On Line and Other Game-Based Learning for Mathematics

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***Abstract*—The last decade, researchers and educators have shown particular interest for the use of educational video games in mathematics education, in an effort to provide educational character to entertainment. In this paper we represent some of the most representative studies which evaluate the effects of video games on mathematics achievement as well as the improvement of memory, attention and cognitive skills. As indicated by the studies, video games may constitute useful tools in mathematics education as they support children's comprehension on fundamental concepts, but also motivate them to see positively the course of mathematics.**

***Index Terms*—Game based learning, educational video games, mathematics, cognitive skills, online math games.**

I. INTRODUCTION

Recent research on mathematics education shows that students face difficulty in understanding mathematical concepts and to develop logical thinking and strategy to deal with math problems. It is required from teachers to implement teaching which will result in the development of critical mathematical thinking by students, rather than a sterile assimilation of mathematical formulas. In an attempt to analyze what makes it difficult to learn mathematical concepts and skills, we consider straightly involved attention problems, cognitive-processing problems, auditory problems, memory problems and metacognitive deficits [14].

Students develop rapidly and differentiate their habits by far from the previous. From kindergarten now they use computers, cell phones, digital music players and of course video games. Video games constitute useful tools, as children learn from an early age how to follow specific strategies to achieve their object. Furthermore the frequent engagement with video games contribute to the improvement of visual attention as the user is concerned with different things at the same time [17]. Considerations that video games grow antisocial and obese children are increasingly discarded. Instead video games seem to contribute to socialization through collaborative playing. Players learn to think critically and solve problems through trial and error [3]. At the same time, video games give the users the opportunity for experiential learning as within the acts and experiences gained, they broaden their knowledge and they get familiar with new environments and situations.

Therefore educators nowadays should be consistent with the children's interest and integrate into the education system modern teaching methods which motivate students more than ordinary classroom instruction [30]. Video games are also convenient in enhancing students' motivation and learning progress, as they enrich their experiences [24].

The last decade researchers show increasing interest towards using video games in mathematics education, as well as development of new educational math video games. Although, designing an educational game is a complex issue, as requires the combination of entertainment and education. Most educational video games fail to be amusing and attractive to children [39].

In this paper we analyze the effects of playing video games in students' mathematics achievement, their auxiliary role in the teaching of mathematics in the classroom, as well as their impact in the improvement of students' visual attention, working memory and cognitive skills, representing some of the most representative articles published during the last decade. Here are presented online video games, computer-based video games and video games which are available on handheld game consoles or mobile devices.

Video-game-based learning has positive effect on students' mathematical skills? Can video games improve students' cognitive and mental skills? Can educational games enhance students' attitudes towards mathematics course? Answering these questions would contribute to the integration of video games in teaching mathematics inside or outside the classroom as well as motivate researchers for further development of educational math games.

II. VIDEO GAMES CAN CHANGE THE BRAIN

A. Memory, Attention and Executive Control.

Working memory and long-term memory both could be affected by the use of video games. As long-term memory is meant the ability to store information for long time, while working memory is the ability to store temporary information for current management [35].

Children with mathematical disabilities are usually linked to poor working memory. Working memory seems to be directly related to students' mathematics achievement, as well as its two subsystems, the phonological loop and the visuospatial sketchpad which are used for passive information storage [11]. Furthermore students who have trouble in maintaining their attention for a sufficient period of time, face difficulties in mathematics as they find it hard to follow concrete steps and easily fall into errors.

Boot et al examined the effects of video game playing, on attention, memory and executive control. Twenty one pupils, eleven expert video game players, in games such as *Halo*, *Grand Theft Auto* and *Unreal Tournament*, and ten non-video-game players participated in their study.

The researchers used visual and attentional tasks, short memory tasks and executive control and reasoning tasks to find out whether there are differences between people who play video games frequently and those who don't. The results showed that video game experts outbalanced non-video-gamers in most tasks. Video game training seems to be a promising way for entertaining perceptual, attentional and cognitive abilities improvement [5].

Dye, Green and Bavelier in 2009 suggested that action video games could develop attention skills. A total of 131 students participated in their study, 56 video games players and 75 non-video games players. All participants were asked to take the Attentional Network Test (ANT) in order to measure their attention skills. Analysis of the tests showed that playing action video games speeded processing of visual information and improved attention skills of the players. Furthermore, there was no significant difference between gamers and non-gamers on how they use a valid spatial cue to allocate their attention [15].

