring themes or patterns in the data. To increase the reliability of the findings, the activities were analyzed and categorized by all three researchers. Inter-rater discrepancies were resolved through discussion.

Results

Teaching intervention overview

The lesson started with the teacher informing the class that the headmistress needed information about students' preferences on afternoon activities, to plan for the next school year. Therefore, she would like each class to collect data on their preferences, organize them, and present them in way that would help her come up with a schedule of activities that would satisfy as many children as possible.

To tackle the task, the class first decided to do a census where each student selected their favorite afternoon activity among five options. Then, they recorded their preferences on a tally table, and counted the total number of students selecting each activity. This was followed by class discussion

on how to best present the survey results to the headmistress. During this discussion, children were introduced to bar graphs, the process of their construction, and the ways in which this graphical representation can help to present and interpret the results of a survey, and make decisions.

Next, children played in pairs the digital game Prankster Planet on their iPads. They were asked to go through all eight increasingly difficult missions of the game. Within each mission, they responded to various questions where they had to interpret a bar chart or a pie-chart, or to construct such graphs, in order to collect as many points as possible (see Figure 1). Throughout the activity, the teacher went around the class and offered personalized assistance to each pair of students. Although children were fully engaged with the game and quickly learned its mechanics (possibly due to their high degree of familiarity with digital games as the vast majority owned a tablet at home), they needed some help from their teacher in understanding the posed questions, which were in English.

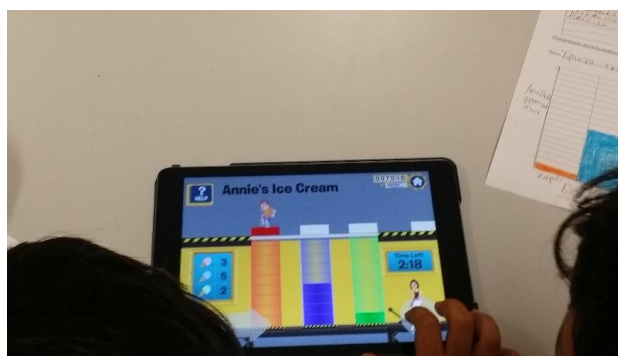


Figure 1: A pair of students interpreting a bar graph in Prankster Planet

Finally, children completed an exercise adopted from their mathematics textbook. They were presented with a table showing the number of hours of sleep per day of 12 different mammals. First, they worked in pairs to complete a task in Kahoot! where they responded to various questions related to the information included in the table. The task was set up as a contest, where each correct answer gave different points to the pair, depending on their response time. For each question, the right answer appeared on the whiteboard, as well as a bar chart showing the children that answered it correctly, and the score of each pair. After completing the task, the children worked individually to construct a “bar graph” of the data in their notebook (a simple histogram in reality), with each bar corresponding to an interval of hours of sleep (i.e. animals sleeping between 0-5 hours, between 6-10 hours, etc.). Finally, through a second contest, they were again given the opportunity to collect points and to win by interpreting the graph they had just built, and answering various questions (e.g. *How many animals sleep more than 5 hours and less than 16 hours per day?*).

At the end of the lesson, a discussion took place, where the teacher highlighted the main statistical concepts introduced during the lesson. Children were encouraged to express their opinion about the format of the lesson and whether they would like to again use similar digital games in class.

Reflection on the teaching intervention

The case study teacher's past exposure to mathematics education games was limited to drill-and-practice, which he tended to use in class for motivational purposes, and/or for students to practice already acquired skills. However, his participation in the program helped him realize digital games' true potential for supporting learning in educationally powerful ways. Through familiarization with the design principles for constructivist gaming environments and experimentation with a range of game apps, he gained better understanding of how to implement game-based mathematics and statistics instruction in the early years. He also improved his ability to assess the educative power of different games, to properly identify their advantages and disadvantages.

Observation of the teaching intervention, and the quality of the lesson plan and tasks prepared by the teacher, indicated that the specific educator acquired the necessary skills and competencies for teaching this topic and similar statistical topics using tablets and game apps like Prankster Planet and Kahoot! He selected appropriate game apps and then exploited them to organize teaching in a constructive, learner-centered way, so that his young students would have the opportunity to work together in constructing statistical concepts and processes. Specifically, in several activities, children collaborated to build joint understanding of the new concepts they had just encountered. For example, to respond to some of the Prankster Planet questions, students worked together to understand and interpret pie-charts, which had never been mentioned in class before.