B. Cognitive Skills.

In 2013 Adam Oei and Michael Patterson examined how video games can enhance students' cognition. In their study participated 75 undergraduates from Nanyang Technological University in Singapore. Participants used their iPhone or iPod Touch to download one of the proposed training games: three non-action video games (*Hidden-object game*, *Memory Matrix 1.0*, *Match-3*and *The Sims 3*) and one action video game (*Modern Combat: Sandstorm*). The intervention lasted four weeks in which participants played the games one hour pre day for 5 days a week. All students were asked to complete four computerized cognitive tasks before and after the intervention. The results showed that playing non-action games enhanced students' cognitive performance just as action game-playing [25].

C. Mental Rotation Skills.

Isabelle Cherney (2008) investigated how 3D and 2D computer game practice can improve mental rotation skills. Sixty one colleagues from a US Midwestern private university participated in her study. The participants trained on *3D Antz racing*, a racing computer game and *2D Tetrus*, a computer version of the puzzle type game Tetris. 2D Card Rotation Test (CRT) and 3D VMRT were used as pre and post tests for data collection. The results of the study confirmed that a very short practice in computer game play does improve performance on mental rotation measures as well as there is a negative relationship between anxiety levels and performance on the mental rotation tests [8].

III. ONLINE VIDEO GAMES

A. Educational Math Games.

In 2007 Fengfeng Ke and Barbara Grabowski examined the effects of gameplaying on 5th grade students' math performance and attitudes. One hundred twenty five students from six public schools in Pensylvania practiced in this study. Astra Eagle, a range of web-based computer math games was used. The participants were randomly divided into three experimental groups: 1.Teams-Games-Tournament (TGT) cooperative group, 2.Competitive gameplaying group and 3.no-gaming group. The students practiced in these groups for four weeks and took a multiple-choice Game Skills Arithmetic Test (GSAT) as post-test in order to measure their math skills, including addition, subtraction, quantities' comparison and points' locating. According to the analysis' results, students who practiced in gaming groups benefited more than those in no-gaming group, as well as cooperative groups'participants achieved greater math performance than the others [19,20].

Harris' study in 2008 investigated how playing video games could affect student collaboration on complex logic problems. During the intervention 34 primary school students divided into pairs played The logical journey of Zoombinis a problem solving computer game. Researchers remarked that collaboration while playing the educational computer game may have positive consequences on mastery and performance goals of the children [18].

Bakker et al (2015) investigated the effects of playing mathematics computer games on primary school students' multiplicative reasoning ability. 719 students (Grade 2 and Grade e) from 66 schools participated in a 10 week intervention program. They used adaptive versions of multiplicative mini games from a Dutch mathematics games website Rekenweb. Three dependent measures were used to assess the students' learning of multiplicative reasoning (the knowledge test, the skills test and the insight test) as well as a general mathematics ability test. Their findings revealed that mini games could improve students' procedural and conceptual knowledge [4].

B. Adventure Games.

Rodrigo's study in 2010 evaluated the cognitive affective states of 164 7th grade Philipino students (average age 12,8 years) as they used a pre-algebra video game. Participants were asked to play Math Blaster 9-12, an online adventure game. According to the game's concept, a galactic commander is stranded on a planet of monkeys. In order to escape the player has to join in pre-algebra games, which require additions, subtractions, multiplications or divisions of whole numbers or decimals. Eight master's students in education or computer science conducted the observation team. Observers recorded the students' cognitive-affective state, including boredom, confusion, delight, engagement, frustration, surprise and neutral state. Consistent with the observations recorded, the game, as many other educational games, failed to prevent boredom, as most of the participants found it very simple. Researchers suggested that educational games should be more competitive in the future [31].

Valente and Marchetti (2012) presented a prototype of Prime Slaughter, a 2D action adventure game for playful math learning, targeted to primary and early secondary school children. The player can explore the six levels of the game through various doors. The goal of the game is to kill as many number-monsters as possible, in order to collect points by answering mathematical questions. If the answer is wrong, the character loses energy. The game provides a framework to learn mathematical concepts and operations like division, multiplication, factorization and primality [37,38].

C. Simulation Games.

In 2010 Irene Polycarpou et al developed *Math-City*, a simulation-based educational game, which could improve K-12 students' achievement in mathematics. The game provides a city simulation environment where users have to earn money to build roads, houses, hospitals, police

departments and fire stations, as in real life. The player begins with a small amount of money and can earn more by answering mathematics questions, which include fractions' addition and subtraction, multiplication and division, and problem solving. Ten mathematics teachers tested the game and answered a questionnaire in a pilot study. The feedback from the teachers was encouraging and motivated researchers for further improvement of the educational game in the future [29]. *Collaborative Math City*, which uses a networked collaborative environment, extends the *Math City* and allows students' to work together and communicate via text, voice or video [36].

One year later Pareto et al presented a teachable-agent arithmetic game and evaluated the game's effects on students' performance in mathematics, attitude and self efficacy. This educational game was designed to train basic arithmetic skills through an animated simulation environment. Players had to act arithmetic operations, packing and unpacking animated squares. In the study got involved five 3rd grade and four 5th grade classes from different schools of Sweden with a total of 153 students. Each one of the participants who played the arithmetic game for 9 weeks, 40 minutes per week, completed pre and post tests that included arithmetic problems, questions on students' attitudes towards mathematics and questions addressing math self efficacy. The results, confirming the research hypotheses, showed that the game improved students' conceptual arithmetic understanding and enhanced students' confidence, however playing the game did not improve students' attitudes towards mathematics [27].

IV. MOBILE VIDEO GAMES

Shin et al (2006) developed a four month period study during the spring semester of 2005, to investigate the effects of handheld gaming on student learning in mathematics. In the study participated 50 2nd grade students from an elementary school in Midwest. The material used was Skills Arena, an educational GameBoy game program, designed to teach students about basic arithmetic skills. The game was structured in six speed levels, from easy to difficult, using cartoon characters. Users could receive immediate feedback for their answers. Researchers placed participants in three groups. 1.Handheld Game Group, consisted of 20 students, who trained on Skills Arena software program for 15 minutes, five days per week, for 13 weeks. 2.Card Game Group, consisted of 21 students who used flash fact cards, which are triangle shapes with one number in each angle, for 5 weeks, and the remaining weeks they practiced using Skills Arena. 3.Delayed Handheld Group, consisted of 9 students, trained on Skills Arena for the last 8 weeks of the project. The results of the study revealed that the handheld game activity in the classroom could improve arithmetic skills, especially on low ability students [34].

Rosas et al (2003) presented a study whose main goal was to evaluate the effects of the educational video games into the classroom, on basic mathematics and reading comprehension. The software contained five programs (Magalu, Hermes, Tiki-Tiki, Roli and Hangman), running on Nintento's Gameboy. In this study participated 1274 students, attending 1st and 2nd grade and 30 teachers, of 6 schools in Santiago de Chile. Students were divided and placed in three groups: Experimental group, with 758 students in 19 classes, who played video games 20-40 minutes daily, Internal Control group, with 347 participants in 9 classes in the same schools as the experimental group, and External Control group with 169 students in different schools. According to the researchers and teachers, the use of video games in classroom, motivated the students' attendance and punctuality, and increased their concentration and attention [32].

Diah, Ehsan and Ismail proposed an alternative mobile educational game. They designed MathRush a constructivism-based game which could be used to support primary school mathematics; learning outside the classroom. The game includes all the necessary features that should have a video game in order to stimulate children's interest, such as goals, rules, competition, challenge, fantasy and entertainment. Users have to respond as soon as possible a series of questions based on basic mathematical operations, like addition, subtraction, division and multiplication. This video game has been developed to provide an unexpected learning experience and could be a useful auxiliary educational tool in mathematics learning [13].

In their study (2009) Main and O'Rourke compared the use of handheld game consoles with traditional methods of teaching in development of mental math skills. Fifty nine students from 2 schools in the Perth metropolitan area in Australia, participated in the study, placed in 2 groups. Students in the experimental group trained with Dr Kawashima's Brain Training game on Nintendo DS while students in the control group maintained their usual program in mental mathematics. The One Minute Test of Basic Number Facts, developed by Westwood in 1987, was used to measure students' numeracy skills before and after the 10 week intervention. In addition to the control group, students of the HGC group showed significant improvement on their math performance and self-concept [23].