As expected, the game-based nature of the lesson was well received by students and increased their morale and motivation. In the end of intervention discussion, children expressed their enthusiasm about the games they engaged with during the lesson, *"because they gave [them] the chance to play and learn at the same time"*. Although expressing a preference for *"the game where [they] had to prevent the Lady from changing the letters"* (i.e. Prankster Planet) which they found to be *"more adventurous"*, they also liked the game on Kahoot! because it was set up as a contest. The children stressed that they would love all their lessons to have a similar format since games enable them *"to learn more things about mathematics and to have a joyful time in class"*.

In the reflection paper he wrote after the teaching intervention's completion, the teacher also noted that he was very impressed by the fact that the lesson ended up being so successful:

Teacher: The children got excited with the games, were constantly active, there was rivalry between the teams, but also collaboration within each team, and this had a positive impact on children's motivation, but also on the attainment of the instructional objectives. Even the supposedly "weakest" students had strong interest and active participation during the lesson and gave several thoughtful answers, with no trace of fear of making a mistake. These are qualities I do not usually experience in lessons where I do not use digital games.

According to the teacher, the use of the games led to an effortless involvement of all children, and contributed substantially to the achievement of the learning objectives, but also to ensuring fruitful cooperation among learners and collaborative construction of knowledge in a creative and enjoyable way. Lastly, use of technology worked exactly as he had anticipated, providing the opportunity to introduce in the classroom activities with added value, that could not otherwise be implemented.

While the classroom experimentation further strengthened the teacher's belief that appropriate use of game apps can help create motivational and more conducive to learning environments, it also helped him to build more realistic expectations about what games' instructional integration might entail in practice. He recognized that games are not a panacea, and that their incorporation into the curriculum does not guarantee improved learning. He mentioned various challenges and drawbacks to digital games' incorporation in the mathematics classroom, including time constraints, difficulties in locating high-level games, the risk of the learning objectives being neglected for the sake of playfulness, and language issues for non-native English speakers:

Teacher: The fact that Prankster Planet is in English, prohibited its optimal use. While students played, I had to constantly move around to translate things to them.

The teacher stressed the key role of educators not only in choosing appropriate digital games with the goals of gameplay being closely aligned with instructional objectives, but also in "*coordinating classroom activities appropriately so as to keep children focused on the achievement of the learning objectives*", and in facilitating learning by providing continued support and scaffolding. He pointed out that games should not dominate class time, but should be used as part of carefully planned learning experiences, and explained how, in his teaching experimentation, the use of alternative pre-game and post-game instructional activities led to a fuller learning experience. His comments concur with the literature, which indicates that digital games are more effective when acting as adjuncts to more traditional teaching methods rather than as stand-alone applications (Gee, 2007).

Discussion

This case study has several limitations, emerging primarily from its exploratory nature, which constrain the interpretation of the research results. A serious drawback is the limited generalizability of the research findings. The qualitative methodology used to research the case, the small scale of the study, and its limited geographical nature, means that generalizations to cases that are not very similar should be done cautiously as the specific classroom investigated might not be representative of all pre-service teacher classrooms. Despite, however, the tentative and non-generalizable nature of its findings, the conducted research contributes some useful insights into the accumulating body of literature on game-enhanced statistics teaching and learning.

In accord with the research literature (e.g. Niess et al., 2009), our research has illustrated the usefulness of the TPACK framework as a means of both studying and facilitating teachers' professional growth. Although there was no pre-post test assessment to formally track changes teachers' TPACK, there are strong indications in the collected data that the training was quite successful in helping the case study teacher (as well as the other program participants) move beyond his restricted views of digital games as educational tools (for more details see Meletiou-Mavrotheris et al., 2018). Secondly, that it helped to convey to him technological and pedagogical knowledge regarding the teaching of specific mathematical and statistical concepts with games. Thirdly, that it improved the teacher's confidence and ability to transfer and adopt the TPACK competencies acquired through their training to actual teaching practice.

There are important implications for the design or revamping of pre-service or in-service teacher training curricula and programs on digital game integration. Insights from the study suggest that

utilizing a conceptually based theoretical framework about the relationship between technology and teaching like TPACK, can enrich teachers' professional development. Findings also indicate that the development of teachers' TPACK necessitates the provision of opportunities for both theoretical and experiential learning of technology-based pedagogical approaches to mathematics education. Concurring with prior research (e.g. Serradó, Meletiou-Mavrotheris, & Paparistodemou, 2014), this study provides evidence that teachers' involvement in professional development activities such as lesson design and classroom experimentation, can support them in developing their teaching competencies with ICT and understanding of TPACK in ways transferable into their own practice.

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