V. COMPUTER VIDEO GAMES

A. Teachers' perspectives about computer game-based learning in mathematics

In 2010 Muhammet Demirbilek and Susan Lema Tamer conducted a qualitative research in order to investigate math teachers' perspectives on using educational computer games in math education. Semi-structured interviews were used to collect data from thirteen math teachers in Turkey. Teachers expressed their concern about the risk of losing the class control, caused by computer game playing in lessons. While some teachers believed that educational math games could be a useful tool in math teaching, other teachers claimed that using games in math teaching is not appropriate. In addition, teachers agreed that there is need of appropriate hardware infrastructure in the schools in order to include computer games into the educational process. Most of the teachers maintained that computer math games could improve ustudents' creativity as well as their comprehension of math concepts [12].

B. Students' attitudes towards computer game-based learning in mathematics

Serkan Cankaya and Aysen Karamete (2009) investigated the differences of attitudes of 176 7th grade primary school students from Balikesir, Turkey, towards mathematics course and educational computer games. Participants played two educational computer math games, *Proportional Tetris* and *Proportional Clown,* developed from the researchers for the survey. The results of the survey

revealed that students who had positive attitudes towards mathematics course, had also positive attitudes towards educational computer games [6].

In the same year, Serkan Costu, Serhat Aydin and Mehmet Filiz revealed the students' views about browser-game-based learning in mathematics education. For this purpose sixteen 6th to 8th grade students in a primary school in Trabzon interviewed on their conceptions about the educational game TTNetVitamin. Students expressed that the game motivated their interest about the course of mathematics which sometimes was really boring and helped them understand the subjects. In contrast some students found the game useless and claimed that other games like chess would bring better results [10].

In 2012 Afari et al investigated whether the use of mathematics games into college-level mathematics classes in the United Arab Emirates could improve students' attitudes towards of mathematics as well as their academic efficacy. In their study participated 352 students from three Arab colleges. Students were given questionnaires, designed by researchers to measure students' perceptions on the learning environment, after a six-week period game-based learning interaction. Participants enjoyed their mathematics lessons during the experiment and felt confidence in their academic competence [1].

C. Simulation Games

Sampson and Panoutsopoulos (2012) utilized digital game-based learning for the achievement of standard curriculum Mathematics educational objectives. The game used in this study was *Sims 2-Open for Business*, a commercial business simulation game, in which users operate within the labor market, as managers of their own business. Players learn this way to operate in difficult situations and develop specific strategies for problem-solving. The subject matter educational objectives in the study referred to linear functions. Participants admitted that the use of the game had positive effect on understanding real-world situations. Although, students who trained on digital game educational activities achieved no different results on math performance with those who did not [33].

D. Role-Playing Games.

Ahmad, Shafie and Latif (2010) developed *Math Quest,* role playing game for learning mathematics. Math Quest is an interactive computer game based on the mathematics curriculum for the primary schools in Malaysia. The player has to protect his civilization from the enemy's attacks by answering random mathematics questions. Six teachers were given a demo during a heuristic evaluation of the game and subsequently they answered a questionnaire in order to identify any usability problems. As the teachers' feedback was supportive, the next target for the researchers is to extend the game to multi players [2].

One year later, Chen et al developed and presented *My Pet My Quest*, a game-based learning system for mathematics learning support. The system, which was designed for elementary students, allows math learning into a pet-nurturing game, including conceptual understanding, computational fluency and problem solving activities. In *My Pet My Quest*, children have to take care of their pets, satisfy their needs and provide them a happy life. Fifty three 4th grade elementary school students participated in an experimental study, with a view to evaluate the effects of the game on students' subject learning in terms of perception of enjoyment and goal-pursuing. The results showed that the game had positive consequence on elementary students, as it connects directly game goals with learning goals [7].

In 2013 Michail Giannakos proposed Gem-Game, a game designed to improve mathematical skills of players. The mission of the main character of the game, Peter is to find his dog who has been kidnapped. Peter has to collect diamonds through different trials to pay the kidnapper. Giannakos conducted a study in order to investigate the differences in learning performance among game-based learning and traditional instruction. Twenty middle school students (13 years old) constituted the game group, while twenty one students the traditional instruction group. All participants followed the same course syllabus and had similar performance in mathematics. For four weeks students practiced on educational games which had the same technology as Gem-Game and on traditional instruction respectively. After that all participants were given a test to measure their performance. According to the research findings, students who trained in the game group performed equally well with the students who trained on an interactive way of learning [16].

E. Strategy Games

In 2008 Kebritchi, Hirumi and Bai evaluated the effects of math computer games on students' math achievement and motivation in a public high school in the southeast United States. In the study participated 981 Algebra and pre-Algebra math students divided into experimental control groups and 10 math teachers. The treatment included 2 single player math video games, *Evolver* and *Dimenxian*, and a set of 3 multiplayer strategy math video games, *Swarm*, *Obstracle Course* and *Meltdown.* Students in the experimental groups scored remarkably higher on the math performance post-test than those in the control group. According to the teachers' and students' interviews, math video games had positive effect on students; motivation in the classroom. Finally the results revealed that playing math video games could be more essential on students' cognitive gains than traditional classroom interaction [21].

Tsung-Yen Chuang and Wei-Tan chen in 2009 investigated the effect of computer–based video games on children's cognitive processes in Tainan city, Taiwan. One hundred and eight 3rd grade students, divided in two groups, practiced on a computer-assisted instruction and *Fire Captain,* a 3D strategy game. Subsequently, all participants were asked to take a quiz in order to access their learning achievements. According to the findings, computer-based video game playing can improve children's fact recall processes as well as promote problem solving skills by recognizing multiple solutions [9].

F. Educational Games.

In 2013 Chun-Hung Lin proposed a game-based learning interaction for 6th grade students. They used a digital version of the popular game *Monopoly* and instructional videos as remedial teaching tools. In this educational game, each location on the gameplay map corresponds to a question category, including multiple choice and open-ended items. The learning content of *Monopoly* game in this study was the area of circle (area, sectors, central angles, etc.). Each time player answers incorrectly, an instructional video about the corresponding topic is acti-

vated. The use of the game and the instructional videos both had positive effect on the enhancement of mastery learning and mathematics performance [22].

Plass and O'Keefe (2013) investigated the impacts of an educational mathematics video game on middle school students' learning, performance and motivation. *Factor Reactor* is a PC game, designed to train arithmetic skills. Player has to collect as many rings as possible, solving problems based on simple arithmetic operations. Fifty eight 6th, 7th and 8th grade students were randomly assigned to individual, competitive and collaborative group. As the results revealed, competition and collaboration generated students' interest more than in the individual group and motivated them to rich high score. Players' math fluency scores had improved overall from pre to post tests, although it is possible that participants improved their game-playing skills rather than their arithmetic skills [28].

Panagiotakopoulos' conceptual mini game (2010) was designed to improve students' skills in simple mathematical operations. *Playing with numbers* (PwN) is an educational computer game for mathematics. Thirty three 5th grade primary schools students played the game for a total of one hour and gave feedback through a questionnaire. The educational content of the game includes additions with integers or decimals and multiplication of integers. The game is attractive to use, as it creates competition among the children to achieve a high score. The study's findings showed that the educational game promotes fast calculation and provides motivation to the children for learning maths [26].

VI. CONCLUSIONS

The purpose of this study was to examine the most representative studies over the last decade, which investigated the contribution of video games or educational video games in mathematics education. Video game-based learning seems to have positive effect on students' mathematical skills, as well on students' cognitive and mental skills. At the same time, educational math video games could motivate students' towards the course of mathematics. As revealed by surveys, video games could constitute useful auxiliary learning tools, in order to build an innovative teaching model. However, further investigation is required on the educational content that video games afford, as well as the feasibility on their utilization in the classroom.

REFERENCES

[1] Afari, E., Aldridge, J. M., Fraser, B. J., & Khine, M. S. (2013). Students' perceptions of the learning environment and attitudes in game-based mathematics classrooms. Learning Environments Research, 16(1), http://dx.doi.org/131-150. 10.1007/s10984-012-9122-6

[2] Ahmad, W. F., Shafie, A. B., & Latif, M. H. (2010). Role-playing game-based learning in mathematics. The Electronic Journal of Mathematics and Technology, 4(2), 185-196.

[3] Annetta, L. A. (2008). Video games in education: Why they should be used and how they are being used. Theory Into Practice, 47(3), 229-239. http://dx.doi.org/10.1080/00405840802153940

[4] Bakker, M., van den Heuvel-Panhuizen, M., & Robitzsch, A. (2015). Effects of playing mathematics computer games on primary school students' multiplicative reasoning ability. Contemporary Educational Psychology, 40, 55-71. http://dx.doi.org/10.1016/j.cedpsych.2014.09.001

[5] Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. Acta psychologica, 129(3), 387-398. http://dx.doi.org/10.1016/j.actpsy.2008.09.005

[6] Çankaya, S., & Karamete, A. (2009). The effects of educational computer games on students' attitudes towards mathematics course and educational computer games. Procedia-Social and Behavioral Sciences, 1(1), 145-149. http://dx.doi.org/10.1016/j.sbspro.2009.01.027

[7] Chen, Z. H., Liao, C. C., Cheng, H. N., Yeh, C. Y., & Chan, T. W. (2012). Influence of Game Quests on Pupils' Enjoyment and Goal-pursuing in Math Learning. Educational Technology & Society, 15(2), 317-327.

[8] Cherney, I. D. (2008). Mom, let me play more computer games: They improve my mental rotation skills. Sex Roles, 59(11-12), 776-786. http://dx.doi.org/10.1007/s11199-008-9498-z

[9] Chuang, T. Y., & Chen, W. F. (2007, March). Effect of computer-based video games on children: An experimental study. In Digital Game and Intelligent Toy Enhanced Learning, 2007. DIGITEL'07. The First IEEE International Workshop on (pp. 114-118). IEEE. http://dx.doi.org/10.1109/DIGITEL.2007.24

[10] Coştu, S., Aydın, S., & Filiz, M. (2009). Students' conceptions about browser-game-based learning in mathematics education: TTNetvitamin case. Procedia-Social and Behavioral Sciences, 1(1), 1848-1852. http://dx.doi.org/10.1016/j.sbspro.2009.01.326

[11] De Smedt, B., Janssen, R., Bouwens, K., Verschaffel, L., Boets, B., & Ghesquière, P. (2009). Working memory and individual differences in mathematics achievement: A longitudinal study from first grade to second grade. Journal of Experimental Child Psychology, 103(2), 186-201. http://dx.doi.org/10.1016/j.jecp.2009.01.004

[12] Demirbilek, M., & Tamer, S. L. (2010). Math teachers' perspectives on using educational computer games in math education. Procedia-Social and Behavioral Sciences, 9, 709-716. http://dx.doi.org/10.1016/j.sbspro.2010.12.222

[13] Diah, N. M., Ehsan, K. M., & Ismail, M. (2010). Discover mathematics on mobile devices using gaming approach. *Procedia-Social and Behavioral Sciences*, *8*, 670-677. http://dx.doi.org/10.1016/j.sbspro.2010.12.093

[14] Drigas, A., & Kostas, I. (2014). On Line and other ICTs Applications for teaching math in Special Education. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 2(4), pp-46. http://dx.doi.org/10.3991/ijes.v2i4.4204

[15] Dye, M. W. G., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. Neuropsychologia, 47(8), 1780-1789. http://dx.doi.org/10.1016/j.neuropsychologia.2009.02.002

[16] Giannakos, M. N. (2013). Enjoy and learn with educational games: Examining factors affecting learning performance. Computers & Education, 68, 429-439. http://dx.doi.org/10.1016/j.compedu.2013.06.005

[17] Gros, B. (2007). Digital games in education: The design of games-based learning environments. Journal of Research on Technology in Education, 40(1), 23-38. http://dx.doi.org/10.1080/15391523.2007.10782494

[18] Harris, A., Yuill, N., & Luckin, R. (2008). The influence of context-specific and dispositional achievement goals on children's paired collaborative interaction. British Journal of Educational Psychology, 78(3), 355-374. http://dx.doi.org/10.1348/000709907X267067

[19] Ke, F. (2008). A case study of computer gaming for math: Engaged learning from gameplay?. Computers & Education, 51(4), 1609-1620. http://dx.doi.org/10.1016/j.compedu.2008.03.003

[20] Ke, F., & Grabowski, B. (2007). Gameplaying for maths learning: cooperative or not?. British Journal of Educational Technology, 38(2), 249-259. http://dx.doi.org/10.1111/j.1467-8535.2006.00593.x

[21] Kebritchi, M., Hirumi, A., & Bai, H. (2008). The effects of modern math computer games on learners' math achievement and math course motivation in a public high school setting. British Journal of Educational Technology, 38(2), 49-259.

[22] Lin, C. H., Liu, E. Z. F., Chen, Y. L., Liou, P. Y., Chang, M., Wu, C. H., & Yuan, S. M. (2013). Game-Based Remedial Instruction in Mastery Learning for Upper-Primary School Students. Educational Technology & Society, 16(2), 271-281.

[23] Main, S., & O'Rourke, J. (2011). 'New Directions for Traditional Lessons': Can Handheld Game Consoles Enhance Mental Mathe-

matics Skills?. Australian Journal of Teacher Education, 36(2), 4. http://dx.doi.org/10.14221/ajte.2011v36n2.4

[24] Munz, U., Schumm, P., Wiesebrock, A., & Allgower, F. (2007). Motivation and learning progress through educational games. Industrial Electronics, IEEE Transactions on, 54(6), 3141-3144. http://dx.doi.org/10.1109/TIE.2007.907030

[25] Oei, A. C., & Patterson, M. D. (2013). Enhancing cognition with video games: a multiple game training study. PLoS One, 8(3), e58546. http://dx.doi.org/10.1371/journal.pone.0058546.g010

[26] Panagiotakopoulos, C. T. (2011). Applying a conceptual mini game for supporting simple mathematical calculation skills: Students' perceptions and considerations. *World Journal of Education*, *1*(1), http://dx.doi.org/p3. 10.5430/wje.v1n1p3

[27] Pareto, L., Arvemo, T., Dahl, Y., Haake, M., & Gulz, A. (2011, January). A teachable-agent arithmetic game's effects on mathematics understanding, attitude and self-efficacy. In Artificial Intelligence in Education (pp. 247-255). Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-642-21869-9_33

[28] Plass, J. L., O'Keefe, P. A., Homer, B. D., Case, J., Hayward, E. O., Stein, M., & Perlin, K. (2013). The impact of individual, competitive, and collaborative mathematics game play on learning, performance, and motivation. Journal of Educational Psychology, 105(4), 1050-1066. http://psycnet.apa.org/doi/10.1037/a0032688

[29] Polycarpou, I., Krausea, J., Rader, C., Kembel, C., Poupore, C., & Chiu, E. (2010). Math-City: An educational game for K-12 mathematics. Procedia-Social and Behavioral Sciences, 9, 845-850. http://dx.doi.org/10.1016/j.sbspro.2010.12.246

[30] Prensky, M. (2005). Computer games and learning: Digital game-based learning. Handbook of computer game studies, 18, 97-122.

[31] Rodrigo, M. M. T. (2010). Dynamics of student cognitive-affective transitions during a mathematics game. Simulation & Gaming. http://dx.doi.org/10.1177/1046878110361513

[32] Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., ... & Salinas, M. (2003). Beyond Nintendo: design and assessment of educational video games for first and second grade students. Computers & Education, 40(1), 71-94. http://dx.doi.org/10.1016/S0360-1315(02)00099-4

[33] Sampson, D. G., & Panoutsopoulos, H. (2012). A study on exploiting commercial digital games into school context. Journal of Educational Technology & Society, 15(1), 15-27.

[34] Shin, N., Norris, C., & Soloway, E. (2006, June). Effects of handheld games on students learning in mathematics. In Proceedings of the 7th international conference on Learning sciences (pp. 702-708). International Society of the Learning Sciences.

[35] Spence, I., & Feng, J. (2010). Video games and spatial cognition. Review of General Psychology, 14(2), 92. http://psycnet.apa.org/doi/10.1037/a0019491

[36] Stone, K., Polycarpou, I., Krause, J., & Rader, C. (2011). Electronic Collaborative Learning in Math-City. In the Proceedings of the 2011 International Conference on Frontiers in Education: Computer Science and Computer Engineering (pp. 295-301).

[37] Valente, A., & Marchetti, E. (2012). Prime Slaughter: Playful Prime Numbers. In *Arts and Technology* (pp. 136-144). Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-642-33329-3_16

[38] Valente, A., & Marchetti, E. (2012, March). Kill it or Grow it.: Computer Game Design for Playful Math-Learning. In *Digital Game and Intelligent Toy Enhanced Learning (DIGITEL), 2012 IEEE Fourth International Conference on* (pp. 17-24). IEEE. http://dx.doi.org/10.1109/DIGITEL.2012.11

[39] Virvou, M., Katsionis, G., & Manos, K. (2005). Combining Software Games with Education: Evaluation of its Educational Effectiveness. Educational Technology & Society, 8(2), 54-65.

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